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Faculty of Technical Sciences Čačak

TIE 2024

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Čačak, Serbia, 20-22 September 2024

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Preface

The tenth international scientific conference Technics, Informatics, and Education – TIE 2024 aims to promote and support research in the education of new generations in technical and technological fields across all levels of education. It also seeks to contribute to the development of technology and the improvement of education.

After a double-blind review process, 89 papers were accepted for the current edition of the Proceedings in the form of plenary lectures and original scientific papers covering various fields of technical, IT and technology-supported education at all educational levels – primary, secondary, higher education and education for adults. Five more papers were accepted to be published in Appendix A of the Proceedings (in Serbian) for the Symposium "Technics and Informatics in Education: School Teachers for Teachers" that is organized within TIE 2024.

Authors are responsible for any spelling, grammar and stylistic errors in their papers.

Articles in the *Proceedings TIE 2024* are organized by the following topics:

- Computer Science and Information Technology;
- Educational Technology;
- Engineering Education and Practice;
- IT Education and Practice;
- Professional Development for the new Technological Environment;
- Outlines of the Digital in ESP: Language and Technology;
- Resilience and Support in the Digital Environment.
- Technics, Technology and Informatics in Primary Education;
- Engineering, Technology and Materials.

Special activities within the Conference include:

- Round Table: Enhancing digital and psychological resilience through peer networking in online environment in times of crises.

The Scientific and Organizing Committee wishes to express its gratitude to all the professionals from various fields who contributed to the Conference.

We would like to thank the Partner Institutions which participated as co-organizers of the Conference.

We express special thanks to the Ministry of Science, Technological Development and Innovation of the Republic of Serbia for its financial contribution to this scientific gathering.

Ivan Milićević
Editor

Presidents’ Foreword

Faculty of Technical Sciences Čačak, University of Kragujevac, has the honour to organize the tenth international scientific conference “Technics, Informatics, and Education – TIE 2024”.

The Conference follows the tradition of gathering teachers, researchers and professionals engaged in various levels of technical, technological and IT education. From 2006 to 2016 the conference “Technics and Informatics in Education – TIE” was organised biennially at the Faculty of Technical Sciences as a national conference with international participation. As of 2018 TIE has a form of an international conference. Nine conferences titled “Technics, Informatics and Education - TIE” were held from 2006 to 2022. The TIE conferences have had a huge impact on the development of IT, technical and scientific subjects in both primary and secondary education. The significant impact has also been perceived in diverse fields related to technical and IT education at university level. However, the new circumstances necessitate organising scientific assemblies in the field of technics and the related technologies.

The TIE 2024 conference aims to improve the exchange of knowledge and experience between experts, professionals, researchers and teachers from Serbia and the region. The conference is expected to provide an analytical review of technical, technological and IT education, focusing on teacher training, terminology in the related fields, as well as the achievements regarding teaching aids, student books, educational assistive technology, technology supporting the enhancement of mental health and well-being, etc.

The Conference involves all the levels of technical, technological and IT education, from preschool institutions, primary and secondary schools over higher and university education, to various forms of lifelong learning. Furthermore, special emphasis is given to the importance and role of informatics and computer science in technical education, as well as the correlation between technical education and other natural, social and education sciences. Since TIE 2022, the thematic field of ESP, which encompasses foreign/second and professional languages in the realm of technics, technology and informatics, has been added to the Conference.

Within the TIE 2024 Conference a special thematic segment will be dedicated to the ongoing ERASMUS+ project which is realized under the section Strategic Partnerships in Higher Education and is run by the University of Kragujevac (2021-2024). Project activities propose a special session titled "Resilience and Support in the Digital Environment" and a round table to disseminate the project results and address the issues of psychological and social resilience of students in times of crises.

The results of the conference are expected to aid in shaping the development of education in the fields of technology, engineering, IT and computer sciences. Additionally, these outcomes will support the exchange of educational practices and align with regional, EU and global trends.

We hope that the experience gained from the Conference will be highly beneficial for both the participants and the advancement of the technical and technological education field.

Presidents of the Scientific Committee and Organizing Committee

Organization

The 10th International Scientific Conference Technics, Informatics, and Education – TIE 2024 is organized by the Faculty of Technical Sciences Čačak, University of Kragujevac, Serbia.

The Conference is held under the patronage of:

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- University of Kragujevac, Faculty of Technical Sciences Čačak, Serbia

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Table of Contents

Session II: Educational Technology

Plenary Session: Keynotes

Notes:

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Plenary session
Professional paper
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Importance of Industry-Academia Collaboration in Robotics for Modern Education, Research and Industry

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Abstract: *What were software and computers in the nineties, today are artificial intelligence and robots. Therefore, the quick and efficient adoption of robotic technologies in education, research, and industry can leapfrog the current technological and societal level to an advanced and modern one. To that end, a structured collaboration of academia and industry is essential. Collaborative robots entered the market as inherently safe, user-friendly, easy to program, and, as such, the fastest-growing robotics segment. Such features create new opportunities to make robotics technologies more affordable, accessible, and more appropriate for small and medium companies, new applications, businesses and education. This paper demonstrates an example of the University of Belgrade – School of Electrical Engineering collaboration with industry in robotics and the impact such collaboration makes on education, research, and industry. The collaborative activities include setting up join robotic system testbeds, creating open educational materials, organizing student competitions for a broader understanding of robotic applications and capabilities, providing real industrial needs, real data, and field testing for competitive and impactful research actions, conducting return of investment and proof of concept services for the industry. The role model shows the impact of academia-industry collaboration on creating new opportunities for talents in academia and industry.*

Keywords: *industry-academia collaboration; robotics; robotics education; robotics research; collaborative robots.*

1. INTRODUCTION

Robots and artificial intelligence (AI) are today, what were computers and software three decades ago. Contemporary robots are already omnipresent in all spheres of our lives and work. Moreover, robots are the technology expected to bring the most changes to our living and working environments and daily routines in the future. The global robotics technology market is estimated at 72 billion USD in 2022, with an expected cumulative growth rate of 15% in the next ten years [1].

Emerging technology, represented by the two key components, software (AI algorithms) and hardware (robots), have been developing synergistically, complementing and pushing each other's boundaries. Today, when the latest collaborative robots are developed as machines that are inherently safe to physically interact with humans and environments, the further development of AI based on physical interaction will go beyond what we know as cutting-edge AI - predominantly in audio (large language models) and video domain (image processing). As with the deployment of computers in the 1990s, the quick adoption of robotic technologies in education, research, and industry can leapfrog the current technological and societal level to an advanced and modern one.

To exploit the opportunity that new robotics technologies bring, the structured collaboration of key stakeholders, academia and industry, is essential. In [2], the authors provided evidence of academia-industry collaboration as one tool to increase technology transfer in different regions. The importance of industry-academia collaboration for enhancing educational opportunities and outcomes under the digital-driven Industry 4.0 was elaborated in [3]. Still, the paper was focused on AI in its software part, while the role of academia-industry collaboration in robotics is even more significant.

This paper provides the authors' understanding of needs, opportunities, possible approaches and the importance of this collaboration. It provides an example of academia-industry collaboration in robotics at the University of Belgrade – School of Electrical Engineering (ETF) as a case study.

Therefore, the paper does not introduce any technical novelties but summarizes previous research findings based on robotic industry needs [4, 5, 6, 7] and the general conclusions of the authors [8] about the trends in robotics development and applications.

The rest of the paper is structured as follows. Section 2 provides a basic understanding of current robotic technologies, current robot applications in various domains and the latest trends in robotics development, reflecting the topic's importance. Section 3 presents roles and main features of industry-academia collaboration in robotics and introduces the success story of such a collaboration around the University of Belgrade – School of Electrical Engineering (ETF). Section 4 brings concluding remarks, including the impact academia-industry collaboration makes on education, research and industry.

2. APPLICATION DOMAINS AND TECHNOLOGY TRENDS IN ROBOTICS

In industry (automotive, electronics or metal and machine industries), large batch productions absorb more than 400,000 robots annually for tasks such as machine tending, assembly, arc or spot welding, palletizing, packaging, painting, gluing or surface finishing [9]. One of the indicators of the level of economic development of a society is the so-called worker robot density, which represents the number of installed robots per 10,000 workers employed in the manufacturing and processing sector. According to these indicators [9], the Republic of Korea is the world leader with a density of 1,000 robot workers, followed by Japan and Germany with around 400, and China as the fastest growing country in this segment with 320 with an annual growth of 35% in the last few years. Based on the information available to the authors, about 2,600 industrial robots have been installed in Serbia, which for 500,000 employees in the relevant sector [10] results in a density of 52 robot workers, which is significantly below the global average of 141.

In healthcare, robots are used for the rehabilitation of upper and lower extremities, surgery (as assistive or teleoperated systems), diagnostics (usually in combination with new medical imaging techniques), direct patient support (as exoskeletons, prostheses, and orthoses), or support to the medical staff (in hospital logistics) [11].

In agriculture, robots are one of the key technologies for the new concept of Agriculture 4.0 [12], which focuses on sustainability and the more efficient exploitation of resources. Typical roles of autonomous mobile robots or drones in agriculture are soil sampling (estimation of moisture, PH value, mineral and nutrient content) or image collection (presence of parasites, ripeness of fruits), harvesting and picking fruits with precision and care, spraying weeds, and eliminating parasites through monitored and targeted herbicide dosing.

In operations in inaccessible or dangerous areas for humans [13], autonomous or guided robots (rovers) are mostly used as sensor platforms. They explore the terrain and geological content of remote locations (Mars), sea and river depths where sensors such as sonar are superior to human senses, surveying and terrain clearing robots in radiation zones, such as the recent actions at the Fukushima nuclear power plant, or work in volcanic zones to collect data on volcanic activity and monitor gas emissions to predict eruptions.

In service applications, mostly used for social interaction in public spaces (museums, hotel receptions, airports, banks, etc.) where they greet visitors, provide service information, answer questions and improve the overall quality of service. Social robots are increasingly important in education. Their role is vital in the therapy and education of sensitive groups such as children with autism spectrum disorders who conform to robots as a category that, in addition to therapy, also has an animation effect [14].

While the examples of robot applications are numerous and already significantly impact life and work, it's clear that the presence of robots is limited in applications requiring direct physical interaction with humans. The physical interaction between a robot and a human presents numerous technical, legal, and ethical challenges. However, this domain of human-robot physical cooperation holds high socio-economic importance. It's not about humans being replaced by robots, but about working in synergy to leverage the superior cognitive properties of humans and the superior physical aspects of robots. This underscores the need for collaborative robots, which are emerging as a key technology for the further development and application of robots.

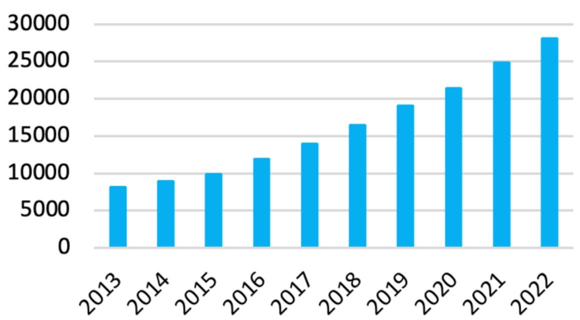

Figure 1. *Number of scientific papers mentioning the word "collaborative robot" or "human-robot interaction" during the period from 2013 to 2022. (Source: Google Scholar)*

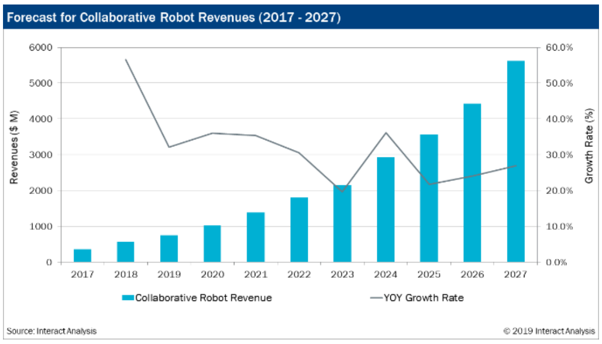

Figure 2. *Collaborative robots market value with forecasts from 2017 to 2027 [15].*

The relevance of human-robot collaboration and collaborative robotics is depicted through the constant increase in the number of academic papers on this topic (Figure 1), as well as the constant increase in the market (Figure 2) of collaborative robots as the fastest-growing robotic technology (combined annual growth of 30%). Figures 1 and 2 also demonstrate the trend of transferring dynamics of academic research to the market, where research and market trends are shifted for about five years.

Many aspects of collaborative robot technology stand for the excellent opportunity for collaboration between academia and industry. Conventional industrial robots are restricted to working in safety-separated zones (without humans) and programming in specialized software. That technology was convenient for large factories and large batch production, which is by its nature closed, designed and maintained by a small group of people with specialization in robotics. On the contrary, collaborative robots open opportunities in more dynamic industrial environments, in the small and medium enterprises sector, and are accessible to a wide range of engineering professionals. Therefore, collaborative robots have become a platform for education and research in robotics [16] due to the safety of use, user-friendly interfaces that provide the possibility of simple programming of robots through various software tools (graphical programming, or robot operating system - ROS [17]), the possibility of simple and fast re-allocation and adjustments of robots to a new task, the openness of the software architecture and facilitated communication with other peripherals and systems, which were not the characteristics of conventional industrial robots. However, in order to maintain their share in the collaborative robot market as the fastest growing robot market, there is a noticeable trend of adaptation by the world's largest robot manufacturers who open their control/programming interfaces through dedicated applications interfaces (API) for programming in ROS [18]. However, according to [19], the most significant barrier to adopting cobots is the need for more knowledge about potential applications, reference cases, and ease-of-use. The academia-industry collaboration in robotics has the potential to bridge these barriers.

3. ROLE OF INDUSTRY-ACADEMIA COLLABORATION - ETF CASE STUDY

Such a technology shift from conventional closed industrial robots to inherently safe, user-friendly collaborative robotics technology creates completely new opportunities and open challenges for academia and industry, emphasizing the need for collaboration between the two sectors. The following sections introduce new opportunities, challenges and good practices in three domains: education, research and industry. However, addressing these challenges and opportunities requires a concerted effort from educational institutions, industry partners, and policymakers to ensure that robotics education is effective and aligned with the needs of the modern workforce for the industry. Since policymaker decisions and framework timelines often have slower dynamics than such a dynamic technology requires, the positive outcomes often rely on a symbiosis between education and industry. The authors' findings are partly verified in the robotics ecosystem around the University of Belgrade – School of Electrical Engineering (ETF).

3.1. Robotics Education

Modern robotics education faces several challenges that must be addressed to ensure effective learning and development of skills. Hands-on training, academic or industrial, requires significant economic investment in terms of equipment/robots, skilled teaching staff, keeping pace with the latest software and hardware and their maintenance, and spacious laboratory facilities. Furthermore, keeping students engaged and motivated is a continuous challenge, so actual real-world problems and trendy tools (software and hardware) should be offered to students in laboratory work and final thesis. Most specifically, international collaboration at the postgraduate level is necessary to provide attractive opportunities for the most advanced talents in developing countries like Serbia.

To respond to the challenges, the following actions have been carried out in collaboration between ETF and industrial partners. The efficient use of resources - training facilities, between academia and industry is achieved through setting up hardware systems at the university lab and making it open to industrial training and pilot testing. This approach is also known in the literature as an open test-bed concept [20], especially promoted within Industry 4.0. Licensed software for robot programming is provided to the university. In return, academic staff provides industrial training on dedicated robotic software. In such a setting, the university offers modern education with hands-on sessions. On the other hand, the industry benefits from a number of trained students who are aware of the benefits robotics can bring to the industry and have the experience and confidence of working with specific advanced tools. To complement modern education, well-structured and attractive learning materials are important. To that end, industry-supported development and printing of the educational material (a workbook) developed by university staff that covers solved problems in robotics, which is in turn offered free of charge to the wider audience at the publisher's website [21]. Due to the significant role robotics have and will have in different industries, a basic understanding of robotics technologies, features and capabilities of robots is needed in various engineering disciplines. A basic education and introduction to robotics is offered to a broader group of students, beyond those who follow a robotics curriculum, through student competitions in the form of a hackathon. While the industry offers real-world challenges as a hackathon topic and provides appropriate awards for the most successful student teams, academic staff, together with student associations, ensure higher participation of engineering students from different disciplines and provide basic training necessary to solve industrial challenges to the hackathon participants.

3.2. Robotics Research

Industry-academia collaboration plays a pivotal role in modern robotics research. It drives innovation, fosters the development of cutting-edge technologies, and ensures that research outputs have practical, real-world applications. As usual, such a collaboration comes with challenges. Especially in developing countries, industry needs are more oriented toward the straightforward application of robotic technologies that do not require significant novelties attractive for academic research actions. Moreover, the industry is rarely interested in high-risk, high-gain actions. Research breakthroughs in robotics require big, usually international and multidisciplinary teams. Sometimes, the industry hesitates to collaborate with academia due to internal intellectual property rights (IPR) policies that can be patented and commercialized. This is especially true in developing innovation ecosystems where understanding and support for IPR are underdeveloped. As in another field of technology, robotics research strongly depends on the engagement of the Ph.D. students, but collaboration between academia and industry also suffers from regulations on IPR. While Ph.D. students need publications for their promotion, IPR policies often restrict publishing the outcomes. Although the institution of industrial Ph.D. is recognized by the law in Serbia, the institution of industrial Ph.D. is still underexploited.

The industry's role is to point out practical applications, formulate real needs, and guide researchers to work on topics that impact industry and society. On the other hand, the role of academia is to bring the latest cutting-edge technologies and methods available in scientific literature to make the best use of them in the context of industry needs. Led by a company's need to reduce assembly errors caused by a human factor, the authors introduced the concept of a neuroergonomic workstation [22] in collaborative tasks. In this human-centered concept, a collaborative robot is used to provide physical assistance, improve worker satisfaction and ergonomics, based on advanced sensor systems for assessing the psychophysical state of workers (Figure 3). As was the case in this collaboration, the industrial need was amended by an additional research component (brain-computer interface for monitoring human focus) to reach a level of "excellence" to secure European research funding. Therefore, the role of academia is to secure additional funding for joint activities through national and international frameworks and, consequently, stimulate collaboration and facilitate reaching impactful research outcomes. However, industry data and field testing in a real operation environment create an optimal framework for securing funding through grants.

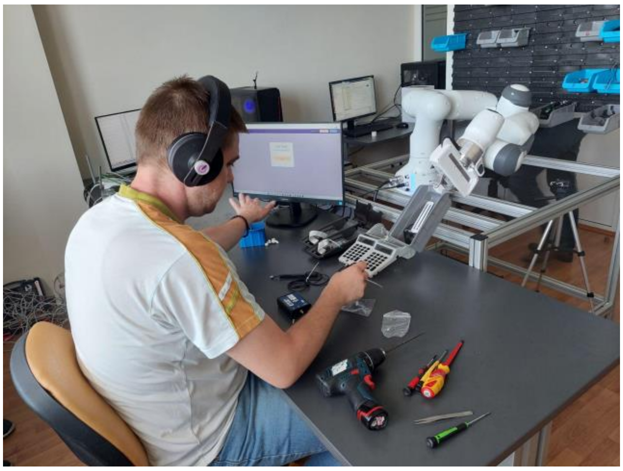

Figure 3. *Neuroergonomic workstation as a novel research concept based on human-centered industry needs.*

The importance of public debate on industrial needs, application challenges and current research and technology trends is recognized at the EU level, where the EU Robotics Association every year gathers about 1.000 participants of different profiles: academia, industry, and policymakers. This annual event, the European Robotics Forum, is recognized as the most influential event in robotics in Europe, and it is the venue where the most influential actors discuss and define topics of collaborative research projects combining contributions of academia and the private sector across Europe. Valorizing research results, especially at higher TRLs that require extensive technology testing and validation, might not be possible through academic funding alone. Therefore, co-funding from the industry sector brings double benefits - continuation of research until the commercialization phase and recognition of the research impact. Within this framework, the authors work on a modular and versatile collaborative intelligent waste management robotic system for the circular economy [23].

3.3. Robotics Industry

For robotics-related industries, collaboration with academia can bring benefits in different fields. Companies, in general, are in constant pursuit of new ways to stay ahead of their competitors and to meet market demands more effectively. However, this effort often leads to insufficient capacity, time and resources for research, development and keeping up with the latest trends. One of the most significant advantages for industry partners is access to cutting-edge research and technological advancements. Reputable academic institutions such as the ETF are at the forefront of scientific discovery, pioneering innovations that have the potential to revolutionize industries, and enable and inspire them to leapfrog to the latest standards through human-centred solutions [22]. Depending on the size, structure and industry sector, companies can also benefit from different services provided by the academia, including case studies, return-on-investment (RoI) [23, 24, 25, 26] calculations, training courses and promotional events.

However, to enable major advances and improvements, companies, most notably SMEs, often require not only access to know-how and insights into the latest research but also access to means to verify and apply them. To that end, ETF also offers companies a cost-effective way to conduct research and development through access to expensive specialized equipment and facilities for individual companies to own and maintain. By offering such services, companies are able to perform proof-of-concept experiments, run pilot productions, or get hands-on experience in showrooms or promotional events. Academic institutions, in this case, can be seen as neutral, yet influential members of the ecosystem, free of commercial interest of different competing vendors, but able to work together with them to push robotic technologies to the market. To provide wider industry and academic audiences with advanced equipment, academia and industry partnered with third parties (concretely a science technology park) where industry provided the hardware and software while ETF provided skilled staff to educate and assist industrial users (or other academic community) in testing and deploying robotics systems.

Another major area beneficial for the industry are collaborative projects which can attract government and private funding and grants aimed at fostering innovation. Industry partners can gain access to research funding opportunities that are typically available only to and/or through academic institutions. In the past, joint research initiatives through different national and transnational projects have enabled both parties to pursue ambitious projects that might otherwise be financially unfeasible. The ETF plays a crucial role in these projects, enabling companies to access a broader network of researchers, institutions, and other companies [27, 28], facilitating the exchange of ideas and best practices and fostering a collaborative ecosystem. Joint projects often lead to the development of new methodologies and approaches that can be applied across various sectors [27]. Many of these projects and frameworks are aimed towards identifying the needs of the companies and shaping policies on national and international level. Therefore, collaboration can influence policy development in ways that benefit both academia and industry, ensuring that regulations support innovation and growth [26, 28].

Finally, collaboration with academia can enhance a company's reputation and brand, positioning it as a leader in innovation by demonstrating a commitment to advancing knowledge and contributing to societal progress [26, 28].

4. CONCLUSION

Strong robotics education, research and industry are key pillars to tackle main societal challenges and exploit business opportunities that societal challenges create in specific sectors. In industry, a constant need for better exploitation of resources, increased production efficiency and improved well-being of humans at the workplace follow the new paradigm of Industry 5.0. In healthcare, increased volume and improved quality of medical services follow the global increase and aging of the population, raising awareness of disease prevention and the development of new treatments. In agriculture, the need for increased volume and more robust supply chains follows the increase in global population and climate changes affecting food sources. At home, increased demand for social and physical assistance follows global trends of population aging and increased migrations, leading to social and physical exclusion of elderly people. In all aforementioned sectors, robots are key enabling technologies to respond to societal challenges.

As new emerging technologies, collaborative robots introduce new paradigms in robotics: inherent safety for the user, user-friendly and standardized programming interfaces, and openness of control and software architecture. Therefore, new opportunities for collaboration between academia and industry can leapfrog the current level of industry and society to modern ones. Collaborative robots facilitate physical interaction with users and hands-on robot activities, which makes robotics available to a wider audience, students and companies, through university labs and robotic test beds. In turn, the new generation of engineers skilled and confident in working side by side with robots supports the further deployment of robots in industry and society. Exposure of a broader audience to robotic setup at university labs creates benefits for the robotic vendor industry by facilitating the deployment of their technologies in the market. At the same time, small and medium companies benefit from proof-of-concept services and validation and testing of potential solutions in university lab facilities. Direct interaction between academia and industry supports academia in understanding industry needs, formulating impactful research actions and ensuring further funding through grant schemes. Joint research efforts create added value for academic partners and increase the reputation of involved companies. Finally, stakeholder engagement and joint actions between academia and industry increase innovation potentials, create new opportunities for young talents, and directly tackle the brain drain.

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Optimization in Acoustic Echo Cancellation using Adaptive Filters and Applied Machine Learning

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Abstract: *To achieve efficient stereophonic acoustic echo cancellation (SAEC), it is imperative to employ an adaptive filter structure that incorporates a significant number of weights or taps. The determination of the number of weights or taps is dependent upon the specific attributes of the room impulse response and the acoustic pathway undergoing the cancellation process. However, for an adaptive filter with finite impulse response, using a large tap size results in a significant delay in convergence and intensifies the complexity of the tapped delay line arrangement. In order to tackle this problem, it is imperative to devise an optimal methodology for determining the tap length, which will lead to enhanced convergence for the adaptive filters employed in SAEC. This paper introduces a new approach for optimising the tap length of long-length adaptive filters used for SAEC to find a balance between convergence and steady state performance. The optimal tap length and step size of the adaptive filter are determined by considering an impulse response with an exponentially decreasing envelope, mimicking a variety of acoustic echo paths. The tap length optimisation is implemented on a singular extensive adaptive filter with numerous coefficients to minimise the overall weight count, hence decreasing the computational load. To enhance the pace at which the system reaches convergence, we implemented a tap-length optimisation technique on an already existing echo canceller that is based on several sub-filters to provide a convergence analysis for the proposed algorithm.*

Keywords: Adaptive filtering, Tap-length, Stereophonic Acoustic Echo Cancellation, Multiple Sub-Filters, Convergence, Signal-to-Noise Ratio.

1. INTRODUCTION

Acoustic echo cancellation in teleconferencing and hands-free phones employs adaptive filtering techniques to minimise the acoustic reflections resulting from the interaction between the loudspeaker and microphone. Dual-channel stereo acoustic devices improve the digital quality of audio during desktop conferencing and enable hands-free phone conversations for telepresence technology. These technologies enable the recognition of speakers by meeting attendees, even in scenarios when numerous individuals are engaged in speaking. In contrast, these instruments exhibit a higher level of complexity compared to monophonic instruments [1]. Stereophonic configurations frequently comprise of two-way full-duplex channels, wherein dual speakers and microphones are strategically placed at opposite ends of a communication channel, as depicted in Fig. 1 [2].

The major goal of the system that is represented in Fig. 1 is to significantly reduce the amount of variation that is present in the echo signal. The comprehensive process is generally referred to as adaptive stereophonic acoustic echo cancellation (SAEC).

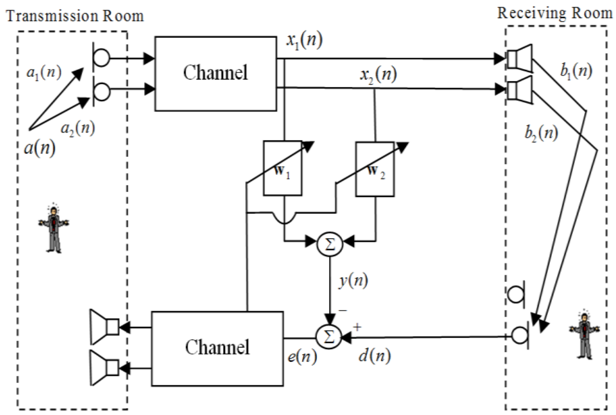


Figure 1. *Adaptive* filter based SAEC for both near-end and far-end users

The length of the filter is directly proportional to the length of the impulse response of the echo return path [3]. Modelling the impulse response of the echo return path in SAEC presents greater challenges compared to single-channel echo models due to the necessity of simultaneously modelling two distinct paths [4].

Generally, adaptive finite impulse response (FIR) filter based acoustic echo cancellers incur computational costs and poor convergence due to thousands of filter coefficients. For convergence and filter coefficient optimisation, decomposition [5, 6, 7] and adaptive tap-length-selection methods [8, 9, 10, 11] are used.

In order to address the issues of complexity and improve convergence, it is required to optimise the filter length in echo cancellers. Various adaptive algorithms like fractional tap-length LMS (FT-LMS) method [12], the variable-leakage-factor FT-LMS algorithm [13], and the variable-tap variable-step LMS (VT-VSLMS) algorithm [14] have been developed to reduce the complexity of adaptive designs but, generalization of these algorithms to SAEC is not available. The shortcomings of these existing algorithms have been emphasised in [15]. So, in certain scenarios, it necessitates a greater tap-length requirement when compared to the FT-LMS.

Adaptive filter acoustic echo cancellation is not something that is evaluated for the variable-tap-length approaches [16], which reflect an exponentially-decreasing impulse response. Therefore, in order to enhance the pace at which they converge, signal processing applications such as echo cancellation, active noise reduction, and equalisation require an improved tap-length optimisation technique [17, 18].

It has been presented a highly advanced tap-length optimisation strategy for feedforward active noise suppression using filtered-x LMS [19]. However, it is worth noting that this technique does not incorporate MSF-based algorithms to enhance convergence. Therefore, it is necessary to develop an enhanced algorithm for optimising tap length and step size in high-order adaptive filters employed in SAEC systems based on single-long-filter (SLF)- and MSF.

The primary aim of this study is to present an enhanced solution, which is outlined as follows:

i. This study proposes an enhanced tap-length selection algorithm for adaptive filters employed in SAEC, aiming to achieve superior performance compared with conventional variable tap-length algorithms.
ii. A comparative convergence analysis of existing and the proposed algorithm is proposed for SLF and MSF-based COEA SAEC.

The approach described in this study does not employ random assignment of adaptive parameters, as seen in FT-LMS. Instead, it identifies the optimal filter length for high-order adaptive filters, leading to expedited convergence in comparison to previous algorithms.

2. PROPOSED ALGORITHM

This work presents the derivation of a variable-step-size algorithm and conducts a convergence analysis. The taps are updated by the traditional LMS algorithm approach,

$$\mathbf{w}_{D(n)}(n+1) = \mathbf{w}_{D(n)}(n) + \mu(n)\, e(n)\, \mathbf{x}_{D(n)}(n), \tag{1}$$

where $D(n)$ is the tap length, $\mu(n)$ is the step size and $e(n) = d(n) - y(n)$, (2)

is the error signal at the nth iteration where $d(n)$ is the desired signal and the filter output $y(n) = \mathbf{w}^T_{D(n)}(n)\mathbf{x}_{D(n)}(n)$. (3)

The input vector to the adaptive filter is $\mathbf{x}_{D(n)}(n) = \left[x(n), x(n-1), ..., x(n-L(n)+1)\right]^T$ and weight vector pertaining to filter length is

$\mathbf{w}_{D(n)}(n) = \left[w_0(n), w_1(n), ..., w_{D(n)-1}(n)\right]^T$.

The observed intended signal is obtained by summing the transmitted signal convolved with the impulse response of the echo path and an additive noise function.

$$d(n) = \mathbf{r}^T_N \mathbf{x}_N(n) + \alpha(n) \quad , \tag{4}$$

where the channel response is $\mathbf{r}_N = \left[r_0, r_1, ..., r_{N-1}\right]^T$ modelled by $r_j = g(j)e^{-\lambda(j-1)}$, $j = 0,1,..., N-1$, the input vector to the unknown channel with N coefficients is $\mathbf{x}_N(n) = \left[x(n), x(n-1), ..., x(n-N+1)\right]^T$, $g(j)$ is a Gaussian zero-mean stochastic process with unit variance, positive constant for the decay rate λ and additive noise $\alpha(n)$, assumed to be statistically independent of the input sequence $\mathbf{x}_N(n)$. It is assumed that both $\mathbf{x}_N(n)$. and $\alpha(n)$ are independent zero-mean Gaussian white noise signals, indistinguishable distributions over time. So, in this case, to estimate the unknown impulse response, the adaptive filter with tap length $D(n) \le N$ is used. Here, for updating the tap length $D(n)$ and the step size $\mu(n)$ at each iteration, we propose an analysis

Following the formulation in [18], the exponentially-decaying impulse response $\mathbf{r}_N$ is partitioned into two parts as $\left[\mathbf{r}', \mathbf{r}''\right]^T$, where $\mathbf{r}'$ is modelled by $\mathbf{w}_{D(n)}(n)$ and the unmodelled part is $\mathbf{r}''$

Accordingly, we have two representations for the coefficient error vector $\zeta(n)$ as [18]

$$\zeta_{D(n)}(n) = \mathbf{w}_{D(n)}(n) - \mathbf{r}' , \tag{5}$$

and

$$\zeta_N(n) = \mathbf{w}_N(n) - \mathbf{r}_N \ , \tag{6}$$

where $\zeta'_{D(n)}(n)$ is the estimation error of $D(n) \le N$ partial coefficients and $\zeta_N(n)$ is the total coefficient estimation error. The vector $\mathbf{w}_N(n)$ is obtained by padding $\mathbf{w}_{D(n)}(n)$ with $N - D(n)$ zeros as,

$$\mathbf{w}_N(n) = \begin{bmatrix} \mathbf{w}_{D(n)} \\ 0_{N-D(n)} \end{bmatrix} \ . \tag{7}$$

Combining (3) with (4) and substituting into (2), the error signal $e(n)$ can be rewritten as

$$e(n) = \left[\mathbf{r}_N - \mathbf{w}_{D(n)}(n)\right]^T \mathbf{x}_N(n) + \alpha(n) \ . \tag{8}$$

Padding $\mathbf{w}_{D(n)}(n)$ with $N - D(n)$ zeros, as shown in (7), and replacing it with $\mathbf{w}_N(n)$, we have

$$e(n) = -\mathbf{x}_N^T(n)\zeta_N(n) + \alpha(n). \tag{9}$$

Substituting (9) for $e(n)$ in the weight update equation (1) and then subtracting $\mathbf{p}_M$ from both the sides and replacing $\mathbf{w}_N(n)$ with $\begin{bmatrix} \mathbf{x}_{D(n)}(n) \\ 0_{N-D(n)} \end{bmatrix}$, we get

$$\zeta_N(n+1) = \zeta_N(n) - \mu(n) \begin{bmatrix} \mathbf{x}_{D(n)}(n) \\ 0_{N-D(n)} \end{bmatrix} \left[\mathbf{x}_N^T(n)\zeta_N(n) - \alpha(n)\right] . \tag{10}$$

Simplifying the above equation by substituting

$$\mathbf{A}(n) = \mathbf{I}_N - \mu(n) \begin{bmatrix} \mathbf{x}_{D(n)}(n) \\ 0_{N-D(n)} \end{bmatrix} \mathbf{x}_N^T(n), \tag{11}$$

we can write (10) as

$$\zeta_N(n+1) = \mathbf{A}(n)\zeta_N(n) + \mu(n)\alpha(n) \begin{bmatrix} \mathbf{x}_{D(n)}(n) \\ 0_{N-D(n)} \end{bmatrix}, \tag{12}$$

where $\mathbf{I}_N$ is the $N \times N$ identity matrix. For finding the optimum step size and tap length parameters, MSD is formulated as the figure of merit. The cost function $f(n)$ is expressed as the expected square of the l_2 norm of the coefficient error vector $\zeta_N(n)$ as

$$f(n) = E\left[\|\zeta_N(n)\|_2^2\right]. \tag{13}$$

Let the input $x(n)$ and the additive noise $\alpha(n)$ have variances σ_x^2 and σ_α^2, respectively. Following the evaluation of MSD made in [18], we formulate

$$f(n+1) = \delta E\left[\|\zeta_N(n)\|_2^2\right] + (\eta - \delta)\|\mathbf{r}''\|_2^2 + \theta$$

$$= \delta f(n) + (\eta - \delta)\|\mathbf{r}''\|_2^2 + \theta \,, \tag{14}$$

where, as mentioned earlier, the un-modeled part $\mathbf{r}''$ is represented by $\mathbf{w}'_{N-D(n)}(n)$ and

$$\delta = 1 - 2\mu(n)\sigma_X^2 + \{[D(n)+2]\mu^2(n)\}\sigma_X^4 \tag{15}$$

$$\eta = 1 + D(n)\mu^2(n)\sigma_x^4 \ , \tag{16}$$

$$\theta = D(n)\mu^2(n)\sigma_x^2\sigma_\alpha^2 \ . \tag{17}$$

Substituting (15)-(17) into (14), we get

$$\begin{aligned} f(n+1) &= \left\{1 - 2\mu(n)\sigma_x^2 + \left[D(n)+2\right]\mu^2(n)\sigma_x^4\right\} f(n) \\ &+ \left[2\mu(n)\sigma_x^2 - 2\mu^2(n)\sigma_x^4\right] E\left[\|\mathbf{r}''\|_2^2\right] + D(n)\mu^2(n)\sigma_x^2\sigma_\alpha^2 \ . \end{aligned} \tag{18}$$

2.1. Variable step size

Here, the objective is to minimize the MSD cost function with respect to the step size $\mu(n)$ by equating $\dfrac{\partial f(n+1)}{\partial \mu} = 0$, where

$$\begin{aligned} \frac{\partial f(n+1)}{\partial \mu} &= 2 f(n)\sigma_x^2\left[(D(n)+2)\mu(n)\sigma_x^2 - 1\right] \\ &+ 4\sigma_x^2\left[0.5 - \mu(n)\sigma_x^2\right] E\left[\|\mathbf{r}''\|_2^2\right] + 2\mu(n)\sigma_x^2\sigma_\alpha^2 D(n) \ . \end{aligned} \tag{19}$$

Hence, we get

$$\mu(n) = \frac{f(n) - E\left[\|\mathbf{r}''\|_2^2\right]}{f(n)\sigma_x^2\left[D(n)+2\right] - 2\sigma_x^2 E\left[\|\mathbf{r}''\|_2^2\right] + D(n)\sigma_\alpha^2} \ . \tag{20}$$

The squared norm of the un-modeled part of $\mathbf{r}_M$, having an exponentially-decaying impulse response, can be expressed as [18]

$$\|\mathbf{r}''\|_2^2 = \frac{e^{-2D(n)\lambda} - e^{-2N\lambda}}{1 - e^{-2N\lambda}} \|\mathbf{r}_N\|_2^2 \ . \tag{21}$$

Taking the expectation of both sides, we get

$$E\left[\|\mathbf{r}''\|_2^2\right] = \frac{e^{-2D(n)\lambda} - e^{-2N\lambda}}{1 - e^{-2N\lambda}} E\left[\|\mathbf{r}_N\|_2^2\right] \ , \tag{22}$$

where,

$$E\left[\|\mathbf{r}_N\|_2^2\right] = \frac{1 - e^{-2N\lambda}}{1 - e^{2\lambda}} \ . \tag{23}$$

Substituting (23) into (22), we have

$$E\left[\|\mathbf{r}''\|_2^2\right] = \frac{e^{-2D(n)\lambda} - e^{-2N\lambda}}{1 - e^{-2\lambda}} \ . \tag{24}$$

Substituting (24) into (20), we get equation (25)

$$\begin{aligned} \mu(n) &= \left[f(n) - (1 - e^{-2\delta}) - e^{-2L(n)\delta} + e^{-2N\delta}\right] * \\ &\left[\left\{f(n)\sigma_x^2\left[L(n)+2\right] + L(n)\sigma_\zeta^2\right\}(1 - e^{-2\delta}) - 2\sigma_x^2(e^{-2L(n)\delta} - e^{-2N\delta})\right]^{-1} \end{aligned} \tag{25}$$

The equation (25) says that the step-size variation depends on the tap length $D(n)$, the decay rate λ, the cost function $f(n)$, and the variances of the noise and input signal.

Considering the filter input and filter coefficients to be independent, the MSE of the LMS adaptive filter can be expressed as [15]

$$E\left[e^2(n)\right] = f(n)\sigma_x^2 + \sigma_\alpha^2. \tag{26}$$

Moreover, the statistical squared average $E\left[e^2(n)\right]$ can be approximated recursively by its time average estimate as [18, 19]

$$E\left[e^2(n)\right] \approx \hat{e}^2(n) = \beta\hat{e}^2(n-1) + (1-\beta)e^2(n), \tag{27}$$

where β is the smoothing constant [15].

Combining (13), (26), and (27) and substituting into (25), we get equation (28)

$$\mu(n)=\Big[\beta\hat{e}^2(n-1)+(1-\beta)e^2(n)-\sigma_\alpha^2-\Big[(1-e^{-2\lambda})-e^{-2D(n)\lambda}+e^{-2N\lambda}\Big]\sigma_x^2\Big]\Big[\Big\{\Big[\beta\hat{e}^2(n-1)+(1-\beta)e^2(n)-\sigma_\alpha^2\Big]\Big[D(n)+2\Big]+D(n)\sigma_\alpha^2\Big\}(1-e^{-2\lambda})\sigma_x^2-2\sigma_x^4(e^{-2D(n)\lambda}-e^{-2N\lambda})\Big]^{-1} \quad 28$$

The evaluation of the closed-form solution of equation (28) for the variable step size is a challenge. The assumption that the MSD is a convex function of the step size implies that the stationary points of equation (27) have the potential to result in a global minimisation of the cost function $f(n+1)$.

The determination of the convexity of the cost function is challenging as a result of the acquired Hessian solution [19, 22]. Assuming that input to the filter and filter coefficients are independent, the optimal solution is determined by the step size indicated in equation (28), which is contingent upon the tap length at the nth iteration. Here, we consider an approximate solution of $\mu(n)$ by assuming $D(n)\approx D(n-1)$. With this assumption, (28) can be modified as equation (29)

$$\mu(n)=\frac{\beta\hat{e}^2(n-1)+(1-\beta)e^2(n)-\sigma_\alpha^2-\left[(1-e^{-2\lambda})-e^{-2D(n-1)\lambda}+e^{-2N\lambda}\right]\sigma_x^2}{\left\{\left[\beta\hat{e}^2(n-1)+(1-\beta)e^2(n)\right]\left[(D(n-1)+2)\right]-2\sigma_\alpha^2\right\}(1-e^{-2\lambda})\sigma_x^2-2\sigma_x^4(e^{-2D(n-1)\lambda}-e^{-2N\lambda})} \quad (29)$$

Now, for simplicity, we consider the assumptions mentioned in [18, 22] to find the step-size convergence in this case: zero background noise with $\sigma_\alpha^2=0$ and the tap length of the filter perfectly modeled such that $\|\mathbf{r}''\|_2^2=0$. Again, we assume $D(n)\approx D(n-1)$ to avoid the dependencies between step size and tap length in every nth iteration. Otherwise, a pair of stationary points for both $\mu(n)$ and $D(n)$ will be obtained at each iteration and it will be difficult to find a closed-form solution for convergence. Using these assumptions, (20) can be expressed as $\mu(n)=\dfrac{1}{\left[D(n-1)+2\right]\sigma_x^2}$. (30)

We can use similar assumptions for large decay rate $\lambda >> 1$ and $f(n)-1\approx f(n)$ in (29) to get (30). The observed relationship indicates that a larger tap length corresponds to a smaller step size, leading to a slower convergence rate, and conversely. Therefore, in order to achieve convergence, the step size should fall inside the range

$$0<\mu(n)\le\frac{1}{\left[D(n-1)+2\right]\sigma_x^2}. \quad (31)$$

2.2. Optimum tap length

The optimum tap-length can be found out by minimizing the cost function $f(n+1)$ of (18) with respect to tap length $D(n)$, which requires that

$$\begin{aligned}\frac{\partial f(n+1)}{\partial D(n)}&=f(n)\mu^4(n)\sigma_x^2+\mu^2(n)\sigma_x^2\sigma_\alpha^2\\&+2\mu(n)\sigma_x^2\left[1-\mu(n)\sigma_x^2\right]\frac{d\,E\left[\|\mathbf{r}''\|_2^2\right]}{d\,D(n)}=0.\end{aligned} \quad (32)$$

We need to differentiate $E\left[\|\mathbf{r}''\|_2^2\right]$ with respect to $D(n)$ to evaluate (32). We get the result

$$\frac{d\,E\left[\|\mathbf{r}''\|_2^2\right]}{d\,D(n)}=\frac{-2\lambda e^{-2\lambda D(n)}}{1-e^{-2\lambda}}. \quad (33)$$

Now, substitute this into (32),

$$e^{-2\lambda D(n)}=\frac{\mu(n)(1-e^{-2\lambda})\left[f(n)\sigma_x^2+\sigma_\alpha^2\right]}{4\lambda\left[1-\mu(n)\sigma_x^2\right]}, \quad (34)$$

which implies that

$$D(n)=0.5\lambda^{-1}\ln\frac{4\lambda\left[1-\mu(n)\sigma_x^2\right]}{\left[f(n)\sigma_x^2+\sigma_\alpha^2\right]\mu(n)(1-e^{-2\lambda})}. \quad (35)$$

Now by replacing the step size $\mu(n)$ in the above expression with (30) and get:

$$\begin{aligned}D(n)&=0.5\lambda^{-1}\ln\frac{4\lambda\left[1-\frac{1}{D(n-1)+2}\right]}{\left[\left(f(n)\sigma_x^2+\sigma_\alpha^2\right)(1-e^{-2\lambda})\right]\frac{1}{D(n-1)+2}}\\&=0.5\lambda^{-1}\ln\frac{4\lambda\,D(n-1)\sigma_x^2}{\left[f(n)\sigma_x^2+\sigma_\alpha^2\right](1-e^{-2\lambda})}.\end{aligned} \quad (36)$$

From (36), $D(n-1)$ can be obtained as

$$D(n-1)=0.5\lambda^{-1}\ln\frac{4\lambda D(n-2)\sigma_X^2}{\left[f(n-1)\sigma_x^2+\sigma_\alpha^2\right](1-e^{-2\lambda})}, \quad (37)$$

We define $\Delta D=D(n)-D(n-1)$ as the difference between the tap lengths at any two consecutive iterations so we have

$$\begin{aligned}\Delta D&=D(n)-D(n-1)=0.5\lambda^{-1}\ln\frac{D(n-1)\left[f(n-1)\sigma_x^2+\sigma_\alpha^2\right]}{D(n-2)\left[f(n)\sigma_x^2+\sigma_\alpha^2\right]}\\&=\frac{1}{\lambda}\ln\sqrt{\frac{D(n-1)\left[f(n-1)\sigma_x^2+\sigma_\alpha^2\right]}{D(n-2)\left[f(n)\sigma_x^2+\sigma_\alpha^2\right]}}.\end{aligned} \quad (38)$$

Hence, the tap-length adaptation equation can be expressed as:

$$\begin{aligned}D(n)&=D(n-1)+\Delta D\\&=D(n-1)+\frac{1}{\lambda}\ln\sqrt{\frac{D(n-1)\left[f(n-1)\sigma_x^2+\sigma_\alpha^2\right]}{D(n-2)\left[f(n)\sigma_x^2+\sigma_\alpha^2\right]}}.\end{aligned} \quad (39)$$

Substituting (26) into (39) and iterating, we have

$$D(n) = D(n-1) + \frac{1}{\lambda}\ln\sqrt{\frac{D(n-1)\,\hat{e}^2(n-1)}{D(n-2)\,\hat{e}^2(n)}} \quad (40)$$
$$= D(0) + \frac{1}{\lambda}\ln\sqrt{\frac{D(n-1)\,\hat{e}^2(n-1)}{D(0)\,\hat{e}^2(0)}}\ .$$

Replacing the squared estimated error in (40) with (27), we have

$$D(n) = D(n-1) + \frac{1}{\lambda}\ln\sqrt{A/B},$$
$$A = D(n-1)\left[\beta\hat{e}^2(n-2) + (1-\beta)e^2(n-1)\right] \quad (41)$$
$$B = D(n-2)\left[\beta\hat{e}^2(n-1) + (1-\beta)e^2(n)\right].$$

This displays that the proposed tap-length adaptation based on the optimisation criteria has an exponentially decreasing envelope. The filter length is an integer; however, the best filter order returns a fractional number which should be rounded to an integer.

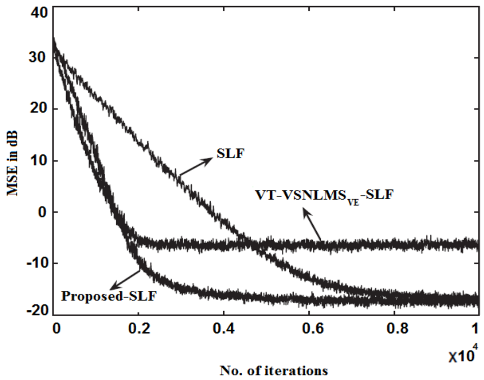
3. SIMULATION AND RESULTS

This section exclusively emphasises on the adaptive filtering component of the echo canceller. The objective is to analyse the proposed optimal tap-length selection algorithm and evaluate its performance in comparison to existing methods. This will involve assessing convergence under various SNRs and comparing the outcomes of SLF- and MSF-based SAEC designs with and without the implementation of the variable-tap-length algorithm.

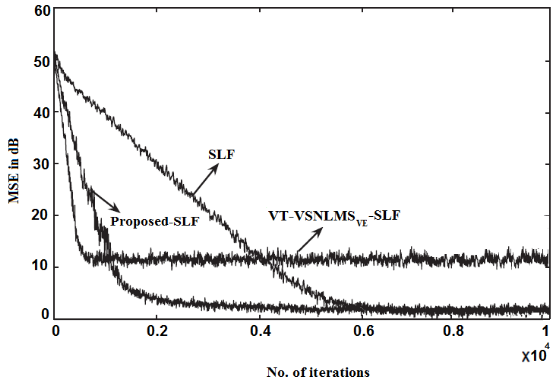
The method under consideration is implemented on the SLF with an increased coefficient count, and on the MSF with equivalently reduced sub-filters, in order to assess the disparities in convergence, tracking, and echo return loss enhancement (ERLE).

For the SAEC adaptive filters, we set the SLF tap length at 1200 and the MSFs to 4 sub-filters with 300 coefficients each and a decay parameter of 0.005. A white zero-mean random Gaussian sequence with variance 0.1 is the noise signal. Average over 200 separate runs yields results.

We employ tap-length optimisation with the suggested method and the VT-VSNLMSVE algorithm to examine SLF MSE convergence and compare the results to an adaptive SLF with a predetermined length of 1200. Fig. 2(a) and 2(b) show results for 20 dB and 0 dB SNRs. The adaptive SLF converges to a low steady-state value after 8000 and 6000 iterations at 20 dB and 0 dB SNR. However, the proposed approach converges after 3000 and 2000 iterations and outperforms VT-VSNLMSVE in steady-state performance.



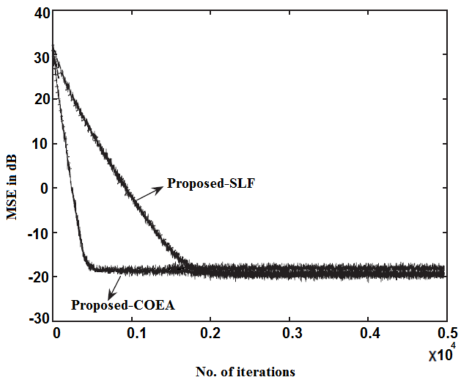
(a)



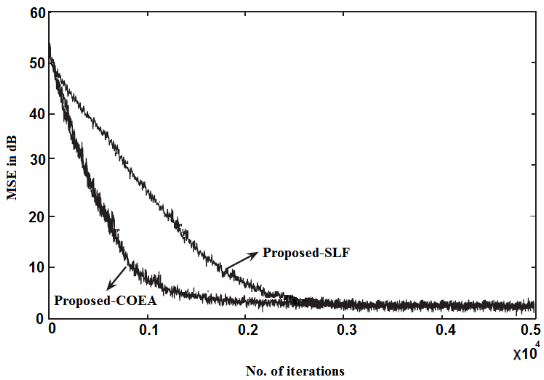
(b)

Figure 2. *MSE vs. number of iterations for adaptive SLF convergence analysis with and without tap-length optimization, for SNR (a) 20dB, (b) 0dB.*

Fig. 3. MSE vs. number of iterations for adaptive SLF and MSF-based COEA using the proposed tap-length optimization, for SNR (a) 20 dB. (b) 0 dB.



(a)



(b)

Figure 3. *MSE vs. number of iterations for adaptive SLF and MSF-based COEA using the proposed tap-length optimization, for SNR (a) 20 dB. (b) 0 dB.*

The proposed variable-tap-length algorithm optimises the tap-lengths of each 300-tap sub-filter in the COEA for the MSF design. The proposed algorithm was applied to the 1200-coefficient adaptive SLF above. In Fig. 3 (a) and (b) for SNR = 20 dB and 0 dB, respectively, we plot the MSE vs total iterations to compare convergence.

In Fig. 4, following the implementation of the SAEC approach, the acoustic signal that was received is segmented and presented in conjunction with the erroneous signal. The purpose is to illustrate the operating principles of SAEC design. The ERLE, is a metric used to quantify the extent to which an echo canceller suppresses echo. It is calculated by dividing the original echo power by the residual echo signal power following the cancellation process.

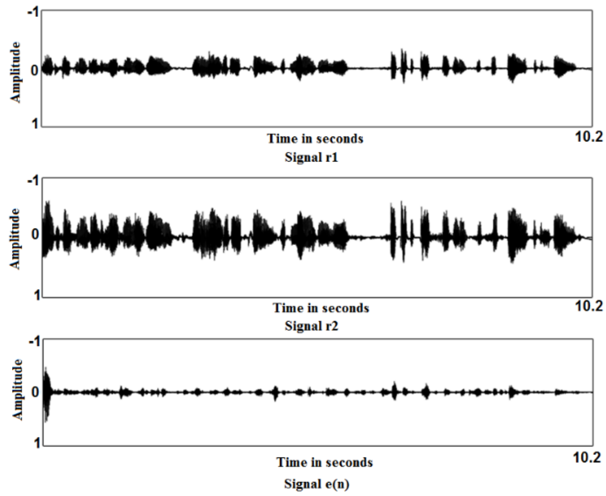


Figure *4*. *Separated received signals at the near end. (a) r1. (b) r2. (c) Error signal* $e(n)$.

A higher ERLE value indicates better adaptive echo canceller performance. In Table 1, we list out the maximum, minimum, and average ERLE along with execution time. It indicates that the proposed technique cancels echo better with a slightly longer execution time.

Table 1. *Comparison of ERLE in dB and execution time for all discussed tap-length-optimization algorithms applied to SLF-SAEC*

Tap-length Algorithm	Max. ERLE (dB)	Min. ERLE (dB)	Avg. ERLE (dB)	Exe. time (Sec)
FT-LMS	35.5	-35	11.8	138.0
VT-MSD	38.5	-20.02	18.6	142.1
VT-VS-NLMS$_{VE}$	41.7	-10.8	21.2	147.5
Proposed	46.4	-10	24.5	155.4

The ERLE implementation of the COEA-based echo canceller with tap-length optimisation exhibits inferior performance compared to that of an SLF echo canceller. In contrast, it offers quicker convergence and is a superior option for stereophonic echo cancellers that utilise advanced adaptive filters with long tap lengths. Therefore, we can conclude that the COEA with the optimal tap length produces superior convergence compared to the variable-tap-length adaptive SLF.

4. CONCLUSION

The proposed tap-length-optimization technique emulates a system with a reduced number of filter coefficients compared to variable-tap-length algorithms. It exhibits faster convergence and superior steady-state performance for both high and low SNRs. The use of the new tap-length optimisation has been assessed in the SAEC framework, both with and without the inclusion of MSF. The results of the comparisons demonstrate that the MSF-based COEA with variable tap length achieves convergence in stereophonic echo canceller. This approach can also be made resilient for applications badly affected by strong noise with an SNR below 20dB.

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Programming Languages in Development of Embedded systems: Preliminary Review

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Abstract: *In this work, a brief analysis of related work and comparation of programming languages in development of embedded systems has been presented. Focus of this paper is to show different programming languages used in various embedded systems as well as their popularity and efficiency in terms of speed and processing required data.*

Keywords: *programming; embedded; systems; review; development*

1. INTRODUCTION

Programming and development of embedded systems is a task that requires planning and making decisions about the most suitable programming language to be used based on the requirements and complexity of the embedded systems that are being built. These systems can vary from complex military systems, drones, surveillance equipment and security systems up to identification card readers and small, home devices often integrated within Internet of Things systems. Commonly used programming languages in development of embedded systems are C and C++, but recently, Java, Rust and Python gained popularity as well.

All these programming languages have their own advantages and disadvantages such as execution time, behavior of execution, complexity of the source code, available libraries, tools and abilities that system needs to meet. As embedded software is becoming more important with the emergence of the Internet of Things, the devices face a wider range of security threats, and it is of great importance to reduce possibilities of security breaches in such systems in order for internet of things software to be accepted widely [1].

Aim of this paper is to show advantages and disadvantages of different programming languages and scripts in terms of execution speed, code readability and implementation over different microprocessor based devices. The paper is organized as follows: next section explains basic terms related to the embedded systems and their usage, section three presents short overview of popular programming languages used for their development, while section four brings comparative analysis of previously presented programming languages - C, C++, Java, Rust and Python. Final section brings conclusions and future work.

2. BACKGROUND

An embedded system is a specific type of the system that works with hardware and mechanical parts. Purpose of such system is to handle specific environment, acquire and process data from sensors and execute tasks [2]. Embedded systems are mostly small systems with limited performance capabilities that perform analogue to digital operations and data processing.

Programmable parts of embedded systems are usually hardware elements such as microcontrollers or FPGA devices. The common structure of an embedded system consists of main device (performing some useful activity such as air conditioner), sensor (to detect the status of the main device or working environment of the main device – for example: the temperature in the room), processor (microcontroller or FPGA), actuator (to perform corrective action upon the main device) [3].

Below is shown the image of the block-level diagram of the system-level design.

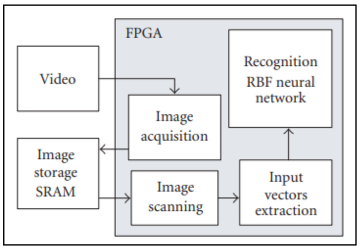

Figure 1. *Diagram of the system-level design [3]*

In the picture below is shown the example of reconfigurable platform.

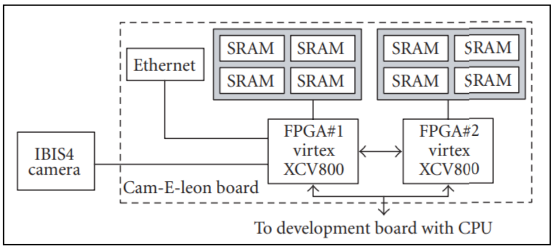

Figure 2. *Cam-E-leon dynamically reconfigurable web camera platform from IMEC [3]*

Embedded systems can extend their own capabilities by the usage of modules for wireless transmission or internet connection (which enables embedded systems to be integrated in Internet of Things - IoT), long range transmission, audio and video recording, temperature measurement, gyroscope mechanism as well as communicating between each other. As for IoT, embedded systems can be utilized within smart houses which have additional software having small artificial intelligence models for consumer purposes, control the lights, shutters and security systems. Below is shown the depiction of Internet of Things system.

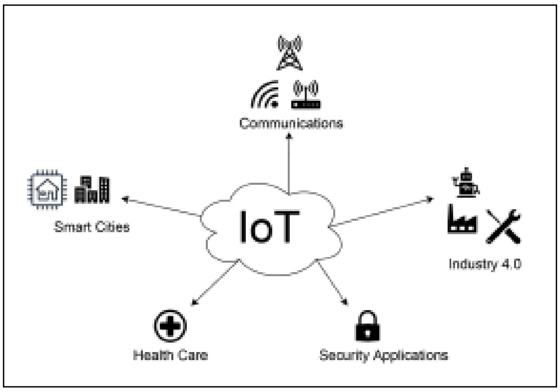

Figure 3. *Internet of Things system application domain [4]*

Besides application domain, below is shown the image of features that Internet of Things system could contain.

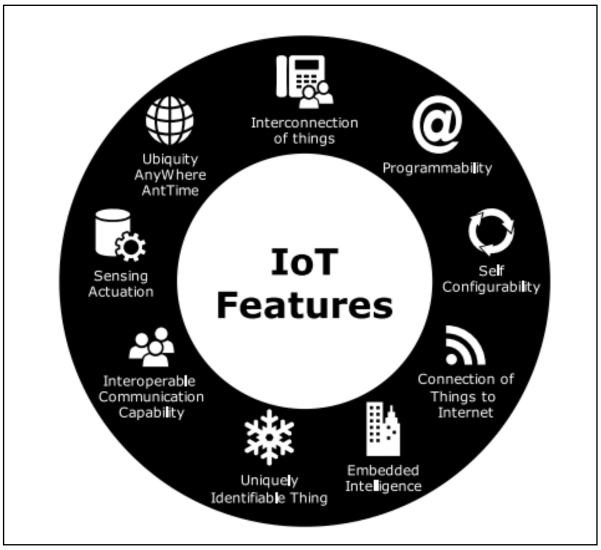

Figure 4. *Features of system that is considered to be Internet of Things device [4]*

3. PROGRAMMING LANGUAGES FOR EMBEDDED SYSTEMS

Speaking of the purpose of real-time embedded systems, they were originally used for industrial and military purposes which implicates that results are not only correct from an arithmetic-logical point of view, but these results also need to be produced before a certain deadline [5].

Real-time operative systems are used for small embedded systems as well, and aspect of memory management and execution time is an important factor to consider in the development of the source code which usually tends to be multi-threaded [5].

3.1. C programming language

C and C++ are low level programming languages with fast execution speed and are often used in embedded systems where the time of execution is important for system to function properly. While C is procedural programming language, using C++ offers object-oriented approach which could be harder to implement, but could provide more readable source code. On the other side, there are several ways to extend the usability of C programming languages in embedded systems.

C programming language can satisfy the requirements of both high performance and memory efficiency. Semantics of C programs can depend on both processor architecture and compiler, due to the fact that size of each data type is fixed by compiler itself. For example, C programs written for 32-bit processors can behave differently on 16-bit processors. Speaking of ways to extend C language, the Valen-C and retargetable compiler could be used. Valen-C is an extension designed for C programming language which offers the possibility for programmers to specify required bit length of each variable in a program. While C programming language offers three integer sizes such as short, int and long, those sizes are determined by the compiler designers. On the other side, Valen-C extension gives the possibility for programmers to use more kinds of data types, such as int11 which means that precision is of 11 bits [6].

Several ways to improve behavior of C in embedded systems could be achieved by using top level constructs such as leveling of the functions and structure declarations. This can provide integration of test cases or new programming paradigms relevant in specific domains, machines or interfaces and components. Second way of improvement can be implemented by using statements such as assert or fail statements in test cases in a specific context. Third way to improve C behavior can be achieved by having new kinds of expressions, like decision table expression that represents a two-level decision tree as a two-dimensional table [7].

3.2. C++ programming language

One of the advantages of C++ programming language over C is the aspect of object-oriented programming, which provides encapsulation, abstraction, polymorphism and inheritance, as well as specific ways to optimize the source code.

C++ compiler can use public and private keywords which can determine method calls and data access that is either allowed or forbidden. Since this is done during the compile time, there is no penalty at runtime, and addition of classes alone does not have impact on code size or efficiency of the program itself. Speaking of function calls, the possibility of method overloading exists, which provides the ability for the existence of the functions with same names, but followed by different parameters. This is achievable due to virtual keyword which has reasonable cost to benefit ratio where the price is paid in the additional memory lookup, before the virtual function can be called. Similar to method overload, the possibility of operator overloading exists as well, and whenever the compiler sees such operator, it will replace it with an appropriate function call [8].

One important feature that C++ offers compared to C is the ability of handling exceptions. Try, catch and throw keywords can be used to define parts of the flow of the program execution.

Once the exception has been thrown, control is transferred to the first available catch block, only if it does not result in a call to std::terminate. Before execution of each catch block, the value is compared to type id of the exception type it handles and the type marked in the type field of the exception state. If types are equal or if the type the catch block handles is a base type of the type in the type field, then the catch block is executed. However, if the types are not equal, execution will jump to the next catch block, and it will repeat this process [9].

In C++ programming language, parts of source code optimization can be done by the compiler itself. However, many aspects of optimization techniques which are performed by compiler usually involve a tradeoff between execution speed and code size. Depending on the embedded system and available resources, it is possible to make the program either faster or to be smaller, but not both. Speaking of C++ programming language, the feature of inline keyword exists which can be added to any function declaration. Purpose of this keyword is to make a request to the compiler to replace all calls to the indicated function with copies of the code that is inside of the function. This leads to the elimination of the runtime overhead associated with the actual function call and is most effective when inline function is called frequently but contains only a few lines of code. Inline function is one of the examples of how execution speed and code size are sometimes inversely linked. Repetitive addition of the inline code is increasing the size of the program but lowers the number of times that the function is called [8].

3.3. Java programming language

Java programming language is a higher-level language used in different parts of software development, such as web-based applications, desktop applications and video games, but it is not limited to embedded systems as well. With a unique feature of java environment and it's architecture, it is possible to develop software designed to run on embedded systems that have Linux based operative systems on Raspberry Pie and Banana Pie devices.

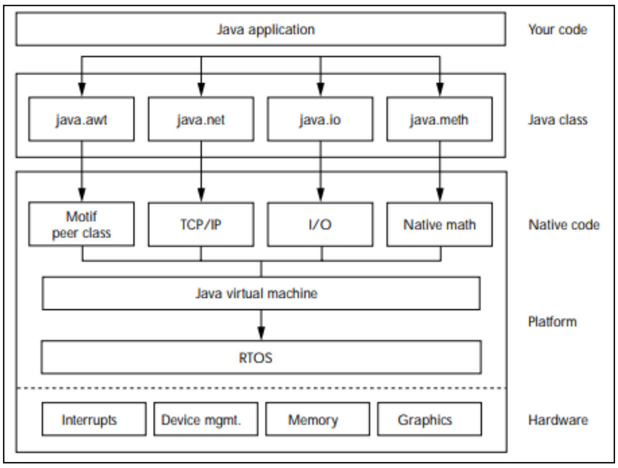

Figure 5. *Architecture of the Java platform [10]*

Java platform architecture consists of five different layers. First layer is related towards the source code which is often JAR file that contains source code of the application itself. Second layer represents Java class, which is Java API class package received with Java Virtual Machine, where API calls are provided. Third layer is related towards the native code and that includes native-code libraries referred to by Java code in the class package, and this layer co-exists with the Java Virtual Machine and Real Time Operative System.

Fourth layer is the platform layer, where the Java virtual machine loads and executes Java classes from memory. Java virtual machine uses the facilities of the real time operative system to manage the Java application operation. Fifth layer is related towards the hardware, containing hardware infrastructure managed directly by the real time operative system which resolves all runtime needs of the Java virtual machines and manages scheduling [10].

It is possible to implement Java virtual machine as a software environment executed on an arbitrary embedded processor, as well as a hardware solution by using a processor that can execute Java byte code natively [11].

On the other hand, Java Optimized Processor is used to enforce that microcode instructions are optimized for Java byte code, since direct implementation of all byte codes in hardware is not a useful approach due to their complexity [10].

By using picoJava, microprocessor directly executes the Java byte codes instruction set and the extended byte codes, intentionally omitted by Java Virtual Machine designers. By having additional byte codes, ability to control hardware emerged as well as access to the memory [12].

Regardless of the execution time compared to C and C++, Java programming language replaces the error-prone style pointers with object references. Compiler is used to enforce type checking, and is performed at runtime, resulting in less programming errors [11].

3.4. Rust programming language

Rust is a low-level programming language that features security practices which are not enforced by C and C++ programming languages by default.

Many modern programming languages were able to implement security features such as guaranteed memory safety and data race freedom, but none of these were able to impose higher margins on the embedded systems market. Memory related problems in C and C++ programming language are based on unrestrained pointer to variable manipulation, as well as pointer to object manipulation that is outside of its memory location and lifetime. One of the Rust's main innovation was the introduction of specific semantics that define ownership and borrowing, by following specific set of rules that Rust's type system enforces. First rule is that all resources such as variables and similar must have clear owners. Second rule is that others can borrow from owner. Third rule is that owner cannot free or mutate the resource while it is borrowed [11].

CWE ID	Name
119	Improper Restriction of Operations within the Bounds of a Memory Buffer
120	Buffer Copy without Checking Size of Input ('Classic Buffer Overflow')
125	Out-of-bounds Read
126	Buffer Over-read ('Heartbleed bug')
122	Heap-based Buffer Overflow
129	Improper Validation of Array Index
401	Improper Release of Memory Before Removing Last Reference ('Memory Leak')
415	Double Free
416	Use After Free
591	Sensitive Data Storage in Improperly Locked Memory
763	Release of Invalid Pointer or Reference

Figure 6. *Common weaknesses found in C/C++ that affect memory [13]*

One of the important aspects of memory management that Rust programming language have over C++ is that it offers high level of memory safety and management without the need of garbage collection, while the C programming language requires manual memory allocation management, resulting in software bugs that could affect the safety and security of such devices [14].

Looking from the aspect of the object-oriented programming, Rust supports polymorphism with traits. Trait in Rust is used to define the interface to a polymorphic type, similar to Java interface. Trait can be implemented by multiple concrete types and it provides two different polymorphic mechanisms. Generics are similar to C++ templates and trait objects are similar to C++ abstract classes. Generics are used to generate method for each concrete type that is used to call generic function, which is called monomorphization and its performance is equivalent to normal function calls. Contrary to generics, trait objects enable dynamic dispatch by using runtime lookups in virtual table. Usage of trait objects is applied when the concrete type that will be passed to the function can vary, or is not known at compile time [15].

3.5. Python

Since Python is an interpreted language, but also higher level language with garbage collector, it is often perceived as a scripting language [16].

Python gained popularity over the years due to simple syntax and ability to achieve similar things with less lines of code. Contrary to compiled languages, Python is using interpreter to translate source code at runtime, which often leads to slower time of execution, as well as increase of runtime-based errors. At the same time, it is the fact that complex systems require fast execution where timing is of key importance, and memory management is necessary.

MicroPython, developed by Damien George is designed as an interpreter of Python 3, and is used for microcontrollers. MicroPython is offering a selection of specific Python libraries and modules, which can access low-level hardware of several microcontrollers. While it can run on ESP32 microprocessors, MicroPython-based programs have much worse performances compared to programs written in C programming language [16].

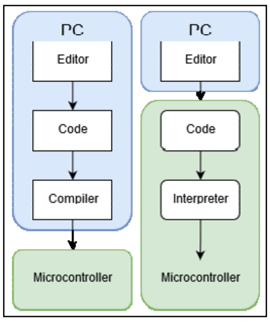

Figure 7. *Graphic presentation of code implementation (left side – C, right side – Python) [17]*

Advantage of MicroPython is based on the rapid development of Internet of Things devices, by using verified and tested libraries in order to achieve routine operation of standard high-level peripherals [18].

To run MicroPython on ESP32 based device, it is necessary to download specific firmware. When ESP32 based device is set to download mode, MicroPython firmware can be flashed on the device which allows it to transfer source code. Instructions are transferred to ESP32 directly by using serial communication or an integrated development environment which is used to store code files [19].

4. COMPARATIVE ANALYSIS

Comparative analysis is used to show some of the differences between programming and script languages used for development of embedded systems. In the table below, the basic difference of programming and script languages is shown.

Table 1. *Basic differences of programming and script languages for embedded systems*

Programming language	Behavior of execution	Level of language
C	Compiled	Low level
C++	Compiled	Low level
Java	Compiled	Higher level
Rust	Compiled	Low level
Python	Interpreted	Higher level

Since the way of execution plays important role for execution time, it is important that language used for development of complex systems is compiled, which can often provide ability to tweak settings of the compiler as well, and impact on performances in different manners. The lower the level of language, the closer it is to hardware, and that provides better optimization as well as compatibility.

Speaking of execution speed, table below shows the expected performances in reviewed languages of this paper.

Table 2. *Expected performances of programming and script languages*

Progra-mming language	Execution speed	Explanation
C	Very fast	C, C++ and Rust are most suitable and were shown to be fastest in most cases [20]
C++	Very fast	C, C++ and Rust are most suitable and were shown to be fastest in most cases [20]
Java	Moderate	Regarding the real-time capability, usage of Java processors have many benefits from the omitted software Java Virtual Machine and operating system [21]
Rust	Very fast	C, C++ and Rust are most suitable and were shown to be fastest in most cases [20]
Python	Slow	MicroPython based programs were shown to be much slower than implementations that were done in other programming languages [20]

Comparing C, C++, Rust and MicroPython language used for development of embedded system devices, table below shows the support of these languages for ESP32 based microprocessors.

Table 3. *Overview of the programming languages and script languages on ESP32 based device [20].*

Programming language	ESP 32 Peripherals Support	Language Features Support on ESP32
C	Full	Full
C++	Full	Full
Rust	High	High
MicroPython	Medium	Limited

Comparing the way of execution and runtime environment, table below shows the key differences between C, C++, Rust and MicroPython.

Table 4. *Overview of execution and runtime environment [20]*

Programmi-ng language	Compiler for ESP32	Runtime Systen on ESP32
C	GCC	C/C++ standard library on FreeRTOS
C++	GCC	C/C++ standard library on FreeRTOS
Rust	LLVM	Rust standard library on FreeRTOS
MicroPython	Interpreted	MicroPython interpreter on FreeRTOS

Tables above shows that most efficient way to provide fast and reliable embedded system is done by implementing C, C++ and Rust. Fast execution speed, large number of supported peripherals as well as language support is considered when making complex systems. However, for small projects where optimisation is not of great importance, MicroPython and Java could be considered as an option. Speaking of clean code and readability, C, C++, Rust and Java have more complex syntax than Python based solution, where Python based solution should be considered as beginner friendly way to start development of embedded systems.

According to [22], Comparison of Time and Memory of searching algorithm in binary search between Python and C++ can be shown in the table below.

Table 5. *Comparison of Time and Memory of Searching algorithm [22]*

	Time in Python (ms)	Time in C++ (ms)	Memory in Python (Kb)	Memory in C++ (Kb)
Best Case	0.19	0.094	19.54	9.65
Worst Case	0.077	0.134	19.53	10.19
Average Case	0.118	0.108	19.53	10.2

According to [22], by performing bubble sort, Comparison of Time and Memory of sorting algorithm is shown in the table below.

Table 6. *Comparison of Time and Memory of Sorting algorithm [22]*

	Time in Python (ms)	Time in C++ (ms)	Memory in Python (Kb)	Memory in C++ (Kb)
Best Case	0.56	0.006	11.6	4.01
Worst Case	1.06	0.011	11.71875	4.04
Average Case	0.93	0.108	11.71785	5.43

According to [22], by performing insertion in a data structure at desired location, Comparison of Time and Memory of Insertion Algorithm can be shown in the table below.

Table 7. *Comparison of Time and Memory of Insertion algorithm [22]*

	Time in Python (ms)	Time in C++ (ms)	Memory in Python (Kb)	Memory in C++ (Kb)
Best Case	0.024	0.005	7.2	4.01
Worst Case	0.03	0.008	7.4	4.04
Average Case	0.028	0.006	7.31	5.43

According to [22], Comparison of Time and Memory of Deletion Algorithm in which elements are removed from the data structures from start, end or other location is shown in the table below.

Table 8. *Comparison of Time and Memory of Deletion algorithm [22]*

	Time in Python (ms)	Time in C++ (ms)	Memory in Python (Kb)	Memory in C++ (Kb)
Best Case	0.010	0.004	3.906	5.67
Worst Case	0.021	0.005	7.8125	6.42
Average Case	0.013	0.0042	7.742	6.12

According to [23], source code for benchmark is developed and several programming languages were chosen. Codes for benchmark were first compiled to machine code and stored in the executable file. Then, four executable bat files were created to run every executable files for ten times in order to provide better overall picture of performance for chosen programming languages. All the outputs of the executable bat files were stored in the files, and the files were used to analyze the performance of four chosen programming languages.

According to [23], by performing mathematical benchmarks for integers, doubles, longs, trigonometry functions and I/O operations, benchmark results were measured and can be seen in the figures below:

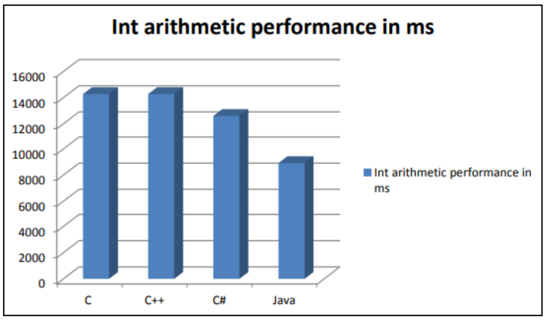

Figure 8. *Int arithmetic performances in ms [23]*

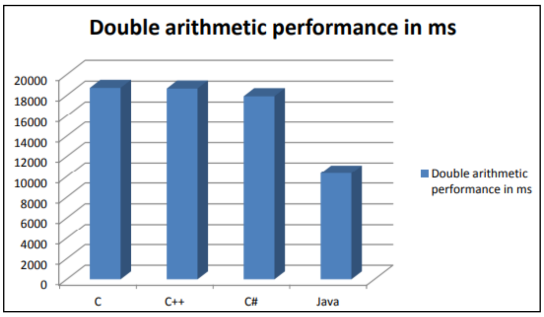

Figure 9. *Double arithmetic performances in ms [23]*

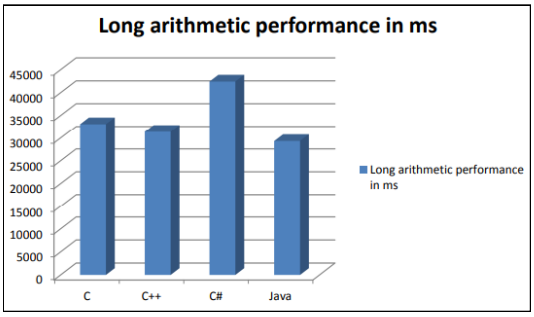

Figure 10. *Long arithmetic performances in ms [23]*

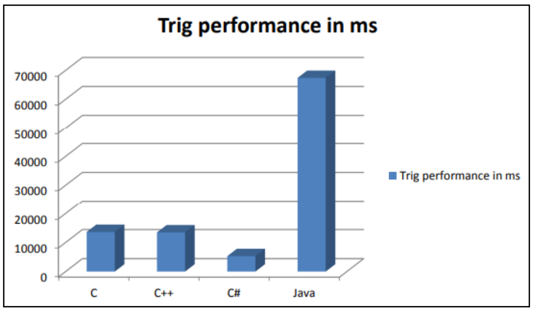

Figure 11. *Trig arithmetic performances in ms [23]*

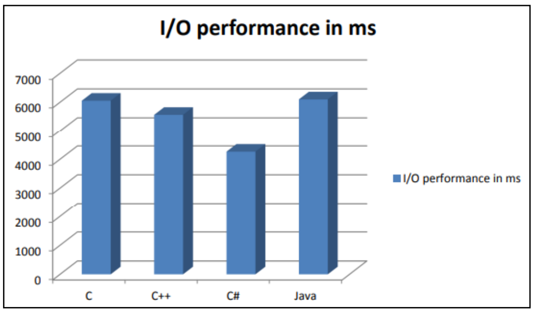

Figure 12. *I/O performances testing in ms [23]*

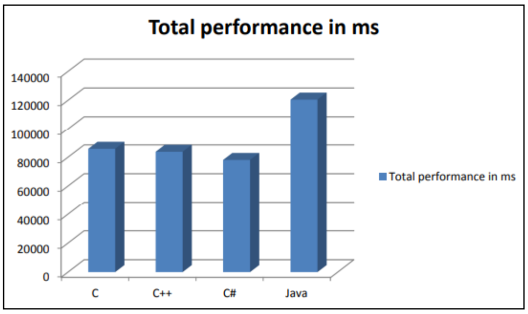

Figure 13. *Total performances testing in ms [23]*

5. CONCLUSION

By having available multiple languages designed for development of the embedded systems, it is of great importance to perform comparative analysis, or benchmarking, in aim to decide which language would be the best choice for specific system and environment. When important and complex systems require the fastest execution time, where error can lead to critical system failure, C, C++ and Rust may be the best choice. In circumstances where the execution time is considered as critical factor, Java and Python may be used.

Regardless of choice, source code should be readable and optimized to achieve best performances and balance between memory consumption and execution speed. Future research in this field could be directed towards experimental approach to evaluate embedded systems in wide set of quality attributes, as well as to have evaluation set in the context of integration of different embedded systems within complex systems such as Internet of Things applied within smart homes, smart cities and smart industry.

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Creating a PHP User Interface for Manipulating MySQL Databases

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Abstract: *In today's digital environment, accessing and manipulating data are crucial aspects of various web applications. This paper explores the process of creating a PHP user interface for efficient manipulation of MySQL databases. Accessing databases through web applications requires careful planning and implementation to ensure security, performance, and practicality. Using PHP as the server-side language and MySQL as the database, we delve into methods for creating an interactive user interface that allows users to read, write, update, and delete data in the database. The focus of the paper is on the application of basic PHP functionalities and techniques such as forms, queries, and error handling to enable a user interface that is intuitive to use and reliable in operation. Through implementation examples and performance evaluation, the key aspects of the process of creating a PHP user interface for manipulating MySQL databases are highlighted, providing guidance for optimization and improving efficiency in developing similar systems. This paper contributes to understanding techniques and practices for creating secure and functional web applications that communicate with databases, with a special focus on PHP and MySQL technologies*

Keywords: *PHP; MySQL; Web application; User interface*

1. INTRODUCTION

In today's digital age, an increasing number of applications require efficient data handling through the user interface to provide users with a rich usage experience. In web development, PHP (Hypertext Preprocessor) is often used as a server-side language for dynamically generating content [1], while MySQL is frequently used as a database for storing and managing data. Connecting PHP with a MySQL database allows developers to create powerful web applications that offer users an intuitive environment for data interaction [1]. Examining the execution speed of computers using the PHP programming language and database enables the optimization of web application performance, making them faster and more efficient in processing and managing data [2].

This paper explores the process of creating a user interface for working with a MySQL database using the PHP programming language. We focus on the analysis of techniques, tools, and practices that enable efficient PHP-MySQL integration for executing queries, displaying data, and managing user interactions [2].

In the first part, we discuss the basics of PHP and MySQL, highlighting their key features and roles in web application development. Then, we explore the principles of user interface design that facilitate the creation of intuitive and functional user experiences. After that, we provide a detailed analysis of the process of connecting to a MySQL database through PHP, examining various methods and techniques used to establish the connection and execute SQL queries [3].

Additionally, we discuss the security aspects of PHP applications that use a MySQL database, emphasizing the importance of implementing security mechanisms to protect data from potential attacks and information leaks. The use of PHP is not limited to database management; it is also widely used in cryptography for secure encryption and decryption of data, ensuring the protection of confidential information in web applications [4].

The significance of this research lies in the context of digital transformation and the development of web technologies, highlighting the need for further exploration and improvement of practices in creating PHP user interfaces for working with a MySQL database.

2. USER INTERFACE

User Experience (UX) design plays a crucial role in creating an efficient user interface, laying the foundation for interaction between users and the application [3]. The central goal of UX design is to understand the needs, expectations, and experiences of users in order to create a user experience that is not only functional but also intuitive and enjoyable to use [5]. This involves careful research of the target audience, identifying their goals and challenges, as well as timely collection and analysis of feedback to iteratively improve the user experience. Through effective UX design [5], users experience comfort and increased confidence while using the application, resulting in higher user satisfaction and loyalty.

Aesthetics and visual design are key factors in creating a user interface that attracts users and provides them with a pleasant user experience. Through careful selection of colors, typography, icons, and graphic elements, designers can create a subtle and coherent aesthetic identity that reflects the application's brand and facilitates user orientation [6]. In addition to improving aesthetics, visual design also plays a crucial role in guiding the user's gaze to important interface elements and in emphasizing functionality and interactivity. Through a harmonious combination of form and function, aesthetics and visual design contribute to creating a user interface that inspires, engages, and leaves a lasting impression on users.

Adaptive design is a key element of modern web development that allows the user interface to adapt to different devices and screens. Through the use of media queries, flexible grids, and other techniques, designers can ensure that the application looks and functions seamlessly on desktop computers, tablets, and mobile phones. This approach enables users to have a consistent experience with the application regardless of the device they use, providing them with the freedom to access content and features wherever they are.

Using icons and symbols in the user interface can significantly improve the ease of use and aesthetics of the application [6]. By using clear and consistent icons, designers can facilitate users' understanding of the interface while adding aesthetic value and enhancing the overall impression of the application.

User interface testing is a crucial step in the development of PHP applications that use a MySQL database. Through user research, prototyping, and A/B testing, developers can identify any shortcomings, usability issues, and design inconsistencies [7]. These tests allow developers to gather valuable feedback from real users and identify areas that require improvement or additional iterations in the design and functionality of the application. Through continuous testing, the application can be improved to ensure the best possible user experience and user satisfaction [8].

Continuous improvement of the user interface is a key practice that allows the application to remain relevant and competitive in a dynamic digital environment. By analyzing usage data, user feedback, and changes in technology, developers can identify new opportunities to improve the user experience and implement them into the application. An iterative approach to development allows the application to evolve and adapt to the needs of users, resulting in long-term user satisfaction and loyalty to the application.

3. TOOLS FOR USER INTERFACE DEVELOPMENT

Tools for user interface development play a crucial role in the process of creating PHP applications that utilize a MySQL database [9]. There is a wide range of tools and technologies available to developers that facilitate the development and design of user interfaces, providing them with the necessary resources and functionalities to create modern and functional web applications [10]. These tools include programming languages such as HTML, CSS, and JavaScript, which allow for defining the structure, styling, and interactivity of the user interface [11]. Additionally, frameworks and libraries like Bootstrap, jQuery, and React provide ready-made components, patterns, and styles that facilitate development, simultaneously improving productivity and code quality [12]. Moreover, interface design tools such as Adobe XD, Sketch, and Figma enable designers to prototype, design, and test the user interface before implementation begins [13]. The combination of these tools allows developers to create PHP applications with a MySQL database that are not only functional and efficient but also aesthetically appealing and user-oriented.

3.1. An overview of PHP Environment

Overview of the PHP Environment is a crucial step in the development of PHP applications that utilize a MySQL database. PHP is a server-side scripting language commonly used for dynamically generating web content. The PHP environment encompasses several components that enable the execution of PHP code on a web server. The core components include a web server, PHP interpreter, and MySQL database [14]. A web server, such as Apache, Nginx, or IIS, serves to receive requests from clients and execute PHP scripts that generate dynamic HTML content [15]. The PHP interpreter processes PHP code and generates HTML sent to the user via the web server. The MySQL database enables storage, management, and manipulation of data used in PHP applications [16]. In addition to these core components, the PHP environment may include additional tools, libraries, and frameworks that facilitate the development and maintenance of PHP applications, such as Composer for dependency management, PHPUnit for testing, and Laravel or Symfony for PHP framework development [17]. An overview of the PHP environment enables programmers to understand the architecture and components necessary for developing PHP applications that efficiently utilize a MySQL database, resulting in stable, scalable, and secure web applications.

3.2. Database Management System - MySQL

MySQL is one of the most popular RDBMS (Relational Database Management Systems) used in web application development [18]. As an open-source system, MySQL is available on various platforms and provides a high level of flexibility, enabling efficient data management in PHP applications. MySQL uses SQL (Structured Query Language) for data manipulation, offering support for transactions, indexing, security mechanisms, and data replication.

MySQL allows users to efficiently store and manage data organized into tables. Databases are crucial for processing large amounts of information, making them essential for many applications, including PHP applications. MySQL enables users to easily manage database access, reducing the risk of errors, and is most commonly used in combination with PHP on Apache web servers [19].

On a server, multiple databases can exist independently, and different administrative rights can be assigned to each user. MySQL creates a super administrator (usually root) with all rights, including the ability to create, modify, and delete databases and tables. MySQL is available for all major operating systems and is distributed under the GPL (General Public License), making it ideal for learning and developing smaller to medium-sized websites.

The MySQL installation includes several key folders: bin (with server and client programs), lib (function libraries), scripts (Perl scripts), share (textual error message files), and include (header files for compilation). Executable files are located in bin and scripts folders, including mysqld (server), mysqladmin (administrative functions), myisamchk (table check and repair), mysqldump (backup), and mysqlshow (displaying database and table data).

4. DEVELOPMENT OF THE USER INTERFACE

This section explores a comprehensive approach to designing the user interface for PHP applications that use MySQL databases. The focus is on creating an intuitive and pleasant user experience that meets the users' needs. Through analyzing user requirements, identifying key functionalities, and creating prototypes, developers can develop a structure, layout, and interactivity of the interface that fulfills the project's goals.

By utilizing modern technologies and tools such as HTML, CSS, JavaScript, jQuery, and others, the development team can create a dynamic and attractive user interface [20]. This interface enables users to easily manage data and interact with the application. Additionally, part of the research focuses on strategies for testing the user interface, identifying shortcomings, and iteratively improving it to achieve optimal user experience.

The focus on developing a user-centric, aesthetically appealing, and functional user interface allows PHP applications that use MySQL databases to achieve a high level of success and user satisfaction.

5. IMPLEMENTATION OF AN APPLICATION FOR WORKING WITH A DATABASE

The idea for creating a PHP application stemmed from the need to customize the interface within the PHPMyAdmin environment for working with MySQL databases on the server. When PHPMyAdmin is launched, in addition to user databases, system databases necessary for MySQL and PHP server operation also appear. To prevent errors and damage to system databases, a PHP application specialized for working with user databases was developed, as shown in Figure 1.

This application allows for the creation, deletion, and addition of tables in databases, as well as modifications to the database structure. Administrative access to system databases is disabled because the application does not load those databases upon startup, thereby increasing security and reducing the risk of errors.

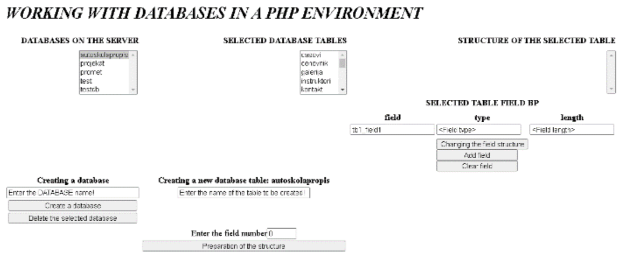

Figure 1. *Database Management Application*

The application design is based on displaying databases on the server, a command block for creating and deleting databases, a list of tables for the selected database, a command button for creating a new table in the selected database, the structure of the selected table, and a command block for editing the structure of the selected database table, as shown in Figure 1. It is important to note that data manipulation commands for the database table are not included within the application; in other words, the purpose of this application is to facilitate the work of database administrators. The application is launched by entering a specific address into a web browser:

http://localhost:8082/tie/indexcb.php

Due to the complexity of the application, in addition to the main program indexcb.php, four additional subprograms have been developed, PHP-1, which are called from the main program. These subprograms include:

- ConnectToServer.php
- DatabaseArray.php

- ChangeTable.php
- Add_Lists.php

PHP - 1

```
1  <?php
2  include("ConnectToServer.php");
3  include("DatabaseArray.php");
4  include("ChangeTable.php");
5  include("Add_Lists.php");
6  ...
7  ?>
```

By using the include command (lines 2 to 5), the PHP compiler is informed that the functions called in the main program are located in one of the specified PHP files.

It is important to note that when performing actions via command buttons, the current page is not left; instead, it is refreshed after each executed command. To achieve this, it is necessary to explicitly specify which action should be taken when an event occurs on the page in the form definition. The command from the PHP server $_SERVER['PHP_SELF'] is executed as shown. The method used for transmitting executed actions is POST.

5.1. Establishing connection to the database server

For the successful operation of this application, as well as any other application working with databases, it is necessary to establish a connection to the database server, as shown in PHP code - 2. In this example, the database server is MySQL, as already noted. To establish a connection to the database server, the function ConnectToServer() is created, which is located in the program ConnectToServer.php. This function is called from the main program or subprograms whenever it is necessary to establish a connection to any of the databases on the server, i.e., before executing any action on the database or its tables. To open the desired database, in addition to the server, it is necessary to specify the name of the database.

PHP - 2

```
<?php
function ConnectToServer ()
{
$connection=mysqli_connect("localhost",
"root","");
if($connection)
{
return $ connection;
}
else
{
exit("Failed to connect to the MySQL server
");
}
}
----
?>
```

5.2. Creating a list of databases on the server

To form a list of databases located on the server, after establishing a connection to the server, it is necessary to execute a query that will load all user databases but exclude system databases. The code achieving this is provided in PHP - 3.

PHP - 3

```
1   <?php
2   include("ConnectToServer.php");
3   include("DatabaseArray.php");
4   include("PromenaTabele.php");
5   include("ChangeTable.php");
6   ---
7   $ Array_Type = array("varchar", "text",
    "char","int","float","decimal","date",
    "datetime");
8   $ Array_021[]= array("id" => 0, "rbt" =>
    0, "tabela" => "");
9   $ Array_02[] = array("id" =>0, "val" =>
    "");
10  $ Array_03[] = array("rbt" => "", "field" =>
    "", "tip" => "");
11  $ Array_01[] = array("id" => 0, "val" =>
    "", " tableCount "=>0);
12  for($i=0;$i<100;$i++)
13  {
14  $ StructureArray[$i]="---";
15  }
16  ---
17  Nizovi($Array_01, $Array_021, $ Array_02,
    $ Array_03, $CountBP);
18  ---
19  ?>
```

The query results are stored in the corresponding arrays. Initialized arrays (lines 7 to 14) hold the following data:

- $Array_01[] - user databases on the server,
- $Array_02[] - tables within the selected database,
- $Array_03[] - structure of the selected database table.

The Arrays function is called with appropriate parameters, which are updated within the function itself. The implementation of this function is located in the Arrays.php program.

Connecting to the database server is performed while defining the query string that will load all databases from the server. The query result is stored in the $result variable. This variable contains names of both user and system databases, so it is necessary to filter the result to load only user databases into the auxiliary array. After that, the previously established connection is released to prepare a new query for reading tables for each of the databases stored in the array.

In this way, the arrays $Array_01[] - user databases on the server, $Array_02[] - tables within the selected database, and $Array_03[] - structure of the selected database table are populated.

5.3. Filling lists of databases, tables, and table structures

After the appropriate arrays have been populated, it is necessary to display the data about databases, tables for the selected database, and the structure of the selected table.

An object ListaBaza is defined with the procedure this.form.submit(), which checks if the user has selected a row, i.e., a database. Forming rows in the list is done by calling the PHP function add_database_list() with the appropriate parameters: $selectedDB - a variable containing the name of the selected database from the list, and the name of the array $Array_01 from which the names of user databases are read. The $selectedDB variable enables selecting the previously chosen database when refreshing the page.

5.4. Creating/Deleting a Database

Creating a new database starts with entering the database name and clicking on the button to create the database. If the database is successfully created, an appropriate message will appear, and after refreshing the page, the name of the new database will appear in the list of databases.

To delete a database from the server, you need to select the database you want to delete from the list of databases and click on the delete button. After performing this action, the selected database will be deleted from the server, and its name will disappear from the list of databases after refreshing the page. On Figure 2, the creation of a database in the application is illustrated.

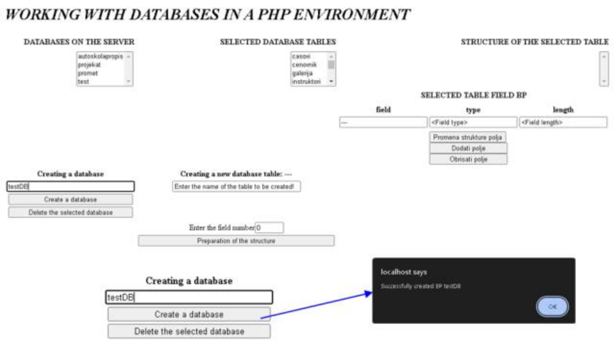

Figure 2. *Creating a Database*

5.5. Creating and Modifying a Database Table

Selecting a database from the database list displays a list of tables in the selected database, and selecting a specific table populates the list with its structure. Choosing a field from the list populates the columns with the field name, type, and length.

To modify the table structure, you can change the type and length of a field and then click the "Change field structure" button, or you can enter a new name, type, and length for a field and then click "Add field". To delete a field, click "Delete field". To add a new table, start by entering the table name and defining the number of fields, then click the "Prepare structure" button. After this action, rows for entering the field name, type, and length are generated. Clicking the "Create table" button creates a table with the entered structure, which will appear in the list after refreshing, as shown in Image 3.

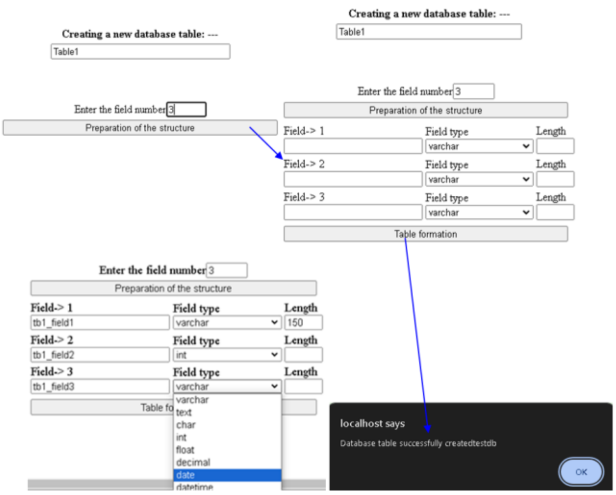

Figure 3. *Creating a database table and selecting the field type*

5.6. Discusion

This paper presents the process of creating a PHP user interface for manipulating MySQL databases, focusing on basic functionalities such as reading, writing, updating, and deleting data. To provide a broader context and highlight the advantages of the developed application, it is useful to compare it with existing user interfaces like phpMyAdmin, Adminer, and MySQL Workbench. phpMyAdmin is known for its ease of use and wide range of functionalities, allowing users to easily execute SQL queries, import and export data, and manage users. However, it can be slow when handling large databases and is often targeted by attacks, requiring careful configuration and regular updates. Adminer is easier and quicker to set up, with lower server resource requirements, but lacks some advanced features offered by phpMyAdmin, limiting its use for more complex tasks. MySQL Workbench offers advanced functionalities and better performance for working with large databases, but as a desktop application, it is not as accessible as web-based tools like phpMyAdmin and Adminer.

The created PHP user interface for manipulating MySQL databases offers several unique advantages. Firstly, it provides flexibility by allowing the creation of a custom interface that can be precisely tailored to the specific needs of users and applications. Additionally, it focuses on security, enabling design with specific security measures that reduce risks associated with general-purpose tools. Moreover, the interface is optimized for performance, particularly for key queries and operations that are significant for users.

Like any customized tool, the user interface also has its limitations. Development and maintenance require more time and resources compared to using existing tools. Furthermore, creating advanced functionalities can be complex and require a high level of technical knowledge to meet specific user and application requirements.

6. CONCLUSION

This paper explores key aspects of creating a PHP user interface for working with MySQL databases. Through an analysis of interface design, development tools, testing, and enhancement, as well as a review of the PHP environment and MySQL database management system, we uncover the importance of integrating these two technological pillars in web application development. Implementing an efficient user interface enables users to intuitively and effectively manage data, while PHP and MySQL provide a robust foundation for secure and scalable operation. Through proper design, development, and testing of the application, it is possible to enhance the user experience and optimize system performance. Overall, this paper contributes to understanding the complexity and significance of creating a PHP user interface for working with MySQL databases, highlighting the importance of this technological combination in modern web development.

This paper presents the process of creating a database management application in a PHP environment. Starting from the defined graphical interface for database administration within the phpMyAdmin software, the basic idea was to create an environment that would allow database administrators to work only with user databases. This is important considering the possibility of modifying the mentioned software and system databases necessary for MySQL and PHP operation. Such a customized environment facilitates database administration, increasing efficiency and reducing the risk of unwanted changes.

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Horizontal Scaling with Session Preservation of PHP Applications with MVC Architecture

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Abstract: *This paper explores horizontal scaling of PHP MVC applications with session preservation for enhanced availability and resource efficiency. It covers theoretical aspects of MVC architecture, PHP in web development, session handling, and horizontal scaling methods, including load balancers, Docker, and Kubernetes. The practical methodology details environment setup, application development, session management, Dockerization, Kubernetes integration, and horizontal scaling configuration. Performance testing reveals significant improvements, showing a response time decrease from an unresponsive state at 1000 RPS (5111 ms) to 32 ms at 2500 RPS with horizontal scaling. The study contributes insights and practical guidance for highly available and scalable web applications.*

Keywords: *horizontal scaling; session preservation; Kubernetes; high availability; load balancing*

1. INTRODUCTION

In the dynamic landscape of web development, the escalating demand for high availability and optimal resource management has highlighted the imperative need for horizontal scaling of web applications. This research addresses a pivotal challenge faced by developers when scaling applications—striking a balance between performance enhancement and the intricate preservation of user sessions. As web applications expand horizontally to meet growing demands, developers grapple with several formidable issues. Challenges include mitigating server overloads, ensuring seamless user experience during server transitions, and maintaining data integrity across distributed instances.

This paper gives a brief overview of the multifaceted problems developers encounter during the scaling process. These challenges encompass the intricacies of session continuity, load balancing intricacies, and the efficient orchestration of containerized environments. To surmount these hurdles, the proposed solution leverages cutting-edge technologies such as Docker and Kubernetes. By navigating through these challenges, this study aims to contribute practical insights, offering a comprehensive solution for developers seeking to develop scalable and highly available web applications.

2. THEORETICAL FOUNDATIONS

2.1. MVC Architecture

Model-View-Controller (MVC) architecture is a design pattern widely employed in software development to enhance the organization and maintainability of applications. At its core, MVC separates an application into three interconnected components: the Model, View, and Controller (Fig. 1).

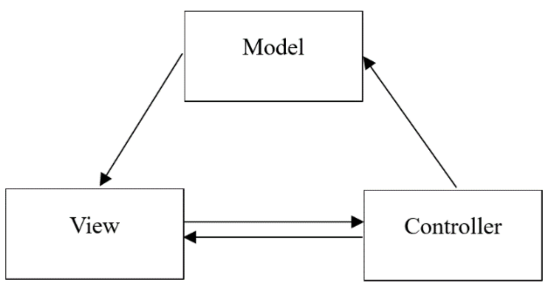

Figure 1. *MVC Architecture*

The Model represents the application's data and business logic, encapsulating the rules governing data manipulation and storage. It serves as the engine that manages and updates the application's state, ensuring a clean separation from the user interface. The View encompasses the user interface elements, presenting data to users and collecting input. It reflects the current state of the Model and displays information to users in a comprehensible format. The View is responsible for visual representation and user interaction but remains detached from the underlying data logic. The Controller acts as the intermediary, facilitating communication between the Model and the View. It interprets user inputs from the View, processes them, and triggers corresponding actions in the Model. The Controller plays a pivotal role in managing the flow of information between the Model and the View, ensuring effective coordination and response to user interactions [1]. This architectural pattern promotes modularity and flexibility, making it easier to update and maintain different aspects of the application independently. MVC not only enhances code organization but also fosters a clear separation of concerns, enabling developers to focus on specific components without compromising the integrity of the entire system [2].

2.2. PHP

PHP stands out as a popular server-side programming language in web development, playing a crucial role in crafting dynamic and interactive web applications. Its multifaceted capabilities empower developers to generate dynamic content on web pages, tailoring them to user demands and database inputs. PHP facilitates interaction with various databases, such as MySQL, PostgreSQL, and Oracle, enabling real-time data storage, retrieval, and updates. Additionally, it excels in processing data from web forms, validating inputs, and executing actions based on user submissions. Furthermore, PHP supports the creation and management of sessions, tracking user states during web page visits for functionalities like authentication, shopping carts, and personalization. Its utility extends to constructing APIs (Application Programming Interfaces) for seamless communication between diverse software components, including web and mobile applications. PHP's capacity to dynamically generate HTML code based on data or logic enhances the creation of dynamic components like lists, tables, menus, and more on web pages. With control over application flow, security features to counteract threats like SQL injection and XSS attacks, seamless integration with other technologies, and compatibility with popular web servers, PHP stands as a versatile and powerful server-side language, making it a cornerstone in the world of web development [3].

Sessions in PHP serve as a mechanism for maintaining state and tracking user information during their visit to a website. This functionality enables applications to temporarily store data on the server and utilize it throughout the user's session, facilitating personalization and interaction [4]. Session data is commonly employed for preserving details about a logged-in user, shopping cart contents, language preferences, or other settings crucial to retain during a website visit. In PHP applications, a session acts as a tool for preserving state across various HTTP requests that a user sends to the server during their visit to the website. Stored on the server, PHP maintains session data in temporary files or memory space, depending on the configuration. Each session possesses a unique identifier (session ID), typically transmitted to the user as a cookie or added to the URL. The mentioned basic concepts of sessions enable PHP applications to uphold states and track user information dynamically, facilitating personalization and interaction throughout their visit to the website. In PHP, sessions are implemented using the associative array global object $_SESSION. To begin a session, the session_start() function is utilized, initiating or resuming a session and allowing access to the $_SESSION array. This array serves as a container to store various session variables. Sessions are typically ended by calling session_destroy(). Accessing stored session values is achieved by referencing the $_SESSION array with the corresponding key. For example, to access a session variable named "username," one would use $_SESSION['username']. To unset or remove a specific session variable, the unset($_SESSION['variable_name']) function is employed, effectively removing the designated value from the session array. This mechanism provides a flexible and straightforward approach to managing session data in PHP applications.

2.3. Horizontal Scaling

Horizontal scaling of applications involves adding multiple instances (copies) of the same application to increase its capacity for handling requests and loads (Fig. 2). This technique is commonly used to enhance the performance, availability, and resilience of applications [5].

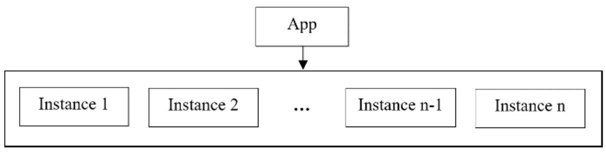

Figure 2. *Horizontal Scaling of an Application*

The key characteristic of horizontal scaling is that instead of overloading a single instance of the application, new instances are added to maintain a load balance among them. This is often achieved with the help of load balancing systems that direct incoming requests to available instances [6]. If one instance of the application becomes unavailable due to a malfunction or issue, other instances can take over the load, ensuring continuous availability. By adding more instances, the application can respond faster to requests and distribute the resources of each individual instance. In case the number of users or requests suddenly increases, horizontally scaled applications can quickly adapt to the increased load. Horizontal scaling enables upgrading and maintaining the application without a complete service outage, as one instance can be updated while others continue to operate. It's important to note that horizontal scaling is not always the ideal solution for all applications and requires careful planning and resource management to achieve optimal performance and efficiency. Additionally, the application must be designed to support horizontal scaling, which may involve certain changes in the application's architecture.

2.4. Load Balancers

A **load balancer**, whether a physical device or software entity, plays a pivotal role in optimizing the performance, availability, and reliability of applications. Its main function is to evenly distribute incoming network requests among multiple servers, instances, or resources [7]. By preventing any single server from being overloaded and ensuring a balanced workload, load balancers contribute to faster response times and improved fault tolerance. In the context of horizontal scaling, load balancers are instrumental in accepting network requests, routing and distributing requests among available instances, ensuring proper load distribution, and monitoring the health and performance of each instance. This results in an efficient and resilient system, where workloads are evenly spread, and any potential disruptions are mitigated through automatic redirection of requests to healthy servers. Ultimately, load balancers are a crucial component in modern infrastructures, enhancing application availability and maintaining optimal performance.

The **IP hashing algorithm** is employed by load balancers to achieve session preservation, ensuring that requests from the same client are consistently directed to the same server. In this approach, the load balancer calculates a hash value based on the source IP address of the incoming request. This hash value determines the server (or instance) to which the request will be forwarded. By utilizing the source IP address, the algorithm ensures that all requests originating from a specific client IP are directed to a single server or instance, maintaining session continuity. Fig. 3 shows the principle with which the IP hashing algorithm operates.

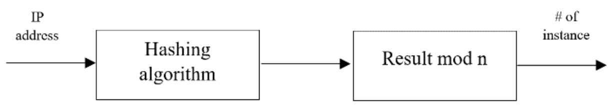

Figure 3. *IP Hashing Algorithm*

2.5. Docker

Docker is a containerization platform that empowers developers to package, distribute, and execute applications and their dependencies in isolated, lightweight, and portable containers. These containers encapsulate applications along with libraries and necessary resources, ensuring complete isolation from the host system and other containers [8]. This technology enables consistent and reliable application execution regardless of the environment. Key components and concepts within the Docker ecosystem include containers, Docker images, Dockerfiles, Docker Compose, and Docker Hub. Containers serve as the fundamental units, containing applications and associated resources. Docker images define the container's content and can be shared and reused. Dockerfiles are textual files specifying the steps for creating Docker images, providing precise configuration control. Docker Compose facilitates the definition and management of multiple containers as part of a single application. Docker Hub, a public registry, enables the sharing and retrieval of Docker images. Orchestration tools like Docker Swarm and Kubernetes work seamlessly with Docker, automating container management and scalability in diverse environments. Application containerization, as a technology, allows developers to isolate applications and their dependencies within containers—distinct environments known as containers. These containers, a form of operating system-level virtualization, package and execute applications along with all necessary resources, such as libraries and configurations, within isolated environments. This technology ensures consistent and reliable execution of applications irrespective of the executing environment. Containers remain isolated from the host system and other containers, preventing interference between applications. Portable and capable of running on various operating systems and cloud platforms without extensive adaptations, containers start quickly by sharing the host's operating system kernel [5].

2.6. Kubernetes

Kubernetes, often referred to as "K8s," is an open-source platform for container orchestration. Kubernetes automates the management, deployment, and scaling of containerized applications within a cluster. It enables automatic scaling and restarting of containers within a group of servers or a "cluster," ensuring applications adapt to variable resource needs [9]. Users define the desired system state through YAML or JSON files, and Kubernetes ensures the cluster maintains that state, taking automated actions to achieve it. Kubernetes possesses self-healing capabilities; in case of issues with an application instance, it can automatically replace it with a functional one. Dynamic scaling of applications is possible to meet changing resource demands, ensuring resilience to load changes. Kubernetes facilitates configuration management of applications and environments through configuration maps and secrets, simplifying the handling of sensitive data. The platform also allows the definition of services and load balancing to provide access to applications and distribute the load among instances. Known for its flexibility, Kubernetes manages various application and resource types, including services, microservices, data storage, and more. Supporting multiple cloud providers, Kubernetes allows the management of multiple clusters from a single control center. Working with Kubernetes requires a set of tools to manage clusters, applications, and resources. These tools are crucial for development, testing, and management of Kubernetes environments. Some essential tools include kubectl for interacting with clusters, Helm for managing Kubernetes packages, kubeadm for fast cluster setup, k9s for interactive management through a Text User Interface (TUI), and minikube for running Kubernetes clusters locally during development. Additional tools like kubectx, kubens, kustomize, Velero, Kubeval, and Kube-hunter extend Kubernetes functionality, providing capabilities such as easy cluster switching, configuration management, backup, validation, and security testing. Kubernetes clusters are the fundamental infrastructure units for executing and managing containerized applications. Comprising nodes and control planes, clusters ensure high scalability, availability, and manageability of containerized applications. Nodes, either worker or master nodes, execute applications and manage the Kubernetes Agent (kubelet), maintaining the desired cluster state. Control planes, acting as the cluster's brain, include components like the API Server, etcd, Scheduler, and Controller Manager, responsible for managing and controlling the cluster. Worker nodes execute containers with applications, while master nodes manage and coordinate the cluster's operations.

3. METHODOLOGY

In the methodology section, comprehensive details regarding the development environment setup will be provided. This will encompass the initial configuration steps tailored for the Alpine Linux operating system, followed by the development of a PHP Model-View-Controller (MVC) application. The section will delve into the intricacies of session management within the application, elucidate the Dockerization process of the application, and subsequently outline the setup of a Kubernetes environment, complete with services and a load balancer. This holistic approach aims to offer a clear and detailed account of the entire process, ensuring a comprehensive understanding of the methodology employed in the development and deployment phases.

3.1. Preparing the Environment

Alpine Linux serves as the designated operating system for the research paper under consideration. The initial step involves installing the nginx web server by executing the command "apk add nginx" in the terminal. Subsequently, the nginx service is started, and its automatic initiation during the operating system startup is ensured by executing "service nginx start" and "rc-update add nginx default" commands in the terminal. Following that, the installation of Docker and related tools is performed, with the Docker service set to launch automatically during the operating system startup using the "apk add docker" and "rc-update add docker boot" commands. The process then continues with the installation of the "kind" tool and the subsequent creation of a Kubernetes cluster using specific commands in the terminal. Once the environment preparation is completed, it is essential to verify the success of each step and check the cluster's status, ensuring its activation using the "kubectl" tool.

3.2. Developing the PHP MVC Application

For this paper, the development of an application is required, encompassing a user login form and a user list with summarized data on HTTP requests sent to the server. This list should be accessible only to successfully logged-in users, with the recorded request types being GET upon accessing the list and POST after a successful login. Additionally, the application should store the user's name and the time of the last access in the session, displaying this information above the request list. It is necessary to define key components, including a model for managing user data, a model for managing user-request data, controllers for processing user requests, and multiple views responsible for the user interface and structured data presentation. The models for managing user and user-request data should include functions for logging in and reading summarized data from the database, respectively. Fig. 4 shows the entity-relationship diagram for the database created for this research paper.

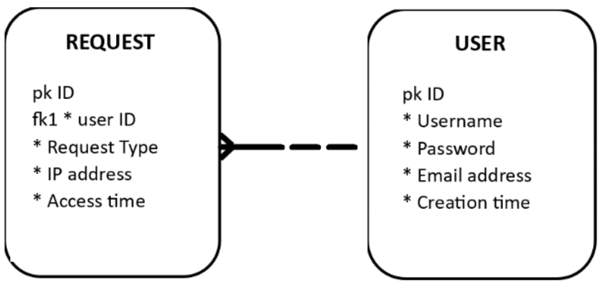

Figure 4. *Entity-Relationship Diagram*

The controller must handle incoming user requests, such as login and displaying summarized data, while the views include essential elements like header and footer for basic information, a login form view, and a data list view.

3.3. Leveraging Session Functionalities

In accordance with the specified specifications, sessions are employed to store information about the user's name and the time of their last access. At the beginning of each PHP script interacting with the session, including login and viewing previous visits pages, a session must be initiated. Typically, this is done by calling the session start function at the top of each PHP script, allowing PHP to access and manipulate the session. Upon user login through the form, their username can be stored in the session using the associative array $_SESSION. Additionally, after recording information about the sent request into the database, the time of the last access can be saved in the session. This facilitates later display of this information on other pages. On pages where it is necessary to display session information, a check can be performed to verify the existence of this information in the session, and if available, it can be displayed. This allows for personalized greetings and the display of the last access time if this data is accessible in the session. When the user finishes the session or logs out of the site (if it is part of the requirements of some other potential application), the session can be terminated by calling the session destroy function. This clears all data in the session and closes it. This process enables the preservation of user information and the time of the last access during their session on the site.

3.4. Dockerizing the Application

The Dockerization process of the given application involves several key steps. Initially, the choice of the base image plays a crucial role in this process. To ensure a compact size, the php:7.4.0-fpm-alpine image was selected, occupying a mere 25 megabytes of space. Subsequently, a Dockerfile must be created in the root directory of the application. This textual file outlines the steps for building the image, specifying the chosen base image, and copying the application code into the appropriate directory within the base image (typically /var/www/html). Adjustments to the Nginx configuration are imperative for seamless integration. The nginx.conf file, tailored to the needs of the web application (such as specifying the server definition), must be copied into the image within the Dockerfile. Fig. 5 shows the Dockerfile written for this research paper.

```
FROM php:8-fpm-alpine3.14
RUN apk update && apk upgrade
RUN apk add nginx --no-cache
RUN mkdir -p /var/log/nginx
RUN mkdir -p /var/www/html
COPY . /var/www/html
COPY nginx.conf /etc/nginx/nginx.con
RUN docker-php-ext-install mysqli pd
EXPOSE 8080
CMD php-fpm && nginx -g 'daemon off;
```

Figure 5. *Dockerfile*

Following this, the Docker image is constructed using the docker build command, which executes the instructions laid out in the Dockerfile. Lastly, in preparation for deployment, Kubernetes Deployment resources need to be created using YAML configuration. This involves specifying the desired number of pods to ensure the application's availability and scalability within the Kubernetes cluster. Through these steps, the application is effectively containerized and ready for deployment in a Dockerized environment, providing a streamlined and consistent execution across various platforms.

3.5. Setting Up Kubernetes Resources

Upon the creation of the Deployment resource in Kubernetes, its responsibility encompasses managing and scaling the application's pods within the cluster. However, this doesn't automatically expose the application to external users. To facilitate external access, a Service resource is typically created. The created Service will also act as a load balancer based on the IP hash algorithm. Defining a Service involves creating a YAML file specifying the resource type as a service, setting the service type to "LoadBalancer," and crucially, configuring the "sessionAffinity" field to "ClientIP." The "selector" field in the service definition is pivotal, pointing to the corresponding Deployment that the service should balance. After defining the YAML file, the resource needs to be applied using the kubectl apply command. Once the Service is created, its status can be verified to determine the external IP address of the load balancer through which the application will be accessed. A YAML configuration written for this research paper is shown on Fig. 6.

```
apiVersion: v1
kind: Service
metadata:
  name: php-nginx-service
spec:
  selector:
    app: php-nginx-app
  ports:
    - protocol: TCP
      port: 8080
      targetPort: 8080
  type: LoadBalancer
  sessionAffinity: ClientIP
```

Figure 6. *Deployment YAML Configuration*

In the context of automatic horizontal scaling based on pod workload, the HorizontalPodAutoScaler (HPA) resource in Kubernetes is utilized. This resource enables automatic scaling of the number of pod replicas based on defined metrics or resources. The HPA offers a set of configurable fields in its YAML definition to precisely manage the horizontal scaling of the application. Crucial fields include "spec," which defines the HPA specification, "scaleTargetRef," identifying the Deployment to be scaled, "minReplicas" and "maxReplicas" to set the minimum and maximum number of replicas, and "metrics," a list defining the metrics or resources used for scaling decisions. Frequently used metrics include processor and RAM load. The "type," "resource," "targetAverageUtilization," and "targetAverageValue" fields further refine the scaling behavior based on the chosen metric type. Once configured, the HPA dynamically adjusts the number of pod replicas to handle varying workloads effectively. A separate Deployment has been created for the database, using MySQL as the database management system. Ten different user accounts were created in the table “Users”, and 200,000 instances were inserted into the table “Requests”.

3.6. Testing Performance

Testing the performance of such an application is crucial to ensure that it can function efficiently and reliably under various load conditions. Application performance directly impacts user experience and the application's ability to handle user requests in real-time. Performance testing aids in identifying potential issues and bottlenecks in the application or infrastructure before deployment. This includes monitoring response times, request processing capacity, resource loads such as processor and memory usage, and identifying points where the application may become slower or unresponsive. Performance testing also helps optimize the application and infrastructure for efficient resource utilization and improved scalability. Informed decisions about scaling needs, code or infrastructure optimization can be made through this testing, ensuring that the application remains stable and responsive during user base growth or increased load. In the context of horizontal scaling testing for a web application, selected metrics include load and response time. The goal of testing is to determine how these metrics change with an increase in the number of application instances. It is expected that the requests per second (RPS) will increase with scaling, while response time remains stable or minimally increases. If response time significantly grows with scaling, it may indicate performance or resource issues that need resolution. The results of testing should demonstrate that the application scales efficiently, supporting a higher number of users without a significant degradation in response time. This is crucial to ensure that the application remains fast and responsive even under high loads, enhancing user experience and satisfaction. Locust, a Python library and load testing tool, can be employed to simulate a large number of users interacting with the web application. This enables load and response time testing to assess the application's behavior under various load conditions and horizontal scaling. Test scenarios can be defined using Python scripts, with each scenario representing simulated user behavior. Testing is then performed with the configuration of the number of users and other testing parameters. After running the test, performance can be monitored through Locust's web interface, displaying relevant metrics. This allows for the analysis of response times, requests per second, and other performance indicators to identify potential problems and optimize the application. For horizontal scaling testing, multiple Locust instances ("slaves") can be added to simulate increased load and evaluate the application's behavior under such conditions.

4. RESULTS AND DISCUSSION

4.1. Results

The performance testing results, utilizing the Locust tool, encompassed multiple load and response time tests, concurrently monitoring the number of pods created by the HorizontalPodAutoScaler. The consolidated results are presented in Table 1, showcasing the application's behavior in both horizontal scaling and non-scaling scenarios. Two types of requests—GET, returning HTML code and a list with summary data, and POST for user login—were employed, each representing 50% of the test load.

Table 1. *Test Results*

Requests Per Second (RPS)	Response Time (in ms)	Number of active instances
Application without Horizontal Scaling		
250	33	1
500	36	1
750	116	1
1000	5111	1
Application with Horizontal Scaling		
1000	27	3
1500	28	5
2000	28	5
2500	32	8

The tests revealed that the application could efficiently handle a small number of requests per second (RPS) without a significant increase in response time. However, under moderate load (750 RPS), the response time tripled, and at 1000 RPS, the application became nearly unresponsive, with response times exceeding 5 seconds and a notable percentage of failed requests. In the case of horizontal scaling, the tests showed positive outcomes. With three active pods, the application efficiently processed 1000 RPS, demonstrating its ability to react effectively to moderate loads. As the number of active pods increased to 5 and 8 in subsequent tests, the application supported higher RPS (1500, 2000, and 2500), indicating effective horizontal scaling. Notably, response times, measured in milliseconds, remained relatively low throughout all tests, demonstrating the application's responsiveness even under increased load. The gradual increase in active pods in each test indicates successful horizontal scaling, highlighting Kubernetes' efficient resource management and ability to scale the application to support growing loads. The results suggest that the application successfully scaled horizontally to handle increased RPS. Response times remained acceptably low, and the number of active pods increased proportionally to accommodate the growing load. This implies that horizontal scaling, combined with session persistence in a PHP MVC application using Docker and Kubernetes, can be an effective strategy to enhance application performance and scalability. The absence of a sharp increase in response time indicates the application's ability to respond well to higher loads, emphasizing the efficacy of the proposed scaling approach.

4.2. Comparison with Similar Research

In comparison with similar research efforts, the findings of this study align with those presented in [10], where an increase in performance, measured in terms of Requests Per Second (RPS), was observed. The current research similarly demonstrates enhanced application scalability, allowing for the handling of higher RPS loads efficiently. However, a distinct approach is taken in [11], where the authors introduce a custom Kubernetes Horizontal Pod Autoscaler Algorithm (KPHA-A) resource. Notably, [11] managed to achieve a notable optimization in response times when compared to using the default horizontal autoscaling resource provided by Kubernetes. The custom KPHA-A resource, designed specifically for their context, resulted in response times that were consistently 1.5 to 2 times lower than those achieved with the default Kubernetes horizontal autoscaler. This discrepancy in performance outcomes emphasizes the significance of tailoring autoscaling strategies to the unique characteristics and requirements of the application or system under consideration. While both studies, including [10], indicate positive scalability results, the novel approach presented in [11] with the custom KPHA-A resource showcases the potential for even greater performance gains by fine-tuning autoscaling mechanisms to suit specific workloads and application architectures.

5. CONCLUSION

In conclusion, this paper delves into the realm of horizontal scaling for PHP MVC applications, emphasizing the preservation of sessions to enhance both availability and resource efficiency. The exploration covers crucial theoretical aspects, spanning MVC architecture, PHP in web development, session handling intricacies, and the implementation of horizontal scaling techniques using load balancers, Docker, and Kubernetes. The practical methodology, encompassing environment setup, application development, Dockerization, Kubernetes integration, and horizontal scaling configuration, is detailed comprehensively. Performance testing highlights substantial improvements, showcasing a noteworthy reduction in response time—from an initially unresponsive state at 1000 RPS (5111 ms) to an impressive 32 ms at 2500 RPS with horizontal scaling. This study contributes valuable insights and practical guidance, offering a roadmap for the development of highly available and scalable web applications. Future work may explore further optimizations in the PHP MVC application's horizontal scaling configuration, aiming to uncover additional performance enhancements and refine resource allocation strategies. Additionally, investigating the integration of emerging technologies or alternative frameworks could provide valuable insights into continuously improving the scalability and responsiveness of web applications.

ACKNOWLEDGEMENTS

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Enhancing Software Development with Microservice Architecture: Application to an Online Sales System

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Abstract: *This paper explores the critical role of microservice architecture in modern software development, illustrating its benefits through the creation of an online store as an example. Microservice architecture is highlighted for its capacity to improve scalability, maintainability, and deployment efficiency by decomposing applications into modular, independently deployable services. The approach facilitates a more robust and flexible system design, allowing for easier updates and better resource management. This study underscores the theoretical advantages of microservices, such as enhanced fault isolation and continuous delivery, while providing practical insights into its implementation. The online store example serves as a practical demonstration of these concepts, showcasing how microservice architecture can lead to more efficient and reliable software solutions.*

Keywords: *microservice architecture, scalability, software solution, continuous delivery*

1. INTRODUCTION

Microservice architectural style is a software development approach in which an application is divided into small, compact services that can be developed, deployed and scaled independently. Each microservice performs a specific business function and communicates with other microservices through well-defined API [1]. As it is well-known, enterprise applications are often built in three main parts: a client-side user interface (consisting of HTML, CSS and JS), a relational database management system (program used to create, update and manage relational databases) and a server-side application. Mostly, the purpose of this application is to handle HTTP requests coming from client-side, retrieve and update data from database and prepare response model in a format that is acceptable by client-side, which will later select and populate its HTML views. In this example, the server-side application acts as a single local executable, or in other words – a *monolith*.

For better understanding of what microservice architecture is, it is useful to compare it to the monolithic style, where all logic for handling a request runs in a single process and can be tested on a locale and deployed into production. As monolithic application puts all its functionality into a single process, the conclusion of deployment issue is very simple: any changes to the system involve building and deploying a new version of the server-side application, and over time, it is often hard to keep a good modular structure. Scaling requires scaling of the entire application rather than parts of it that require greater resource [2].

These adversities led to the microservice architectural style: building applications as suites of services, and the objective of this paper is to highlight the importance and benefits of using this architectural style through practical example in a case study of an online sales system application.

2. MICROSERVICES OVERVIEW

Throughout the years, the microservice architectural style was defined based on common patterns observed across a number of pioneering organizations, where they did not consciously implement microservice architecture [3]. While they evolved to it in pursuit of specific goals, each of them was tied back to the "balancing speed and safety at scale."

Microservice architectural style is even more and more used due to its various benefits, and some of them include:

- Scalability: microservice architecture allows applications to scale up or down quickly based on demand. Developers can add or remove microservices as needed, without affecting the rest of the application.
- Resilience: Microservices are designed to be resilient to failures, meaning if one microservice fails, it does not bring down the entire application.

- Fault isolation: Corresponding to the previous benefit, developers can isolate failures, preventing them from spreading and causing widespread issues.
- Technology independence: Microservices architecture allows developers to be flexible when choosing technologies, meaning it does not need to be tied to a single technology stack.
- Easy maintenance: Since microservices are concise and domain focused, they are easier to maintain than monolithic applications.

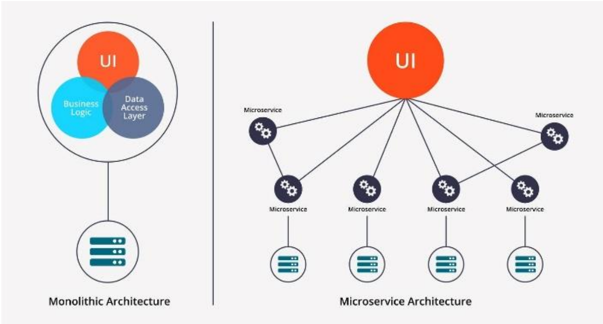

Figure 1. *Monolithic and Microservice architectural style*

Theoretically, we could apply microservice architecture to a washing machine program. However, the question remains whether there is a need to go that far, considering the challenges associated with building software solutions using microservice architecture:

- Development complexity: Each service is a separate entity with its own codebase, making the development process more complex.
- Communication overhead: Microservices communicate over a network which can increase latency and potentially communication failures.
- Data management issues: Each service will mostly have its own database, leading to challenges in ensuring data consistency and managing distributed data stores.
- Deployment complexity: Implementing continuous deployment practices becomes more complex with microservice architecture.

While microservice architecture offers variety of benefits, in some use cases it could bring unnecessary complexities. As it is important to weigh these disadvantages against the benefits to determine which architectural style is the right fit for specific system, it is also worth mentioning that the key in choosing between architectures when designing a program is modularity – the quality of an application being composed of distinct, self-contained parts that, when combined, form a complete whole. In simpler terms, an application is considered modular if each of its components is functional and self-sufficient on its own, eliminating the need for further expansion to maintain or enhance its effectiveness.

3. MICROSERVICE COMMUNICATION

Microservice architecture relies on the division of a large application into smaller, loosely coupled services, each focusing on a specific business function. Effective communication between these services is crucial for the system's overall functionality and performance. In the microservice architecture, all components of the applications run on several machines as a process or service, and they use inter-service communication to interact with each other. Microservices frameworks usually execute a consumer grouping mechanism whereby different instances of a single application have been placed in a competing consumer relationship in which only one instance is expected to handle an incoming message [4]. There are two primary modes of communication in microservice architecture:

- Synchronous communication style
- Asynchronous communication style

Synchronous communication is often regarded as request/response interaction style and pattern. One microservice makes a request to another service and waits for the services to process the result and send a response back. This method involves a service making a request to another service and waiting for an immediate response before continuing its execution. This pattern ensures direct and instant data exchange, which is essential for operations requiring immediate feedback or coordination between services.

Synchronous communication is typically implemented using protocols like HTTP/HTTPS, often through RESTful APIs, which are favored for their simplicity and wide adoption. Another popular protocol for synchronous communication is gRPC, which uses HTTP/2 and Protocol Buffers to achieve low-latency, high-performance communication.

The synchronous approach allows for straightforward error handling and straightforward service-to-service communication patterns, but it also introduces potential challenges, such as increased latency and tighter coupling between services. The decision to use synchronous communication in a microservice architecture should consider these trade-offs, focusing on scenarios where immediate response times are critical and the system can manage the dependencies and potential bottlenecks introduced by this communication style.

The asynchronous form of communication can be implemented in microservices when services exchange messages with each other through a message broker.

This method allows a service to send a request and continue its execution without blocking for a reply, making it well-suited for tasks that do not require immediate feedback. Asynchronous communication is commonly implemented using message brokers like RabbitMQ, Kafka or AWS SQS, which handle message queuing and delivery between services.

This approach can significantly improve system scalability and fault tolerance, as services can operate independently and handle peak loads by processing messages at their own pace. Moreover, it enables more flexible interaction patterns, such as event-driven architectures, where services react to events asynchronously.

However, this method also introduces complexities in terms of ensuring message delivery, handling message ordering, and managing eventual consistency. Despite these challenges, asynchronous communication is a powerful strategy for building robust, scalable, and decoupled microservice architectures that can efficiently manage varying workloads and improve overall system performance.

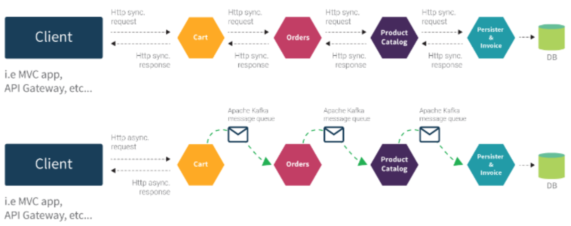

Figure 2. *Synchronous and asynchronous communication between microservices*

Choosing between synchronous and asynchronous communication in a microservice architecture depends on various factors, including system requirements, performance considerations, and complexity trade-offs [5]:

- Latency: If the application or a system requires immediate responses and low latency, synchronous communication via REST API or gRPC may be more suitable.
- Scalability: Asynchronous communication is often preferred for its scalability benefits. It allows services to handle varying workloads by decoupling the sender from the receiver, enabling better scalability compared to synchronous communication, where services may become blocked due to high request volumes.
- Resilience: Asynchronous communication promotes resilience by allowing services to continue processing requests even if a downstream service is temporarily unavailable.
- Consistency: If strong consistency is necessary, synchronous communication may be more suitable, since asynchronous communication can introduce eventual consistency challenges, where data may be temporarily inconsistent across services.

4. CASE STUDY

This case study focuses on the practical aspects of adopting microservices to improve scalability, resilience, and flexibility in the online sales domain. It involves breaking down functionalities into separate, independently deployable services, each serving specific business functions.

Through this case study, the practical advantages and challenges of employing microservice architecture in online sales systems will become apparent, providing valuable insights for businesses in the digital commerce sphere.

We will discuss an example case study of an online sales system, which highlights the usage and importance of microservice architecture with particular attention to repository and service design patterns which utilize and showcase the benefits of microservice architectural style.

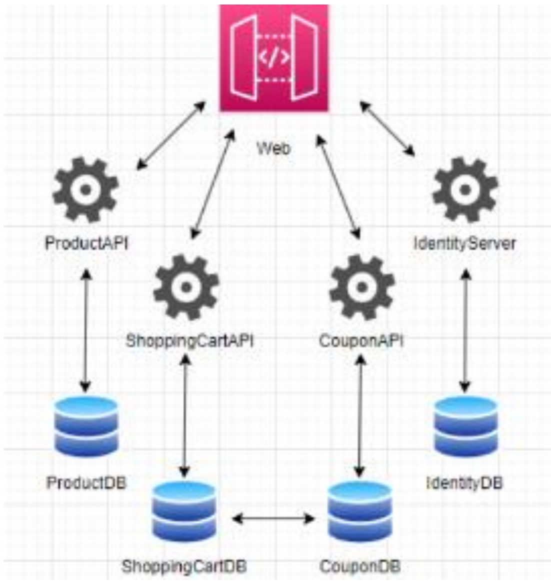

Figure 3. *Microservice overview on the practical example of the case study*

4.1. Repository pattern

The Repository pattern is a structural design pattern that isolates data and the data access layer from the rest of the application and its logic. This design pattern has two main objectives: to provide a separate space for communicating with the database, which is separated from the rest of the application, thus establishing a level of access for other layers of the application when it comes to data communication, and to handle the implementation logic of persistent storage of the application, which is necessary to retrieve data from the database [6]. This pattern can also be combined with other design patterns to significantly increase its functionality and to efficiently expose consistent APIs. In other words, the purpose of this pattern is to unify all methods for accessing database tables in one place, and such methods would be implemented through specific classes using the repository interface as the type of object access for the desired domain. The advantage of this pattern lies in having all the essential database-related logic in one place, and if changes need to be made to the code, they can be done in one place. Repository pattern's benefits extend well into microservice architecture, aiding in its scalability, maintainability, and overall robustness:

- Isolation of Data Access: The Repository pattern allows each microservice to encapsulate its data access logic within its own repository implementation. This isolation ensures that changes to the underlying data store or database schema only affect the repository implementation within that microservice, reducing the risk of unintended side effects on other services.
- Consistency: By providing a standardized interface for accessing data, the Repository pattern promotes consistency across microservices. This consistency makes it easier for developers to understand and interact with different services, as they can rely on familiar patterns and APIs for data access.
- Improved testing and debugging: With data access logic encapsulated within repositories, testing and debugging become more manageable. Developers can easily mock repository implementations for unit testing, and issues related to data access can be isolated within the boundaries of individual microservices.
- Modularity: The Repository pattern enhances the modularity of microservices by decoupling data access logic from the rest of the application. This decoupling allows individual services to scale independently, as changes to one service's data access logic do not affect others.

4.2. Unit of work pattern

It is important to mention that the Repository pattern is often used in conjunction with the Unit of Work pattern to facilitate efficient data access and persistence. It's primarily concerned with managing transactions and ensuring data consistency within an application. It encapsulates the transaction management logic, coordinating transactions across multiple repository operations. This ensures that a group of related database operations either succeed or fail together, maintaining data consistency. When changes are made to objects retrieved from repositories, the Unit of Work pattern tracks these changes and ensures that they are persisted to the database when the transaction is committed. This involves coordinating with the respective repositories to save or update the modified objects.

The Unit of Work typically has a scoped lifetime within a unit of work session, where multiple repository operations are performed within the same transactional context. Once the unit of work session is completed, the changes are either committed or rolled back, ensuring transactional consistency.

4.3. Service layer pattern

The Service Layer pattern is a structural, service-oriented design pattern aimed at organizing services and their functionalities by separating them into a service layer [7]. Services categorized in this manner have the ability to share functionalities, thereby reducing code redundancy. This approach also enhances efficiency and maintainability, as any changes to services are confined to the service layer. The purpose of this encapsulation is to minimize the impact on other parts of the code outside this layer. In other words, if there is an error in a service, the programmer will most likely find the error within the mentioned layer.

Services within this layer need to be defined generically enough to be reusable, with their functions tied to solving domain-specific problems of that service. The Service Layer pattern is an essential step in designing software and systems based on microservice architecture. Service layer sits between the presentation layer and the data access layer, usually in line with Repository pattern, or it can be above Repository pattern but below the presentation layer, providing a clear separation of concerns [8].

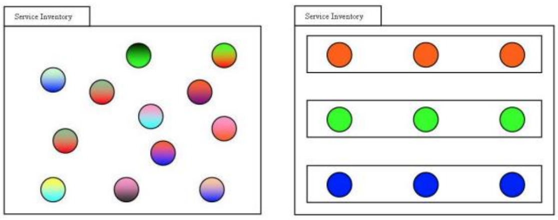

Figure 4. *Simple view of how service layer pattern applies its function to sort domain logic*

The Service Layer provides several essential characteristics that are crucial for the microservice architectural style:

- Scalability: Microservices can be scaled independently based on their specific needs. The service layer ensures that each microservice handles its business logic efficiently, aiding in overall system scalability.
- Reusability: Business logic encapsulated in services can be reused across different parts of the application or even across different applications.
- Autonomy: Microservices are designed to be autonomous. With the Service Layer pattern, each microservice independently manages its business logic, reducing dependencies and improving fault isolation.

- Interoperability: The service layer can expose a well-defined API, facilitating communication between microservices. This standardization simplifies integration and interaction between various services within the microservice architecture.

4.4. Base service implementation

Considering that there are four microservices in the practical example mentioned above, alongside these microservices, there exists a central project responsible for rendering pages, or to put it briefly, it is a client-side of the application. However, this project also has implementation of base service, acting as a gateway and facilitating communication between the client-side and the backend microservices, popularly called API Gateway, with a small footnote that the authorization and authentication strategy is solved by a separate microservice. By employing this architecture, the system achieves a separation of concerns, enabling flexibility, resilience, and the ability to independently scale and evolve its components.

This base service acts as a single-entry point for clients to access these microservices within the server-side application. It essentially functions as a reverse proxy that routes incoming requests from client-side to the appropriate microservices while abstracting the complexities of the underlying architecture. One of the primary purposes of this service is to address the challenges associated with microservices, such as service discovery, load balancing, authentication, authorization, and request routing. By consolidating these concerns into a centralized component, the API gateway simplifies the interaction between client-side application and the microservices.

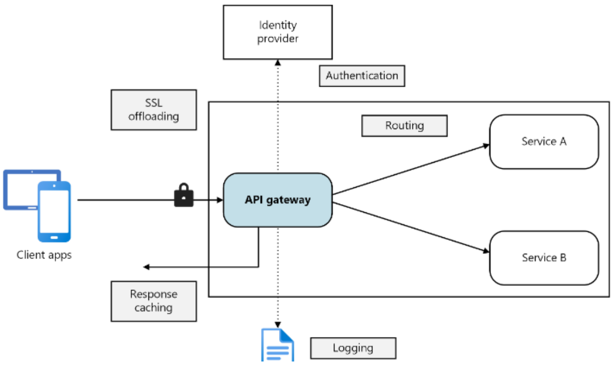

Figure 5. *Implementation of API Gateway (in our case, base service)*

Furthermore, this base service performs additional tasks such as request/response transformation, protocol translation, caching, and logging. These capabilities enhance the performance, security, and resilience of the microservices by offloading common functionalities from individual services to the gateway. From a client perspective, the base service represents a unified interface, shielding them from the complexities of the underlying microservices architecture. Client-side application interacts with the base service using standard protocols and conventions, while the service handles communication with the three specific domain microservices, and the identity server microservice which is responsible for authentication and authorization (this microservice also facilitates the implementation of cross-cutting concerns such as security policies and monitoring, offering a centralized point for enforcing policies and collecting metrics across the entire microservices ecosystem).

However, there is a potential risk to designing this base service, since it could become a single point of failure or a performance bottleneck [9]. To avoid such situations, it's essential to design this concept carefully, applying several strategies such as horizontal scaling, fault tolerance mechanisms, and intelligent routing, who can help mitigate these risks while ensuring the reliability and scalability of the microservices architecture.

Overall, this base service plays a pivotal role in orchestrating communication between client-side application and microservices on server-side application, simplifying development, enhancing security, and improving the overall performance and manageability of distributed systems.

5. CONCLUSION

Microservice architecture leverages server development expertise to enhance the flexibility, scalability, and maintainability of applications. By decomposing complex business system into smaller, independently deployable services and applying this architecture to a smaller system, such as an online sales platform, allows for independent development and deployment of features like user management, product catalog, and payments. This approach, while more complex, provides significant benefits in terms of modularity and scalability. Considering that, the intention of this work was to present an evolutionary perspective to help the reader understand the main motivations that lead to the distinguishing characteristics of microservices [10].

The modular nature of microservices fosters faster development cycles, enabling teams to iterate and innovate more rapidly. This agility is particularly advantageous in today's fast-paced, competitive market, where the ability to deliver value quickly is paramount. Moreover, microservices facilitate scalability, both in terms of technology and team structure. Teams can focus on developing and maintaining smaller, specialized services, reducing the cognitive load and enabling them to make independent decisions regarding technology choices, deployment strategies, and scaling requirements. Additionally, microservices enhance resilience by isolating failures and minimizing the blast radius of issues. If one service experiences a failure, it doesn't necessarily impact the entire system, allowing other services to continue functioning independently. This fault isolation is crucial for maintaining system stability and ensuring high availability in distributed environments.

However, adopting microservices is not without its challenges. The increased complexity of managing distributed systems requires careful consideration of issues such as service discovery, inter-service communication, data consistency, and deployment orchestration. Furthermore, organizations must invest in robust monitoring, logging, and debugging tools to effectively manage and troubleshoot microservices-based architectures.

Despite these challenges, the benefits of microservices architecture are compelling, driving widespread adoption across industries. As organizations strive to innovate and stay competitive in today's digital landscape, microservices offer a flexible, scalable, and resilient foundation for building modern software systems. With careful planning, thoughtful design, and continuous refinement, microservices architecture can unlock new opportunities for organizations to deliver value to their customers and adapt to evolving business requirements.

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Open Source Integrated Circuit Design Tools in Scientific Research: Yay or Nay?

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Abstract: *The design of integrated circuits (IC) has a significant impact on the development of modern world technologies. The subject of this research is the examination of the potential application of open source tools for integrated circuit design in scientific research. This paper analyzes some open source tools. The research results show that the application of these tools has advantages and disadvantages as well, but most importantly, in the context of science that it is feasible and even recommended. Open source tools for integrated circuit design create positive outcome of the financial feasibility of scientific research activities, collaboration, and the advancement of scientific research. The paper also presents possible future research in this area.*

Keywords: *ic design; open source tools; VLSI; research; academia*

1. INTRODUCTION

In modern society, which is evolving with the development of technology, the possibilities for applying electronics are continually growing. The popularization of electronics as a field is influenced by the development of consumer electronics, process automation, the Internet of Things (IoT), robotics, and more [1]. The academic community, including educational and research segments as well plays a significant role in the advancement and promotion of electronics.

A crucial area of electronics for modern technological transformation is integrated circuit (IC) design. IC design involves the design and development of electronic components integrated into a single chip [2]. This allows for the integration of a large number of functionalities into small and efficient components, which promotes the development of communication systems, medical devices, consumer electronics, the automotive industry, and more. This integration simplifies the production of complex devices, improves device performance, reduces power consumption, increases data transfer speed, enables the development of small and lightweight devices, and more.

The complexity of IC design makes use of appropriate tools necessary in order to meet market demands. To satisfy these demands, there are different categories of tools used in IC design. On one side, there are high-quality tools that offer better functionality but as a drawback bring a higher price, while on the other side, there are open-source solutions that, although free, have certain functional limitations.

The target audience in this field can be divided into two groups: industry and academia. Therefore, it is important to consider them separately. This paper analyzes some open-source tools to examine the possibility of their active use in academia, specifically for scientific research purposes, to meet the needs of the scientific community.

2. LITERATURE REVIEW

It is notable that the world of integrated circuit design is dominated by proprietary tools developed by companies such as Cadence [3], Synopsys [4], and Mentor Graphics [5]. Besides commercially available tools, it is important to note that open-source tools are becoming more popular in this field. These tools are maintained by organizations and volunteers who are committed to making field of integrated circuit design freely and openly available for universities, as well as for individuals and smaller companies that cannot afford licenses for proprietary tools. Typical examples of open-source tools include Magic, Klayout, Qflow, Qrouter, IRSIM, Netgen Static, and Yosys [6-8]. Currently, the use of open-source tools in scientific research is not sufficiently covered, resulting in a lack of awareness among the scientific community about these tools. As a result of that, the open access, adaptability, and other benefits of these tools are not reaching the scientific community.

In the following text, the selected tools will be briefly presented with their intended purpose and basic use methods.

2.1 IRSIM

IRSIM is a tool intended for the simulation of digital circuits using switch-level simulation, which involves modeling transistors as switches whose real characteristics are simulated using extracted capacitance and lumped resistance values [9], [10]. The IRSIM tool supports operation in a graphical environment, as shown in Figure 1, and also supports command-line operation using the Tcl/Tk scripting language, as shown in Figure 2.

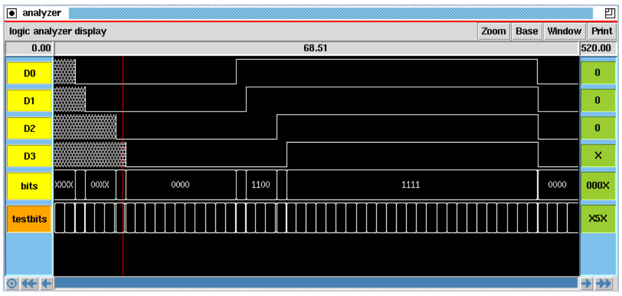

Figure 1. *The "analyzer" graphic display in IRSIM* [9]

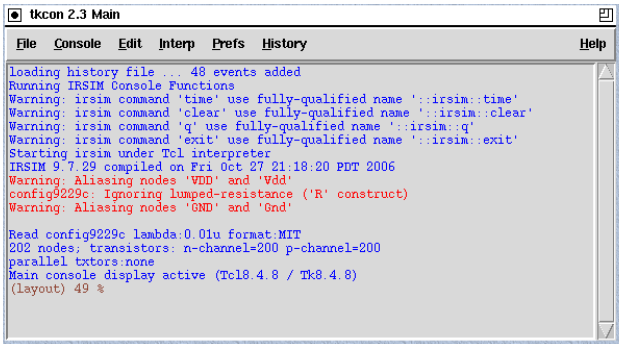

Figure 2. *The IRSIM command console in the Tcl/Tk* [9]

2.2 Magic

Magic is a tool intended for the physical design of circuits in both the analog and digital domains. Although the tool originated in the 1980s, continuous improvements have made it fully compatible with modern standards and integrated circuit manufacturing processes. Magic can be used through a graphical interface (Figure 3) as well as via the Tcl/Tk command console (Figure 4). As addition to that, Magic can be used independently or as part of the Qflow toolchain as well. Qflow will be discussed later.

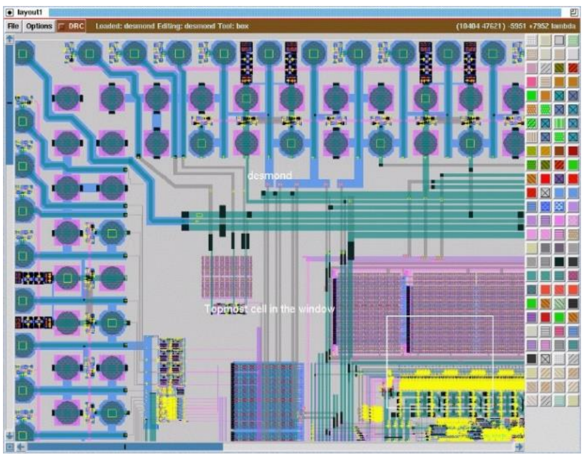

Figure 3. *Graphical interface of Magic* [11]

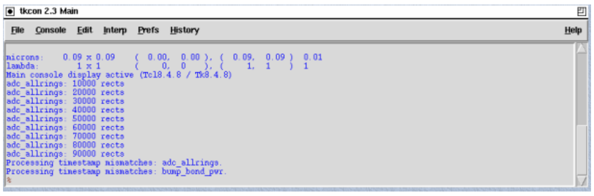

Figure 4. *Command console of Magic* [11]

2.3 Netgen

Netgen is a tool intended for LVS (Layout vs Schematic) verification. The meaning of LVS can be seen in need of verifying physical layout against to schematic representation of the same circuit (Figure 5). Netgen is exclusively used through command console, as shown on figure 6.

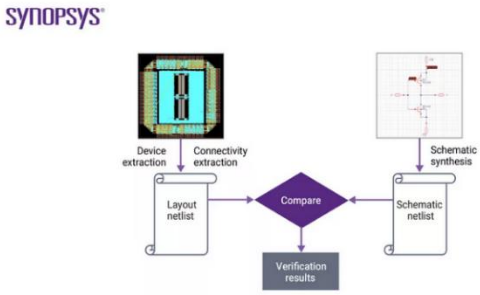

Figure 5. *Process of performing LVS* [12]

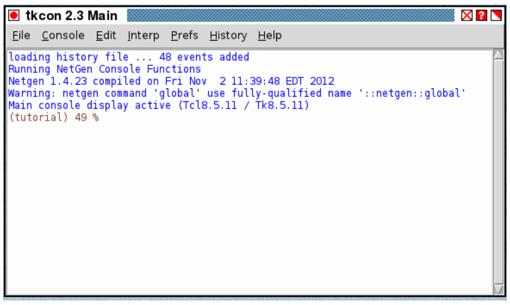

Figure 6. *Command console of Netgen* [13]

2.4 Qflow

Qflow is essentially a set of smaller tools that together fully cover the design of digital integrated circuits from behavioral RTL (Register Transfer Level) design to the GDSII file. The tools that comprise Qflow and their individual purposes are shown in Table 1. Some of these tools are presented in this work as standalone since those tools can be used individually besides being used as part of Qflow toolchain. However, most of the tools used in Qflow are used exclusively as part of the Qflow toolchain. Tools that comprise Qflow are presented in table 1 [14].

Table 1. *Qflow toolchain elements*

Name of Tool	Function
abc	Logic optimization
Magic	Physical layout viewer and editing
Odin-II	Verilog parser and logic verification
graywolf	Placement
qrouter	Detail Router
vesta	Static Timing Analysis
yosys	Verilog parser, HL Synthesis and logic optimization and verification

Qflow is used through GUI control manager, as shown in figure 7.

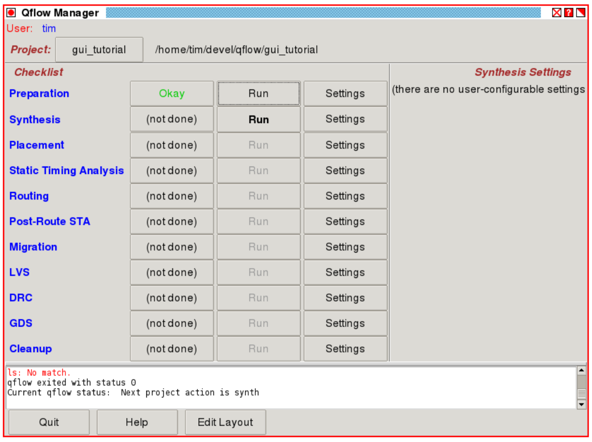

Figure 7. *Qflow GUI control Manager* [14]

2.5 Qrouter

Qrouter is a tool that performs the routing of metal layers with the aim of connecting the submodules (in the most efficient way) that make up the design to be implemented. It is used as part of the Qflow toolchain or as part of another methodology for designing digital integrated circuits, which means it is always part of a toolchain and is used through the command console.

3. METHODOLOGY AND METHODS

The research was conducted in the Laboratory for Computer Science at the Faculty of Technical Sciences in Čačak, University of Kragujevac. Test cases for tool analysis were various digital designs of different levels of complexity. The selection of tools to be analyzed was based on their continuous adherence to and support of the open-source philosophy. The chosen tools fully cover the capabilities required for designing both analog and digital circuits, and the tools analyzed are (1) IRSIM, (2) Magic, (3) Netgen, (4) Qflow, and (5) Qrouter.

All the tools discussed are primarily intended for use on the Linux operating system, with some tools also capable of being installed and used on Windows platforms with few additional installation steps.

The research and data collection were conducted using a combination of different methods, such as functional scenario testing, observation and experimentation. Qualitative data analysis was used for data analysis. The parameters observed and analyzed were grouped into four categories: (1) functionality analysis, (2) user experience analysis, (3) performance analysis, (4) support and documentation analysis.

The combination of results from these analyses provides a comprehensive evaluation of the tools, revealing the quality and efficiency of the tools for integrated circuit design, as well as their advantages and disadvantages. Each of the before mentioned categories consists of several parameters that were analyzed, and the results obtained from the analysis are presented in tabular form.

4. RESULTS

Based on testing of usage and functional value of tools the following analysis results can be obtained.

Table 2. *Analysis of functionality of Open Source tools for IC design*

	Simulation	Circuit Design	Automatic Place and route	Verification
IRSIM	+	-	-	+
Magic	-	+	-	-
Netgen	-	-	-	+
Qflow*	-	-	-	-
Qrouter	-	-	+	-

*It does not contain any capabilities by itself, but instead it connects all necessary tools for digital integrated circuit design in form of toolchain.

In table 2, mentioned tools were tested for their capabilities to perform Simulation, Circuit Design, Automatic Place and Route and Verification.

Table 3. *Analysis of user experience of Open Source tools for IC design*

	Interface	Reliability	Adaptability
IRSIM	GUI/Console	NA*	HIGH
Magic	GUI/Console	HIGH	HIGH
Netgen	Console	NA	HIGH
Qflow	GUI	MODERATE	HIGH
Qrouter	Console	MODERATE	HIGH

*Not applicable

In table 3, user experience aspects of Open Source tools have been tested. For IRSIM and Netgen user experience aspect of reliability cannot be evaluated properly as their reliability of output to user heavily depends on other tools which they are paired with.

Table 4. *Performance analysis of Open Source tools for IC design*

	Speed	Memory requirements	Scalability	Stability
IRSIM	LOW	LOW	NA	HIGH
Magic	NA	LOW	HIGH	HIGH
Netgen	LOW	LOW	NA	HIGH
Qflow	LOW	MODERATE	HIGH	HIGH
Qrouter	LOW	LOW	NA	HIGH

In table 4, performance analysis has been provided for Open Source tools for metrics that can be captured by regular usage of these tools. For few tools, same parameters could not be captured.

Table 5. *Support and documentation analysis for Open Source tool for IC design*

	Documentation	Forums/Community	Video tutorials	Updates
IRSIM	+	+	-	+
Magic	-	+	+	+
Netgen	+	+	-	+
Qflow	+	+	-	+
Qrouter	+	+	-	+

In table 5, learning and support resources availability has been analyzed and it covers all potential resources and materials.

5. DISCUSSION

The results of the conducted research provide information about the characteristics of open source tools for integrated circuit design, defined in four categories: (1) functionality analysis, (2) user experience analysis, (3) performance analysis, (4) support and documentation analysis. The focus is on the context and potential applications for scientific research purposes.

During the research, there were methodological limitations. Specifically, the tools included in the analysis have different roles in integrated circuit design, making it difficult to set analysis criteria that are relevant to every tool. The results of the analysis confirm that, in addition to advantages those tools have for scientific research, there are also disadvantages that could be overcome through professional and scientifically grounded approaches.

One of the advantages of open source tools for IC design identified is the availability of the tools, i.e., free access. In the academic community, one of the prerequisites for using tools is their accessibility, especially since the tool needs to be provided on multiple computers, and universities and institutes have limited financial resources. Using open source tools offers the possibility of accessing new technologies, whose licenses are very expensive when acquired through free market. In this way, the tools would be available to young researchers at the beginning of their scientific careers, or even to doctoral or master's students engaged in scientific research.

Another aspect marked as a significant advantage is the flexibility, i.e., the ability to adapt to specific requirements and needs. In scientific research, this is very important aspect for the development of innovative solutions and the advancement of science, unlike commercial tools that often come with closed code.

Although the official lack of support is a drawback of open source tools, the third characteristic recognized as an advantage is the community created around open source tools. In scientific research, the community gathered around the tools encourages collaboration, which as a result creates environment to exchange of knowledge and ideas and contributes to the advancement of scientific research.

The research results showed that open source tools for integrated circuit design have disadvantages compared to commercial solutions, mostly concerning functionality. While the industry is almost helpless regarding these types of deficiencies and resorts to commercial but reliable solutions for which they are willing to allocate significant financial resources, in the scientific research process, the functional shortcomings of open source tools can be overcome with the knowledge and expertise of researchers using the tools. For young researchers, participation in activities related to the improvement and development of open source tools can be particularly motivating.

6. CONCLUSION

This paper analyzes open source tools for integrated circuit design to explore their potential applications in scientific research. By analyzing five tools with different functions in integrated circuit design, highlighting their advantages and disadvantages, the importance of such solutions for the scientific community is emphasized.

Open source tools for integrated circuit design offer free access, the ability to customize tools to specific needs, and encourage collaboration and knowledge exchange in a research environment. For the academic community, it is important to motivate the development of open source tools for integrated circuit design and their application in scientific research. The use of these tools enforces the principles of open science, enabling greater transparency, mutual benefit, and the promotion of research in integrated circuit design and electronics in general.

Future research can be expanded to investigate functionalities not covered in this analysis. Additional efforts can be made to improve existing shortcomings of such solutions and, finally, consider the possibility of applying these tools in other fields.

ACKNOWLEDGEMENTS

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Analysis of Approaches to Developing Kotlin Multiplatform Applications and Their Impact on Software Engineering

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Abstract: *This paper explores the concept of Kotlin Multiplatform and analyzes the approach to developing multiplatform applications using this tool. The research aims to analyze the key features of Kotlin Multiplatform, including its ability to share code across different platforms such as Android, iOS, and web. Through a detailed analysis of existing literature and case studies, the paper will explore the advantages and challenges of developing multiplatform applications using Kotlin Multiplatform, as well as their impact on software engineering. Special attention will be paid to performance, scalability, and code management within Kotlin Multiplatform projects. Based on the gathered data, the paper will also explore future perspectives of multiplatform application development, including potential trends, technological advancements and other cross platform solutions.*

Keywords: *Kotlin Multiplatform; multiplatform; software engineering; performance; code management*

1. INTRODUCTION

In today's digitally-driven world, the online presence of businesses has become more than just a trend, it's a necessity. With the rapid advancements in technology and the widespread accessibility of the internet, consumers are increasingly turning to online platforms to discover, interact with, and ultimately make purchasing decisions regarding products and services.

This would mean that every company has to develop a separate mobile application, web application, and desktop application. This leads to significant costs and inconsistencies across platforms. It requires having several teams of developers to build the application on each platform and later maintain it.

One way to solve this problem is by creating a single application that would work on all platforms. In 2017, the first version of Kotlin Multiplatform was released, aiming to enable the development of a mobile application that would work on both the Android and iOS systems.

Kotlin Multiplatform is intended to streamline the creation of cross-platform projects, reducing the time spent writing and maintaining separate codebases for different platforms while still allowing for the advantages of native programming. In Figure 1, all platforms supported by Kotlin Multiplatform are shown.

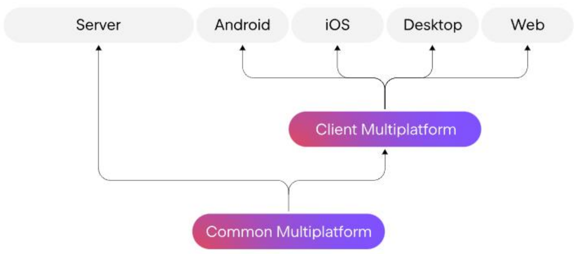

Figure 1. *All platforms supported in Kotlin Multiplatform [1]*

In the paper [2], a comprehensive methodology for developing multi-platform applications using the Kotlin programming language is presented. It highlights the use of Kotlin Multiplatform and Compose Multiplatform frameworks, which allow for the creation of universal logic code and user interfaces for Windows, Android, macOS, and Linux, thereby reducing development time and minimizing errors. The study emphasizes the principles of declarative programming and the MVI architectural pattern, alongside essential tools such as Kotlin Coroutines for asynchrony, Gradle Kotlin DSL, the Decompose library, and the MVIKotlin framework. A modular project architecture is proposed, divided into a common module with core application logic and platform-specific modules for application initialization and launch. Dependency Injection is effectively managed using Koin module files. This methodology offers a streamlined approach to developing user interfaces and application components across multiple platforms using Kotlin.

In the paper [3], the authors address the challenges faced by software developers in supporting multiple platforms, particularly mobile platforms, due to significant platform differences. They propose a native approach for developing multiplatform applications that run on both Java and Android. This approach tackles practical software engineering concerns, including tool configuration and the software design and development process. It enables sharing 37% to 40% of application code between the two platforms, which enhances the quality of the applications. The authors also suggest that this approach can be adapted for transforming existing Java applications into Android applications.

2. METHODOLOGY

To gather the necessary literature, electronic databases such as ResearchGate, Google Scholar, and ScienceDirect were utilized, as these are considered the most efficient tools for comprehensive literature searches. The focus is on papers published in the period from 2018 to 2024 in journals and collections of papers, papers written in English and based on qualitative and quantitative methods. Keywords such as "Kotlin Multiplatform," "cross-platform development", "Kotlin Multiplatform performance," and "Kotlin Multiplatform vs native development" were used. Selected papers have been chosen to investigate the advantages and disadvantages of Kotlin Multiplatform applications, as well as those examining the performance of this tool compared to similar ones. The selected papers were reviewed in full to extract detailed information about Kotlin Multiplatform. This included its technical capabilities, performance metrics, and case studies of its application. The extracted data were synthesized to provide a coherent narrative about the current state and future potential of Kotlin Multiplatform.

A SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis was conducted to evaluate the overall potential and challenges associated with Kotlin Multiplatform. Visual aids, such as charts and tables, were created to illustrate key findings and comparisons.

By employing this detailed methodology, the review aims to provide a thorough and objective analysis of Kotlin Multiplatform, offering valuable insights for developers, researchers, and industry professionals.

3. RESULTS AND DISCUSSION

The traditional approach to programming, known as the native development, involves using a language specific to the platform. For example, Kotlin for Android, Swift for iOS, Java for desktop applications, HTML for web applications, etc.

To avoid this, the industry has shifted towards cross-platform development, where by creating one application and using a single programming language, we obtain an application that works on all platforms.

3.1. Advantages and disadvantages

The main advantages of the native development are [4]:

- Best user experience,
- Great app performance,
- Leverage full platform capabilities

The main advantages of the cross-platform development are [4]:

- Reduce development time by reusing the same code for different platforms,
- Consistent behavior across platforms,
- Fewer bugs

Table 1. *Kotlin SWOT analysis [1]*

Kotlin - SWOT
Strengths: Kotlin Multiplatform enables high code reuse, provides native performance, and offers access to platform-specific APIs. Strong support from JetBrains and Google, along with an active developer community, further enhances its robustness and reliability.
Weaknesses: Weaknesses include a limited number of libraries available for all platforms, initial setup complexity, and a steeper learning curve for new developers unfamiliar with the framework.
Opportunities: Kotlin Multiplatform offers promising opportunities, with growing library support and increasing adoption in the industry. There is potential for expansion into more platforms, which could further enhance its appeal and utility.
Threats: Despite its many advantages, Kotlin Multiplatform faces threats from other cross-platform solutions such as Flutter, Xamarin, and React Native, as well as the rapid pace of technological changes that could impact its relevance and efficiency.

With the Kotlin Multiplatform, developers can maintain a unified codebase for the application logic across various platforms. You also get advantages of native programming, including great performance and full access to platform SDKs. Kotlin provides the following code sharing mechanisms [1]:

- Share common code among all platforms used in your project.
- Share code among some platforms included in your project to reuse much of the code in similar platforms.

In Figure 2, the architecture of Kotlin Multiplatform is shown.

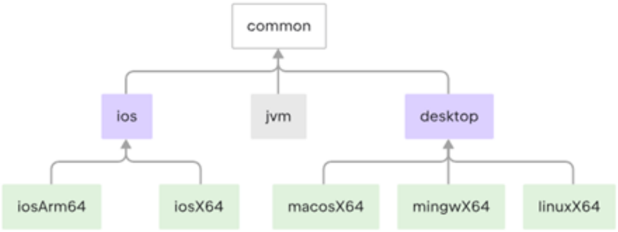

Figure 2. *The Kotlin Multiplatform Mobile (KMM) architecture [1]*

The main challenge that developers encounter in developing such applications is the limited number of libraries that can work across all platforms. The main task is to utilize a shared codebase across all platforms and libraries that function on each platform. If a library isn't supported on one of the platforms, we'd have to locate a platform-specific library and implement its functionality separately

Due to the accelerated development, this is becoming less of an issue, and this year we can even see that many libraries have released their beta versions of plugins that work on multi-platform applications like ktor, library that helps you build servers and clients that can handle tasks asynchronously.

Google's Android team is actively supporting Kotlin Multiplatform by releasing experimental multiplatform versions of Jetpack libraries. So far, they have made several libraries, including Collections, DataStore, Annotations, and Paging, compatible with Kotlin Multiplatform [5].

Kotlin Multiplatform uses the Compose Multiplatform framework for creating user interfaces. With the Compose Multiplatform UI framework, you can push the code-sharing capabilities of Kotlin Multiplatform beyond application logic. You can implement the user interface once and then use it for all the platforms you target – iOS, Android, desktop, and web. By combining Compose and Kotlin Multiplatform you can achieve your codebase to consist of Kotlin for 80–95% depending on the project's complexity. In Figure 3, the growth of the number of libraries supported by Kotlin Multiplatform over the years is shown.

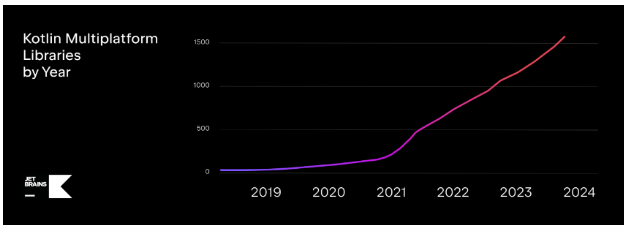

Figure 3. *Kotlin Multiplatform Libraries by Year [3]*

3.2. Performance test

In this chapter, several studies comparing the performance of applications developed using KMM versus native are presented.

In the 2019, Evert [6] published a study on the impacts on development productivity, application size, and startup time for Android and iOS applications developed in Kotlin Multiplatform.

Study [6] shows:

As for if the startup time is affected by using Kotlin Multiplatform instead of native development, the results speak partly for and partly against. The startup times seems to be significantly longer for the multiplatform Android, than the native Android, application. No significance can be seen in the difference in the startup times for the iOS applications.

As for the application sizes, they are shown to be larger in the multiplatform applications, than in the native applications. However, the larger size might very well be due to an initial application size overhead, and the difference in size might decrease with a more extensive application.

The results indicated that the Kotlin Multiplatform framework could make it possible for a developer to write less code but larger application size compared to developing natively.

In the study [7], the performance of Kotlin Multiplatform Mobile was compared to Swift for iOS development in terms of execution time, memory consumption, and CPU usage.

The results demonstrate generally faster execution times for KMM, yet with an overhead in higher memory consumption and CPU usage. This suggests that Kotlin Multiplatform can be opted for in performance-critical applications, whereas Native is suggested for apps that prioritize efficient resource usage [7].

4. DETAILED CASE STUDIES: PRACTICAL IMPLEMENTATION OF KOTLIN MULTIPLATFORM

In the case study [8], companies are showcased that have implemented various code-sharing strategies, including integrating into existing apps and sharing a portion of app logic, as well as building new applications based on Kotlin Multiplatform and Compose Multiplatform.

McDonald's leverages Kotlin Multiplatform for their Global Mobile App, enabling them to build a codebase that can be shared across platforms, removing the need for codebase redundancies [8].

After experimenting with both Flutter and React Native, 9GAG decided to implement Kotlin Multiplatform. They gradually adopted the technology and now ship features faster, while providing a consistent experience to their users [8].

Kotlin Multiplatform helps tech giant Netflix optimize product reliability and delivery speed, which is crucial for serving their customers' constantly evolving needs [8].

To understand the practical implementation of Kotlin Multiplatform across different types of applications, we will consider several detailed case studies. We analyze the use of sensors, games, and background service applications, and evaluate their suitability for Kotlin Multiplatform based on literature and practical examples.

4.1. Use of sensors in applications

The use of sensors in applications is an important aspect for many modern mobile applications, especially in the domains of health, fitness, and geolocation services. Kotlin Multiplatform allows sharing business logic between iOS and Android applications, but it has certain limitations when it comes to direct interaction with sensor hardware. Integration of platform-specific functionalities, such as sensors, requires additional efforts and the use of platform modules to ensure full functionality on both platforms [1]. Therefore, applications that heavily utilize sensors may be less suitable for Kotlin Multiplatform due to the complexity of implementation.

4.2. Games

The paper [16] provides insight into the suitability of Kotlin Multiplatform for game development. Kotlin Multiplatform allows sharing business logic across different platforms, which can be useful in developing simpler games that do not require intensive graphical performance. However, for more complex games that require high performance and optimized graphics, Kotlin Multiplatform may have certain limitations.

KMP has proven to be an effective tool for rapid development and code sharing, but games that demand a high refresh rate, low latency, and complex graphical effects may benefit from native development to achieve optimal performance. For instance, games that use advanced graphics libraries and heavily rely on the GPU may face challenges when developed using Kotlin Multiplatform, as this approach might lead to performance compromises [16].

4.3. Background service applications

Background service applications often require stability, efficient resource management, and the ability to execute tasks concurrently. Kotlin Multiplatform supports asynchronous and parallel programming through coroutines, enabling efficient management of background tasks. These features make Kotlin Multiplatform suitable for developing background service applications that require reliable operation without compromising performance [17].

Kotlin Multiplatform offers a powerful tool for developing applications that share business logic between iOS and Android platforms. While its suitability for certain types of applications, such as games and sensor-intensive apps, is limited due to performance and integration complexity, Kotlin Multiplatform excels in developing background service applications. Each application should be carefully analyzed to determine if Kotlin Multiplatform is the most effective approach for its implementation.

5. OTHER CROSS PLATFORM SOLUTIONS

Cross-platform solutions enable the development of mobile applications for various operating systems. In this section, we will analyze the following technologies through the lens of SWOT to better understand their strengths, weaknesses, opportunities, and threats.

5.1. Fluter

Flutter began as a project by the Chrome browser team at Google to explore the feasibility of building a fast rendering engine with a non-traditional layout model. They wanted to see whether it is possible to build a fast rendering engine while ignoring the traditional model of layout. In a few weeks, significant performance gains were achieved and that is what was discovered:

- Most layout is relatively simple, such as: text on a scrolling page, fixed rectangles whose size and position depend only on the size of the display, and maybe some tables, floating elements, etc.
- Most layout is local to a subtree of widgets, and that subtree typically uses one layout model, so only a small number of rules need to be supported by those widgets.

In the paper [9], the author demonstrated the development of a currency exchange application using both Flutter and Kotlin Multiplatform tools. Since the paper was published in 2018, the main issues the author faced were the unavailability of libraries, which is less of a problem today. Studies indicate that while Kotlin Multiplatform executes faster, it requires more resources. However, with decreasing technology costs and rapid evolution, execution time remains crucial for user experience. The problem with library support is diminishing due to constant adaptation efforts. Introducing Compose Multiplatform has enhanced UI development across platforms, bringing additional benefits to Kotlin Multiplatform. It's worth noting that an author of another paper suggested that these tools offer performance almost identical to native development and referred to them as a sort of "golden bullet" in the debate between native and cross-platform development. This perspective highlights the optimism in the industry regarding the future of cross-platform tools like Kotlin Multiplatform.

As technology evolves, it may become less cost-effective for companies to stick with native development. The decision to transition to Kotlin Multiplatform should be based on the project's specific requirements and the evidence from successful case studies.

Table 2. *Flutter SWOT analysis [10]*

Flutter - SWOT
Strengths: Rapid application development, hot reload functionality, high performance, material design. Supported platforms: iOS, Android, Web, macOS, Windows, Linux.
Weaknesses: Partial support for native APIs, fewer libraries and packages compared to other technologies.
Opportunities: Growing support and popularity, support for web applications.
Threats: Competition from other cross-platform solutions like Xamarin, Kotlin Multiplatform, and React Native.

5.2. XAMARIN

Xamarin is a cross-platform solution that allows development of mobile applications for iOS, Android, and UWP (Universal Windows Platform) using the C# programming language and .NET ecosystem [11].

Table 3. *Xamarin SWOT analysis [9]*

Xamarin - SWOT
Strengths: Stable support for native APIs, high performance, developed community. Supported platforms: iOS, Android, UWP (Universal Windows Platform).
Weaknesses: Complex configuration, need to familiarize with the .NET ecosystem.
Opportunities: Integration with Visual Studio, support for Xamarin. Forms for code sharing.
Threats: Competition from Flutter, Kotlin Multiplatform, and other solutions, limitations in supporting new platform features.

5.3. .NET MAUI

NET MAUI (Multi-platform App UI) is a framework that enables development of multiplatform mobile applications using C# and XAML. It is announced by Microsoft as the successor to Xamarin.Forms, providing a modern, simple, and productive platform for creating applications that work on different devices and operating systems [12].

Table 3. *.NET MAUI SWOT analysis [12]*

.NET MAUI - SWOT
Strengths: Integration with the .NET ecosystem enables easier app development for various platforms. High productivity and code sharing capabilities between iOS, Android, Windows, and macOS. Stable support for native APIs and tools provided by Microsoft .
Weaknesses: Being in development, it may take time for the framework to stabilize and provide all functionalities. Adoption of new technology by development teams may require time.
Opportunities: .NET MAUI promises improvements in performance, tools, and user experience compared to previous versions of Xamarin.Forms. Integration with Visual Studio IDE offers additional support and tools for development.
Threats: Competition from other popular cross-platform solutions like Flutter, which already have a large community and support . Need to adapt to new trends and market demands to remain competitive.

5.4. React Native

React Native is an open-source platform for developing native mobile applications, utilizing standard web technologies such as JavaScript (JSX), CSS, and HTML, but the result is a fully native application. This means that the application runs fast, smoothly, and is equivalent to any native application built using traditional iOS technologies like Objective-C and Swift [13].

Table 4. *React Native SWOT analysis [13]*

React Native - SWOT
Strengths: Active community, hot reload support, access to native APIs. Supported platforms: iOS, Android.
Weaknesses: Performance can be variable, issues with library versioning.
Opportunities: Use of existing knowledge in JavaScript and React, support for a large number of platforms.
Threats: Competition from other cross-platform solutions, potential performance issues for complex applications.

5.5. NativeScript

NativeScript is an open-source framework for mobile app development that allows developers to use JavaScript, TypeScript, or Angular to build high-performance applications for iOS and Android platforms [14].

Table 5. *NativeScript SWOT analysis [14]*

NativeScript - SWOT
Strengths: Full support for native APIs, direct integration with Angular, TypeScript support. Supported platforms: iOS, Android.
Weaknesses: Larger resources needed for application development, smaller community compared to other solutions.
Opportunities: Code sharing between web and mobile applications, access to native components.
Threats: Competition from other cross-platform solutions, limitations in supporting certain platforms.

5.6. Electron

Electron is an open-source framework for developing desktop applications using JavaScript, HTML, and CSS. It enables the creation of cross-platform applications that run on Windows, macOS, and Linux using the same JavaScript codebase. Electron integrates Chromium and Node.js, providing access to a rich set of tools and functionalities for developing complex applications. This framework is a popular choice for creating tools, editors, and other desktop applications [15].

Table 6. *Electron SWOT analysis [15]*

Electron - SWOT
Strengths: Easy integration with web technologies, support for various platforms. Supported platforms: Windows, macOS, Linux.
Weaknesses: Larger resources required for installation and execution, higher memory consumption.
Opportunities: Development of desktop applications using web technologies, access to system resources.
Threats: Competition from other technologies, potential performance issues for complex applications.

6. CONCLUSION

In this paper, we analyzed the concept of Kotlin Multiplatform, its performance, and it's potential to replace native approaches. According to studies [6] and [7], Kotlin Multiplatform executes faster but requires more resources. Today, this isn't a major issue because the cost of technology is decreasing, and it's rapidly evolving, while execution time is crucial for user experience.

The problem with libraries supported for all platforms is diminishing as constant efforts are made to adapt them. Nonetheless, it's possible to separately implement functionality using another plugin if one isn't supported on a particular platform until a compatible one emerges for all.

By introducing Compose Multiplatform, it's now possible to develop user interfaces in Kotlin for all types of platforms, which brings additional advantages to Kotlin Multiplatform.

With the increasing development and improvement of Kotlin Multiplatform, it won't be cost-effective for programming companies to continue with the native approach. Whether it's better to transition to this technology is evidenced by case studies [6] of those who have adopted this approach.

Based on the SWOT analysis presented in Chapter 5, each of these technologies has its strengths and weaknesses. When choosing a cross-platform technology, it's important to carefully consider the specific requirements of the project and the goals of the application development.

Future research should focus on several key areas to enhance Kotlin Multiplatform. This includes advancing library support by developing new multiplatform libraries and improving existing ones. Performance optimization is crucial, with emphasis on compiler optimization, memory management, and execution speed. Enhancements in tooling, particularly in integrated development environments (IDEs) and automated testing tools, are also necessary. Additionally, expanding Jetpack Compose for multiplatform applications will improve user interface consistency. Finally, gathering real-world case studies and fostering community engagement will provide valuable insights and accelerate Kotlin Multiplatform adoption.

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PsAIchology: An Intelligent Direction in Psychological Sciences

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Abstract: *The intersection of machine learning (ML) and cognition is often referred to as 'artificial intelligence', whereas the intersection of psychology and ML is a term we would like to coin as 'Artificial Psychology' or "PsAIchology". The main purpose of this paper is to introduce three commonly used machine learning algorithms for mind research along with their R codes. This paper aims not only to introduce these methods for analyzing data but also tries to provide the answers for questions that may arise for a mind researcher including a) how to choose which algorithm needs to be used for a given dataset, b) How to implement them using R code, c) How to assess model performance to select the best performing algorithm and d) How to interpret the results of the ML algorithms obtained from fitting to a set of data. In this paper, we introduce and illustrate the most commonly used ML algorithms including, AdaBoost, Extreme Gradient Boosting (XGBoost), Random forest and give related R codes with the results obtained from running them. Finally, model performance is interpreted and discussed.*

Keywords: *artificial intelligence; artificial psychology; machine learning; psychology; R language*

1. INTRODUCTION

Psychologists are increasingly interested in adopting powerful computational techniques from the field of machine learning to accurately predict real-world phenomena [1]. PsAIchology or artificial psychology is a highly multidisciplinary field of study in psychology. PsAIchology tries to solve problems that occur when psychologists do research and need a robust analysis method. Conventional statistical approaches have deep-rooted limitations. These approaches are excellent on paper but often fail to model the real world. Mind researchers have been trying to overcome this by simplifying the models being studied. This stance has not received much practical attention recently. Promoting and improving artificial intelligence helps mind researchers to find a holistic model of mental models. This development achieves this goal by using multiple perspectives and multiple data sets together with interactive and realistic models. This comprehensive, holistic, and interactive view may lead to a new research line in the near future. AP can open up a new horizon for mind researchers from clinical to theoretical psychologists to find a more realistic model. This horizon is rooted in a multidisciplinary approach updating our view along with the development of the related sciences leading to the finding of new results even from old datasets and models. AP has some assumptions. Satisfying these assumptions helps find a more precise and deeper way of modeling for artificial psychologists. The assumptions of AP are discussed here. First, we assume that the mind is filled with uncertainty. It is important to note that uncertainty not only occurs in nature but also in almost all man-made systems. Second, we assume that the mind is continuous. In other words, we assume a continuous consciousness in which the brain acts holistically and outputs behaviors discretely [2]; therefore, there is not a sharp dividing line between emotion and cognition. The brain consists of grey matter that constructs mental systems not separated by solid lines. These ambiguous areas are the ones mind researchers are trying to handle by the use of statistical models. The third assumption is that the mind is a complex system; human mentality is made up of complicated systems. Even the simplest systems are complex. This complexity can be captured and interpreted by a dynamic model. The fourth assumption is that there is always a link between mind and data. It is not possible to study mental activities directly. Brain data needs to connect to some psychological constructs and behaviors. Therefore, we need to use multiple sources of data in a single model at the same time. Conventional statistical techniques use rigorous mathematical models. These models require large amounts of data for analysis and prediction. In the real world, we are facing big, imperfectly measured data as well as nonlinear relationships in complex systems. The fifth assumption is that brain data is highly dimensional data. This implies that the dataset has many features even in small sample sizes. This problem commonly occurs in psychological research, especially in clinical, cognitive psychology, and neuroscience, where we need to deal with P > n.

1.1. What Is PsAIchology?

In summary, psychologists need new analysis models to help them model complex mental systems. PsAIchology uses intelligent models that satisfy these assumptions. One technique used in applied computing is to emulate the strategies involved in the intelligent systems or models for problem-solving. Intelligent models are related to the human way of thinking and interpretation. These models use fuzzy logic, artificial intelligence, and genetic algorithms both individually or together. Artificial psychology was first proposed by Dan Curtis in 1963 as a theoretical discipline. PsAIchology is a combination of psychology and artificial intelligence. APsychology can be called the science of studying an individual's mental processes and behaviors. Artificial intelligence also has a wide variety of definitions; however, it is a science that deals with the design of intelligent machines and systems; systems that can perform tasks requiring human intelligence [3]. PsAIchology uses artificial intelligence to design, train, test, and ultimately deploy methodological models in psychology using. features borrowed from psychology and artificial intelligence. PsAIchology in this paper is used to derive robust, interpretable, and explainable models for prediction.

Machine learning, especially supervised machine learning, is one of the most important sections of PsAIchology. Machine learning is a subfield of artificial intelligence that specializes in using data to make predictions or support decision making [4]. In psychology and other social or behavioral sciences, machine learning (ML) has started to emerge as an essential set of tools in predictive modeling to potentially increase the generalizability of findings [1, 5]. ML can. Over the past decade, supervised machine learning (ML) has appeared with increasing frequency in psychology and other social sciences. In psychology, ML has been used to tackle such diverse topics as predicting psychological traits from digital traces of online and offline behavior [6, 7, 8], modeling consistency in human behavior [9], and investigating the empirical structure of self-regulation [10]. Traditional psychological research aims to establish causal effects of predictor variables on outcome variables, whereas machine learning projects aim to achieve maximal (unbiased) accuracy when predicting outcome variables. The most commonly used supervised algorithms will be reviewed along with R code.

1.2. How to choose the best machine learning algorithm?

1-Past experience

A PsAIchology researcher can apply his/her experience from the past in dealing with similar problems or from reviewing the literature.

2-Trial and Error

Various algorithms are fitted to find which one is most appropriate for the given dataset. These algorithms can be improved using optimization with a tuning process or by hybridizing some related algorithms (known as spot-checking). In the context of machine learning, spot-checking refers to the process of testing a suite of standard algorithms on your dataset to establish a performance baseline. This helps identify a few top-performing models that can then be tuned and optimized further. For an effective spot-checking process, here are some recommended practices:

- Splitting the data into training and test data (hold-out method): if the data is huge, then a massive amount of data is needed to make the model accurate.
- Cross-validation divides the data into 5-10 subsets(folds) of almost equal size. Out of these folds is used as a validation set, and the others are involved in training the model. -We generate overall prediction error by taking the total of prediction errors across the folds
- For small amounts of data, we can repeat the K-fold approach multiple times. R code for repeating 10-fold validation 3 times.
- Leave One Out Cross-Validation (LOOCV), this method also splits the dataset into 2 parts but it overcomes the drawbacks of the Validation set approach. LOOCV carries out the cross-validation in the following way: a)firstly we train the model on N-1 data points, b) then test the model against the one data point which was left out in the previous step , c) we calculate prediction error for that one point, d)we repeat the above 3 steps until the model is trained

and tested on all data points, d)we generate overall prediction error by taking the total of the prediction errors. We now present some of the most commonly used supervised machine learning algorithms.

2. ADABOOST AND XGBOOST ALGORITHMS

Boosting is a powerful machine learning algorithm that helps improve the accuracy of models in data science. The AdaBoost algorithm, short for Adaptive Boosting, is a Boosting technique used as an Ensemble Method in Machine Learning. It is called Adaptive Boosting as the weights are re-assigned, with higher weights assigned to incorrectly classified instances. This algorithm builds a model and gives equal weights to all the data points. It then assigns higher weights to points that are wrongly classified. It will keep training models until the lowest error rate is achieved. The AdaBoost algorithm, introduced by Freund and Schapire in 1997, revolutionized ensemble modeling. Since its inception, AdaBoost has become a widely adopted technique for addressing binary classification challenges. This powerful algorithm enhances prediction accuracy by transforming a multitude of weak learners into robust, strong learners. Extreme gradient boosting (xgboost) is similar to the gradient boosting framework but is more efficient. It has both a linear model solver and tree learning algorithms. XGBoost is used both in regression and classification as a go-to algorithm. As the name suggests, it utilizes the gradient boosting technique by adding more and more weak learners until no further improvement can be made. Its parameters include the number of boosting iterations, referred to as nrounds, the learning rate (also known as eta). Eta is a hyperparameter that scales the contribution of each tree in the ensemble, the maximum depth of a tree, which is a pruning parameter designed to control the overall tree depth. Gamma is the minimum loss reduction required to make a further partition on a leaf node of the tree. Subsample is the fraction of all observations to be randomly sampled for each tree. Lambda is the L2 regularization term and alpha is the L1 regularization term. The R code for XGBoost is it is shown at Fig.1

```r
library(gbm)
library(caret)
parts = createDataPartition(P$Painintensity, p = 0.7, list = F)
train = P[parts, ]
test = P[-parts, ]
# train a model using our training data
model_gbm = gbm(Painintensity ~.,
                data = train,
                distribution = "multinomial",
                cv.folds = 10,
                shrinkage = .01,
                n.minobsinnode = 10,
                n.trees = 500)       # 500 tress to be built

summary(model_gbm)
#use model to make predictions on test data
pred_test = predict.gbm(object = model_gbm,
                        newdata = test,
                        n.trees = 500,          # 500 tress to be built
                        type = "response")
pred_test
# Give class names to the highest prediction value.
class_names = colnames(pred_test)[apply(pred_test, 1, which.max)]
result = data.frame(test$Painintensity, class_names)

print(result)
conf_mat = confusionMatrix(test$Painintensity, as.factor(class_names))
print(conf_mat)
```

Figure 1. *R code for XGBoost*

3. RANDOM FOREST

A Random Forest Algorithm is a supervised machine learning algorithm that is extremely popular and is used for Classification and Regression problems in Machine Learning. The greater the number of trees in a Random Forest Algorithm, the higher its accuracy and problem-solving ability. Random Forest is a classifier that contains several decision trees on various subsets of the given dataset and takes the average to improve the predictive accuracy of that dataset. It is based on the concept of ensemble learning which is a process of combining multiple classifiers to solve a complex problem and improve the performance of the model. The following steps explain the working Random Forest Algorithm, Step 1: Select random samples from a given data or training set, Step 2: This algorithm will construct a decision tree for every training data, step 3: Voting will take place by averaging the decision tree, step 4: Finally, select the most voted prediction result as the final prediction result. This combination of multiple models is called Ensemble. Ensemble uses two methods: 1) Bagging creates a different training subset of data from sample training data with replacement. The final output is based on majority voting.2) Boosting combines weak learners with strong learners by creating sequential models to give higher accuracy in the final model.

ADA BOOST, XG BOOST are boosting algorithms, which were discussed in the previous section.

The R codes for Random forest is presented at Fig. 2.

```r
library('Metrics')
library('randomForest')
library('ggplot2')
library('ggthemes')
library('dplyr')
library('DALEX')
library("caret")
P <- read_sav("P.sav")
P$Painintensity<-as.factor(P$Painintensity)
P$Time<-NULL
#dividing the dataset into train and test
index <- createDataPartition(P$Painintensity, p = 0.7, list = FALSE)
train <- P[index, ]
test  <- P[-index, ]
control = trainControl(method="repeatedcv", number = 5, savePredictions=TRUE)
# Random Forest
mod_rf = train(Painintensity ~ .,data = train, method='rf', trControl = control)
library("DALEX")
# Create a custom predict function
p_fun <- function(object, newdata){
  predict(object, newdata=newdata, type="prob")[,2]}
# Convert the outcome variable to a numeric binary vector
yTest <- as.numeric(as.character(test$Painintensity))
# Create explainer objects for each machine learning model
explainer_rf  <- explain(mod_rf, label = "RF",
                         data = test, y = yTest,
                         predict_function = p_fun,
                         verbose = FALSE)
mp_rf  <- model_performance(explainer_rf)
mp_rf
vi_rf <- variable_importance(explainer_rf, loss_function = loss_root_mean_square)
vi_rf
plot(vi_rf)
```

Figure 2. *R code for Random forest*

4. ARTIFICIAL NEURAL NETWORKS

Artificial neural network often known as a neural network or simply a neural net, is a machine learning model that takes its cues from the structure and operation of the human brain. It is a key element in machine learning's branch known as deep learning. Interconnected nodes, also referred to as artificial neurons or perceptrons, are arranged in layers to form neural networks. An input layer, one or more hidden layers, and an output layer are examples of these layers. A neural network's individual neurons each execute a weighted sum of their inputs, apply an activation function to the sum, and then generate an output. The architecture of the network, including the number of layers and neurons in each layer, might vary significantly depending on the particular task at hand. Several machine learning tasks, such as classification, regression, image recognition, natural language processing, and others, can be performed using neural networks because of their great degree of versatility.

In order to reduce the discrepancy between expected and actual outputs, a neural network must be trained by changing the weights of its connections. Optimization techniques like gradient descent are used to do this. In particular, deep neural networks have made significant advances in fields like computer vision, speech recognition, and autonomous driving. Neural networks have demonstrated an exceptional ability to resolve complicated issues. They play a key role in modern AI and machine learning due to their capacity to automatically learn and extract features from data.

A supervised neural network model is a type of machine learning model used for tasks where you have labelled data, meaning you know both the input and the corresponding correct output. In this model, you feed input data into layers of interconnected artificial neurons, which process the information and produce an output. During training, the model learns to adjust its internal parameters (weights and biases) to minimize the difference between its predictions and the actual labels in the training data. This process continues until the model can make accurate predictions on new, unseen data. Supervised neural networks are commonly used for tasks like image classification, speech recognition, and natural language processing, where the goal is to map inputs to specific categories or values.

4.1 Multi-Layer Perceptron Architecture

MLP (Multi-Layer Perceptron) is a type of neural network with an architecture consisting of input, hidden, and output layers of interconnected neurons. It is capable of learning complex patterns and performing tasks such as classification and regression by adjusting its parameters through training. The following is a detailed exploration of the MLP architecture:

- Input Layer: The input layer is where the MLP and dataset first engage with one another. A feature in the incoming data is matched to each neuron in this layer. For instance, each neuron might represent the intensity value of a pixel in picture categorization. These unprocessed input values are to be distributed to the neurons in the next hidden layers by the input layer.

- Hidden Layers: MLPs have a hidden layer or layers that are present between the input and output layers. The main computations happen at these layers. Every neuron in a hidden layer analyzes the data that comes from the neurons in the layer above it. In the same buried layer, neurons do not interact directly with one another but rather indirectly via weighted connections. The hidden layer transformation allows the network to learn intricate links and representations in the data. The intricacy of the task might affect the depth (number of hidden layers) and width (number of neurons in each layer).
- Output Layer: The MLP's neurons in the output layer, the last layer, generate the model's predictions. The structure of this layer is determined by the particular task at hand. The probability score for binary classification may be generated by a single neuron with a sigmoid activation function. Multiple neurons, often with softmax activation, can give probabilities to each class in a multi-class classification system. When doing regression tasks, the output layer frequently just has a single neuron that can forecast a continuous value.

Each neuron applies an activation function to the weighted total of its inputs, whether it is in the input, hidden, or output layer. The sigmoid, hyperbolic tangent (tanh), and rectified linear unit (ReLU) are often used activation functions. The MLP modifies connection (synapse) weights during training using backpropagation and optimization methods like gradient descent. In order to reduce the discrepancy between projected and actual outputs, this method aids the network in learning and fine-tuning its parameters. MLPs are appropriate for a variety of machine learning and deep learning problems, from straightforward to extremely complicated, due to their flexibility in terms of the number of hidden layers, neurons per layer, and choice of activation functions.

4.2 MLP Classifier with its Parameters

The MLP Classifier, short for Multi-Layer Perceptron Classifier, is a neural network-based classification algorithm provided by the Scikit-Learn library. It's a type of feedforward neural network, where information moves in only one direction: forward through the layers. Below is a detailed explanation of the MLP Classifier and its parameters, which in return collectively define the architecture and behavior of the MLP Classifier:

- Hidden Layer Sizes [Parameter: hidden_layer_sizes]: An MLP neural network's hidden_layer_sizes parameter is a crucial structural element. It describes how the network's hidden layers are structured. Each element of the tuple that this parameter accepts represents the number of neurons in a certain hidden layer. The network contains two hidden layers, with the first having 64 neurons and the second having 32 neurons, for instance, if hidden_layer_sizes is set to (64, 32). The network's ability to recognize complex patterns and correlations in the data is greatly influenced by the choice of the number of neurons and hidden layers. In order to model complex data, deeper networks with more neurons may be more susceptible to overfitting.
- Activation Function [Parameter: activation]: Each neuron in the MLP's hidden layers is activated using a different activation function, which is determined by the activation parameter. The network can model intricate input-to-output mappings thanks to the non-linearity introduced by activation functions. There are numerous activation functions, each with their own special qualities. One well-liked option is "relu" (Rectified Linear Unit), which is both computationally effective and successful in reducing the vanishing gradient problem. Both "tanh" (Hyperbolic Tangent) and "logistic" (Logistic Sigmoid) are frequently used and have various uses.
- Solver for Weight Optimization [Parameter: solver]: The neural network's weights are updated during training using an optimization technique, which is determined by the solver parameter. To reduce the loss function of the network, several solvers use various methods. The "adam" algorithm, which combines ideas from RMSprop and Momentum, works well with large datasets and intricate models. The limited-memory Broyden-Fletcher-Goldfarb-Shanno optimization algorithm is used by "lbfgs," which is best for smaller datasets. The stochastic gradient descent algorithm, known as "sgd," adjusts weights based on random selections (mini-batches) of the training data at each iteration.
- Learning Rate [Parameter: learning_rate]: Each training iteration's weight updates are controlled by the learning_rate parameter. It is essential in establishing the training process's stability and rate of convergence. The learning rate might be "constant," "invscaling," or "adaptive," which can all have an impact on how it changes over time. It is crucial to choose the right learning rate since an extremely high rate might cause divergence or slow convergence, while a rate that is too low can cause very slow convergence.
- Maximum Iterations [Parameter: max_iter]: The max_iter parameter restricts

how many iterations can be made before the solver converges during training. Convergence is the condition at which further iterations of the network's weights do not appreciably lower the loss. The solution quits and returns the current findings, which might not be ideal, if it cannot converge within the predetermined limit. When max_iter is chosen appropriately, the training process is neither abruptly stopped nor overly prolonged, allowing the model to converge to the desired level. The R codes is presented at Fig. 3.

```
library("neuralnet")
library("NeuralNetTools")
library("ggplot2")
library("GGally")
library("caret")
library("gmodels")
library("dplyr")
NE <- read_sav("A1s.sav")
NE=data.frame(NE, stringsAsFactors = TRUE)
NE=data.frame(NE, stringsAsFactors = TRUE)
colname=c("CurrentMood","DepressionEpisodes","TraitDepression",
          "TraitRumination","BroodingRumination","ReflectionRumination",
          "ChronicAnxiety","ChronicStress",
          "ExtendedCategoricProportionbynonmissingresponses","SpecGroup")
colnames(NE)=colname
summary(NE)
sapply(NE, class)
NE$CurrentMood=as.numeric (NE$CurrentMood)
NE$DepressionEpisodes=as.numeric (NE$DepressionEpisodes)
NE$TraitDepression=as.numeric (NE$TraitDepression)
NE$TraitRumination=as.numeric (NE$TraitRumination)
NE$BroodingRumination=as.numeric (NE$BroodingRumination)
NE$ReflectionRumination=as.numeric (NE$ReflectionRumination)
NE$ChronicAnxiety=as.numeric (NE$ChronicAnxiety)
NE$ChronicStress=as.numeric (NE$ChronicStress)
NE$ExtendedCategoricProportionbynonmissingresponses=as.numeric (NE$ExtendedCategoricProportionbynonmissingresponses)
NE$SpecGroup<-as.factor(ifelse(NE$SpecGroup==1, "a", "b"))
levels(NE$SpecGroup)
index = createDataPartition(NE$SpecGroup, p = .6, list = FALSE, times = 1)
train =NE[index,]
test= NE[-index,]
CrossTable(NE$SpecGroup)
CrossTable(train$SpecGroup)
CrossTable(test$SpecGroup)
```

Figure 3. *R code for Artificial neural network*

5. DISCUSSION

In this paper we have illustrated applications of ML models. These represent the supervised learning branch of machine learning. This means that there is a training data set that learns patterns from labelled data e.g. group classification by experts. The algorithm learns about relationships in the data and then applies them to new data. Using training data removes bias in prediction from using the same data set to both train and test an algorithm. The training-test set approach is a particularly attractive and viable approach in the twenty-first century given the ever increasing numbers of large amounts of complete data that are collected on-line and by using electronic devices. With increasing computer power procedures to fit these models are becoming more commonly available in software such as R.

It should be noted unsupervised forms of machine learning are used in variable selection and in the clustering of unlabeled data sets [11, 12]. These algorithms discover hidden patterns or data groupings without the need for human intervention and also include variable association models such as unsupervised neural networks.

Farahani et al, 2023 [13] provides further applications of the machine learning models described in this paper using R.

As it is presented in [14] there are a lot of examples of using artificial intelligence for supporting mental health. There is huge potential in using Artificial intelligence in psychological practice. According to [14] "the advancement of AI technologies and their application in psychological practice have important implications that can be expected to transform the mental health care field". However, the main role is on professionals and the main challenge is related to an ethics in these research areas.

6. CONCLUSION

AI has been traditionally used in cognitive research. AI, for example, has been used to reproduce activities of the human brain [15] and improve the level of social intelligence [16].

The most important feature, however, that distinguishes humans from machines is that humans process external input from the world to stimulate different subjective emotional orientations such as satisfaction, dissatisfaction, love and dislike. An important advancement in recent years, therefore, has been the enablement of the computer to understand and express emotions. Huang [17] has used computer modelling on 5,500 face frontal photographs to predict face attractiveness and found this model performed well. Lebedeva et al. [18] further showed that algorithms can be trained to identify beauty preferences using a limited number of images.

Jensen et al. [19] have shown an association between modern biomarkers which has led to a belief that AI can be used to diagnose autism and help autistic people to improve social, communication, and emotional skills [20].

The above show the range of areas AI is being used and its importance to the further understanding of the working of the human brain.

Artificial Intelligence is an area of increasing importance and is now being used in almost every field of science. It has the potential to accelerate the pace of scientific discovery by being trained to discover patterns in data that have not been apparent using traditional methods. The training of AI algorithms is facilitated by the internet which allows the collection of richer sources of data to allow more powerful and detailed predictions and revolutionise our understanding of the world around us.

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Predicting Student Academic Success with Hidden Markov Models

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Abstract: This research paper presents an approach for predicting student academic success using Hidden Markov Models (HMMs). Leveraging a comprehensive dataset encompassing students' demographics, academic performance, attendance records, and course engagement, the study employs an HMM framework to model levels of student academic success. Observable emissions derived from the data, such as grades and interaction patterns, are utilized to train the HMM and infer the most likely sequence of hidden states for new students. Evaluation of the proposed model demonstrates promising predictive accuracy. Through rigorous assessment using standard metrics including state prediction accuracy and state transition accuracy, the effectiveness of the HMM in capturing diverse student trajectories is demonstrated, underscoring the potential of HMMs as a powerful tool for understanding and predicting student outcomes, offering valuable insights for educational interventions and support systems.

Keywords: *Hidden Markov Models; academic success prediction; student trajectories; predictive modeling; educational data analysis*

1. INTRODUCTION

Predicting student academic success is a critical challenge in educational research, with significant implications for targeted interventions and resource allocation. This research focuses on using Hidden Markov Models (HMMs) to analyze and predict student academic trajectories by incorporating various dimensions of student data. Hidden Markov Models, well-regarded for their ability to model time series data and capture latent state transitions, offer a robust framework for understanding the dynamic nature of student performance over time.

The study integrates a diverse dataset, including demographic information, academic performance metrics, attendance records, and patterns of course engagement. These features are utilized to develop a model that can identify and infer latent states of overall academic achievement. Observable emissions, such as grades and interaction frequencies, are employed to train the HMM, enabling it to predict the sequence of hidden states that most likely represent student behaviors and outcomes.

By applying HMMs to educational data, this research aims to uncover insights into the factors driving academic success and challenges. This approach facilitates the identification of at-risk students and the development of tailored support strategies, enhancing educational interventions and contributing to improved student retention and success rates.

2. HIDDEN MARKOV MODELS

Hidden Markov Models (HMMs) are statistical models used to describe systems that are assumed to be Markov processes with hidden states. They are particularly useful for modeling time series data where the system being modeled is not directly observable (hidden) but can be inferred through observable sequences. An HMM is characterized by the following components [1, 2]:

- **States (S):** A finite set of hidden states $S = \{S_1, S_2, \ldots, S_N\}$. The actual state at time t is denoted as S_t, which is not directly observable.
- **Observations (O):** A finite set of possible observations $O=\{O_1, O_2, \ldots, O_M\}$. At any time t, an observation O_t is made, which is dependent on the current hidden state S_t.
- **Transition Probabilities (A):** A matrix $A=[a_{ij}]$ representing the probabilities of transitioning from one state to another. Specifically, a_{ij} is the probability of transitioning from state S_i to state S_j:
$$a_{ij} = P(S_{t+1} = S_j | S_t = S_i) \quad (1)$$
The rows of A must sum to 1:
$$\sum_{j=1}^{N} a_{ij} = 1 \quad \forall i \quad (2)$$
- **Emission Probabilities (B):** A matrix $B=[b_j(o)]$ representing the probability of observing o given state S_j. $b_j(o)$ is the probability of observation o being emitted from

state S_j:

$$b_j(o) = P(O_t = o | S_t = S_j) \quad (3)$$

For discrete observations, each row of B must sum to 1:

$$\sum_{o \in O} b_j(o) = 1 \ \forall j \quad (4)$$

- **Initial State Probabilities (π):** A vector $\pi=[\pi_i]$ representing the probability distribution over the initial states. π_i is the probability that the system starts in state S_i:

$$\pi_i = P(S_1 = S_i) \quad (5)$$

The probabilities must sum to 1:

$$\sum_{i=1}^{N} \pi_i = 1 \quad (6)$$

An HMM is often denoted by the triple $\lambda=(\pi,A,B)$. The **Markov property** of an HMM implies that the probability of transitioning to the next state depends only on the current state and not on the sequence of states that preceded it:

$$P(S_{t+1} | S_1, S_2, \dots, S_t) = P(S_{t+1} | S_t) \quad (7)$$

Given the current state, the probability of an observation depends only on that state and is independent of previous observations:

$$P(O_t | S_1, S_2, \dots, S_t, O_1, O_2, \dots, O_t) = P(O_t | S_t) \quad (8)$$

3. METHODOLOGY

3.1. Data Preparation

The dataset utilized in this study was meticulously compiled from multiple sources, ensuring a comprehensive and diverse representation of student data [3-6]. These sources included institutional academic records, online learning platforms, student information systems, and educational surveys. The integrated dataset encapsulated a wide range of student characteristics and behaviors, crucial for modeling academic success. Key features extracted from these sources, as detailed in Table 1, encompass various aspects of academic performance, socio-demographic attributes, and behavioral indicators. The resulting dataset comprises time-series data of student characteristics tracked and recorded for each semester, providing a dynamic view of their academic progression and behavior over time.

Once the dataset was compiled, the preprocessing phase began with encoding categorical features. Categorical features such as Gender, Parental Education Level and Degree Type were transformed using One-Hot Encoding. This method converts categorical variables into a binary matrix, where each unique category is represented by a separate column, and the presence of a category is indicated by a '1' while its absence is indicated by a '0'. For example, the Degree Type feature, which could take values such as "B.Sc.", "B.A.", or "M.Sc.", was expanded into multiple binary columns, each representing one of these categories. For numerical features, such as Current GPA, Current Semester, and Days Since Enrollment, scaling was performed using the MinMax scaler. This approach scales each numerical feature to a range between 0 and 1, based on the minimum and maximum values of that feature. This normalization ensures that all numerical features contribute equally to the model and prevents features with larger ranges from disproportionately influencing the model's predictions.

Handling missing data was also a critical aspect of data preparation. Features with a small percentage of missing values were imputed using statistical technique of mean imputation, ensuring that these gaps did not affect the model's performance. However, features with a high percentage of missing values were removed from the dataset to maintain data integrity and model accuracy. This systematic approach to data cleaning and preparation ensured that the dataset was robust, reliable, and ready for subsequent modeling processes.

Table 1. *Features in the gathered dataset*

Feature	Description
Age	The student's age.
Gender	The student's gender.
Semester	The academic term or semester the student is currently enrolled in.
Degree Type	The specific academic degree program or major the student is enrolled in, such as Bachelor of Science (B.Sc.), Master of Science (M.Sc.), etc.
Days Since Enrollment	The number of days that have elapsed since the student's initial enrollment date.
Current GPA	Provides a continuous measure of the student's academic performance averaged across all courses for the current term.
Class Attendance Rate	Percentage of classes attended out of the total scheduled classes.
Weekly E-Learning Platform Logins	Number of logins to the online course platform per week.
Parental Education Level	Highest educational attainment of the student's parents or guardians (e.g., high school, college).
Assignment Submission Rate	Percentage of assignments submitted on time in each course.
Number of Courses Enrolled	Total number of courses the student is enrolled in during the current term or semester.
Library Visits per Month	Number of visits to the library per month for academic purposes.

For this research paper's data preprocessing, the Python programming language was utilized alongside its robust libraries: pandas, numpy, and scikit-learn. Pandas facilitated the efficient handling and manipulation of the dataset, allowing for seamless integration and transformation of data from multiple sources. Numpy provided essential support for numerical operations and array management, critical for statistical calculations.

Scikit-learn offered powerful tools for encoding categorical features using One-Hot Encoding, scaling numerical data with the MinMax scaler, and managing missing values through the mean imputation technique.

3.2. Defining Hidden States

In the process of creating a Hidden Markov Model (HMM) for predicting student academic success, the definition of hidden states was undertaken to capture the latent conditions that influence observable academic outcomes. These hidden states represent unobservable factors that significantly affect students' academic trajectories but are not directly measurable through the dataset. The definition of hidden states was informed by a combination of domain knowledge, research objectives, and the nature of the available data.

The identification of latent variables was a crucial step in defining the hidden states. It was essential to represent underlying factors that influence observable features such as grades, attendance, and engagement. Hidden states defined in this study are presented in Table 2.

Table 2. *Hidden States*

Hidden State	Description
At Risk of Drop-Out	This state characterizes students who exhibit poor academic performance, low attendance, and high stress levels. Such students are identified as being at a high risk of discontinuing their studies. This state captures patterns of disengagement and underperformance.
On Track	Students in this state are those performing satisfactorily, maintaining average grades, and consistent attendance. This state indicates a normal progression through their academic program without significant issues.
Excellent	This state represents students who excel academically, demonstrating high grades, strong attendance, and active participation in academic activities. These students are identified as high achievers likely to succeed.

The hidden states were defined with the dual objectives of predictive accuracy and providing actionable insights for educational interventions. States were chosen to meaningfully capture variations in student trajectories relevant to predictive goals. It was imperative that the defined states facilitate the identification of students at risk and those excelling, thereby allowing for targeted interventions to support struggling students or enhance the performance of high achievers. The state transition diagram is shown on Fig. 1.

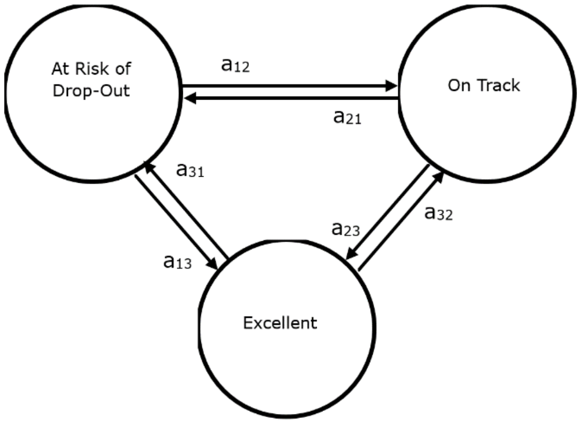

Figure 1. *State Transition Diagram*

3.3. Clustering and Labeling the Dataset

The initial dataset compiled for this study did not include pre-assigned labels indicating the academic success or risk levels of students. Consequently, an unsupervised learning approach was employed to categorize the data into distinct clusters. The K-Means clustering algorithm was selected for this task due to its effectiveness in partitioning data based on inherent similarities. K-Means was applied to the dataset, aiming to group student data points into three clusters, each representing different levels of academic engagement and performance.

The clustering process involved analyzing a multidimensional feature space comprising the student. The K-Means algorithm iteratively adjusted the cluster centroids to minimize within-cluster variance, effectively grouping students with similar academic profiles. After convergence, three distinct clusters were identified, each capturing unique patterns in the student data. These clusters were then subjected to further analysis to interpret their academic implications.

Through detailed examination of the clusters' characteristics, descriptive labels were assigned to each cluster based on the observed data patterns. One cluster, characterized by low grades, poor attendance, and high stress levels, was labeled as "At Risk of Drop-Out", reflecting students who are likely to struggle academically and potentially discontinue their studies. A second cluster, exhibiting average academic performance and consistent attendance, was labeled as "On Track", indicating students who are progressing normally without significant issues. The third cluster, marked by high grades, strong attendance, and active engagement, was labeled as "Excellent", representing students who are thriving academically. This labeling process transformed the unsupervised clusters into meaningful categories, enabling the subsequent training of the Hidden Markov Model with these inferred state labels. Table 3 presents the summary of key statistics (Average Current GPA, Average Class Attendance Rate (%), Average Weekly E-Learning Platform

Logins, Average Assignment Submission Rate) for each cluster. This information highlights distinct patterns and potential intervention points for each group. Additionally, this table aids in identifying characteristic profiles for each cluster, offering clear benchmarks to assess student progress and tailor support strategies effectively.

Table 3. *Key Cluster Statistics*

Cluster	GPA	CAR	EPL	ASR
At Risk of Drop-Out	2.1	58.4	2.1	54.2
On Track	3.0	76.0	7.3	86.2
Excellent	3.6	92.7	11.2	97.7

In Table 3 GPA represents Average Current GPA, CAR represents Average Class Attendance Rate (%), EPL represents Average Weekly E-Learning Platform Logins, and ASR represents Average Assignment Submission Rate.

3.4. Calculating HMM Input Values

Training a Hidden Markov Model (HMM) involves estimating the model parameters, namely the initial state probabilities, transition probabilities, and emission probabilities, from a given dataset.

To calculate **initial probabilities** for an HMM, it is needed to determine the probabilities of starting in each of the hidden states. These initial probabilities represent the likelihood of being in a particular state at the beginning of the sequence. It is necessary to count the occurrences of each hidden state at the start of the sequences. The dataset is examined and it has been counted how many sequences start in each hidden state.

Emission probabilities represent the likelihood of observing a particular feature or set of features given a specific hidden state at time t. The dataset was grouped based on the hidden state labels for each time step. The estimation process for emission probabilities differs based on whether data is discrete or continuous.

- **Discrete Observations**: If the observations are discrete, the frequency of each observation in each state is calculated.
- **Continuous Observations:** If the observations are continuous (e.g., attendance rates), they are modeled using probability distributions. In this research paper, we utilized a Gaussian probability distribution. For each feature, such as attendance rate, a multivariate Gaussian distribution is employed to model the joint probability distribution of all observations given the hidden state. The parameters of the Gaussian distribution, including mean vector and covariance matrix, are estimated based on the observations associated with each hidden state.

Transition probabilities represent the likelihood of moving from one hidden state to another between consecutive time steps. The data needs to be organized as sequences over time (e.g., each student's progression through terms) — which was completed during the data preparation phase. The number of transitions from each state to every other state in the dataset needs to be counted. These counts are in turn normalized to get transition probabilities (by dividing by the total number of transitions out of each state).

3.5. Training and Evaluating the Hidden Markov Model

In this study, Python programming language was utilized along with the hmmlearn library for HMM implementation. The hmmlearn library provides an efficient and easy-to-use interface for training HMM models and estimating their parameters. The hmmlearn library handles parameter estimation by internally, when calling the fit() function. Example code for training an HMM model is shown on Fig. 2.

```
from hmmlearn import hmm
hidden_states = ["At Risk of Drop-Out", "On Pace", "Excellent"]
model = hmm.MultinomialHMM(
      n_components=len(hidden_states),
      n_iter=100
)

# Train the HMM model
model.fit(X)

# Display the parameters
print("Initial state probabilities:", model.startprob_)
print("Transition probabilities:", model.transmat_)
print("Emission probabilities:", model.emissionprob_)
```

Figure 2. *Training the HMM model*

A Multivariate Hidden Markov Model (HMM) was used here to model the joint probability distribution of multiple observed features, allowing for a more accurate representation of the complex relationships and dependencies among the observed variables.

For this research paper, the dataset was split into train and test parts in an 80-20 ratio, allowing for model training on the larger portion of the data while reserving a smaller portion for evaluation purposes. State prediction accuracy and state transition accuracy were subsequently calculated using standard evaluation metrics, enabling the assessment of the model's performance on the test set.

State Prediction Accuracy evaluates the accuracy of predicting the correct state sequence for new sequences of observations. It measures how well the HMM model predicts the latent student trajectories. **State Transition Accuracy** assesses how accurately the model predicts transitions between different states over time. It evaluates whether the model captures the expected transitions in student trajectories.

4. RESULTS AND DISCUSSION

4.1. Results and Discussion

After training and evaluating the Multivariate Hidden Markov Model, the state prediction accuracy was determined to be 91.12%, indicating that the model accurately predicted the latent student trajectories, including "At Risk of Drop-Out", "On Track", and "Excellent", for a significant portion of the dataset. Additionally, the state transition accuracy was found to be 86.70%, demonstrating the model's ability to effectively capture the transitions between different student states over time. These results highlight the promising performance of the HMM in predicting student academic success trajectories. The detailed evaluation metrics, including state prediction accuracy and state transition accuracy, are presented in Table 4, providing a comprehensive overview of the model's performance in capturing the underlying dynamics of student outcomes. These metrics are crucial for understanding and predicting student outcomes as they provide insights into the model's ability to discern and anticipate changes in students' academic trajectories.

Table 4. *HMM Performance Evaluation Results*

Metric	Test Result
State Prediction Accuracy	91.12%
State Transition Accuracy	86.70%

The high state prediction accuracy and state transition accuracy obtained in this study demonstrate the potential of HMMs as a powerful tool for understanding and predicting student outcomes. By accurately capturing the dynamics of student progress and identifying patterns in their academic trajectories, HMMs offer valuable insights for educational interventions and support systems. For instance, based on the predicted trajectories, educators and policymakers can tailor interventions to provide timely support to students who are deemed at risk of drop-out, thereby improving retention rates and fostering academic success. Additionally, insights derived from HMMs can inform the development of personalized learning pathways and intervention strategies, ultimately enhancing student engagement, performance, and overall educational outcomes. Thus, the demonstrated effectiveness of HMMs in predicting student outcomes underscores their potential as a valuable tool for educational research, policy-making, and practice.

4.2. Comparison With Related Research

In a similar manner to [7] this research paper also utilized clustering techniques to label its dataset. By employing the k-means algorithm, the dataset in [7] was clustered based on 12 engagement metrics, categorized into interaction-related and effort-related aspects. This approach enabled the identification of distinct groups of students with varying levels of engagement, thereby facilitating the assessment of student involvement and potential areas for intervention. The clustering process allowed for the categorization of students into different engagement levels, which is crucial for personalized e-learning experiences and effective educational interventions. By leveraging machine learning techniques like clustering, both research papers aimed to address challenges in e-learning platforms, such as personalization and student engagement, ultimately contributing to the improvement of learning outcomes and experiences in online education settings.

Both [8] and this research paper utilize Hidden Markov Models (HMMs) to analyze student behavior in online educational environments, albeit for slightly different purposes. Ref. [8] focuses on predicting student retention in Massive Open Online Courses (MOOCs) by leveraging HMMs to understand student behavior over time. It addresses the challenge of student dropout rates in MOOCs by modeling latent characteristics of students that influence their perseverance using observable interactions with the course. The HMM framework allows for the prediction of a student's behavior in the next time step based on previous states and observable actions.

Ref. [9] focuses on a classification problem, attempting to predict student success or failure based on similar data points — demographic information, studying routines, attendance behaviors, and epistemological beliefs. It compares the prediction accuracy of various supervised classification algorithms, with the Neural Network algorithm achieving the highest accuracy.

5. CONCLUSION

This research paper demonstrates an approach for predicting student academic success using Hidden Markov Models. By integrating a comprehensive dataset comprising students' demographics, academic performance, attendance records, and course engagement, the study effectively employs an HMM framework to model varying levels of student academic success. The model utilizes observable emissions, such as grades and interaction patterns, to infer the most likely sequence of hidden states for new students. The evaluation results reveal a state prediction accuracy of 91.12% and a state transition accuracy of 86.70%, highlighting the HMM's robust capability to predict latent student trajectories. These results showcase the model's efficacy in capturing the underlying dynamics of student outcomes.

The high accuracy rates underscore the potential of HMMs as a powerful tool for understanding and predicting student outcomes, offering valuable insights into educational interventions and support systems. By accurately modeling the dynamics of student progress and identifying critical patterns in their academic trajectories, HMMs can enable educators and policymakers to tailor interventions to students' needs, thereby enhancing retention rates and promoting academic success. This approach can inform the development of personalized learning pathways and timely intervention strategies, ultimately leading to improved student engagement and performance.

Future research could explore several extensions of this study to further enhance the application and effectiveness of HMMs in educational settings. First, incorporating additional features such as social interactions, extracurricular activities, and psychological factors could provide a more holistic understanding of student behavior and success. Additionally, integrating temporal factors more dynamically into the HMM framework could improve the model's responsiveness to changes in student behavior over time. Another avenue for future work involves exploring the application of HMMs to different educational contexts, such as vocational training or adult education, to assess their generalizability and adaptability. Furthermore, comparative studies with other machine learning models, such as neural networks or ensemble methods, could provide insights into the relative advantages and limitations of HMMs. Finally, the development of interactive tools and dashboards based on HMM predictions could facilitate real-time monitoring and intervention by educators, enhancing the practical utility of the model in educational practice.

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The Influence of Daubechies Wavelet Order on Speech Recognition

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Abstract: *This paper will present the results of speech recognition based on different Daubechies wavelet orders. Two speakers (one female and one male) were analyzed in two speech modes: normal and whisper. The patterns are used from the Whi-Spe database. As an input to the recognition system, the Daubechies wavelet feature vectors with different orders were used. As a back-end of the system, the standard Dynamic Time Warping method was considered. The results are given in the form of tables and histograms. They suggest which order of Daubechies is the most convenient for this kind of speech recognition.*

Keywords: *Speech recognition; Discrete Wavelet Transformation (DWT); Daubechies; Whi-Spe database; Dynamic Time Warping (DTW)*

1. INTRODUCTION

Whisper is one of the speech modes that is nowadays very often in use. The usage of mobile telephones is so popular. But, because the speech over the mobile phone can disturb other people around, the speaker usually turns to whisper.

In the last two to three decades this speech mode has in the focus of many researchers. They analyzed different features related to whisper: vocal cord vibration [1], shape of glottis and larynx [2], formant frequency migrations [3, 4] entry levels, signal-to-noise ratio etc.

To make a more realistic mathematical model of whispered speech the researchers used different tools and acoustical features. Hence, the most popular are related to Linear, Mel and Bark scales and their modifications. The whispered speech is transformed into a set of digital vectors and then these vectors are inputs to the system for training and testing.

On the back-end of the Automatic Speech Recognition (ASR) system, there are different tools for recognition. The most popular are DTW (Dynamic Time Warping) [5], HMM (Hidden Markov Models) [6] and ANN/DNN (Artificial Neural Networks/Deep Neural Networks) [7].

In this paper for the acoustical features, the vectors of Discrete Wavelet transformation [8] are used with a specific family: Daubechies wavelet. They are chosen according to the Mel filter bank. For the back-end of this recognition system, DTW is used.

This article is structured in the following way: Section 2 explains Discrete Wavelet Transformation with a focus on the Daubechies wavelet family. Seven different orders of this family were analyzed. Section 3 provides a figure and an explanation of how to extract DWT feature vectors and how to conduct the recognition. Each vector has 12 cepstral coefficients and they are based on 24 frequency subbands. Section 4 gives the results of these experiments. Finally, in Section 5 the conclusion is given with recommendations on what can be done in the future.

2. DAUBECHIES WAVELET FEATURE

The Wavelet Transform (WT) is a mathematical technique used to overcome some shortcomings of the Fourier transform [8]. The Fourier transform gives the signal in the frequency domain but does not provide information about where these frequency components are present in time. With WT the processing signal is cut-off at certain points (in time) and transferred to the frequency domain. Mathematically it can be written as:

$$\gamma(s,\tau) = \int f(t)\psi^{*}_{s,\tau}(t)dt \quad (1)$$

where *f(t)* is the processing signal and $\psi(t)$ is a ”mother” function of the wavelet. “Mother” wavelet is represented as:

$$\psi_{s,\tau}(t) = \frac{1}{\sqrt{s}}\psi(\frac{t-\tau}{s}) \quad (2)$$

where s is a scaling factor and τ is a shift parameter.

The Discrete Wavelet Transform (DWT) is a special case of the Wavelet Transform [9]. It is practical for computer applications. It uses a "mother" wavelet in the form:

$$\psi_{j,k}(t) = \frac{1}{\sqrt{s^j}} \psi\left(\frac{t - k * s^j}{s^j}\right) \quad (3)$$

where j and k are integers. In practices, the sampling pattern is dyadic, so the "mother" wavelet is shifted by $k * 2^j$ and scaled by 2^j . Hence, the value of s is 2.

The DWT is efficient in decomposing signals and provides the approximation and detail coefficients. Usage of the DWT is particularly powerful for signal compression, detecting changes in the signal, time series analysis, speech processing etc [8].

The DWT is uses the concept of multi-resolution analysis. An input signal is successively decomposed into many frequency bands or scales. The signal is going through multiple series of high-pass and low-pass filters. As a result, the approximation (low-frequency) and detail (high-frequency) coefficients are obtained and they are used further in signal processing.

Different DTW wavelet families can be used for implementation. The most popular are: Daubechies, Coiflets, Symlets, Biorthogonal, Haar, Morlet, Mexican Hat, etc. used to simulate features such as frequency localization, linear phase characteristic, and orientation of speech signal [10].

The Daubechies wavelet family (introduced by Ingrid Daubechies) is a set of wavelets often used in DWT implementations. It has specific mathematical features that are suitable for signal-processing tasks.

The results presented in this paper are obtained with Daubechies wavelets with 7 different orders used (from 'db2' to 'db8'). In the notation 'db*x*', the number *x* stands for the number of coefficients in the wavelet function.

Figure 1 presents Daubechies wavelet functions with different orders (from 2 to 8) used for this research.

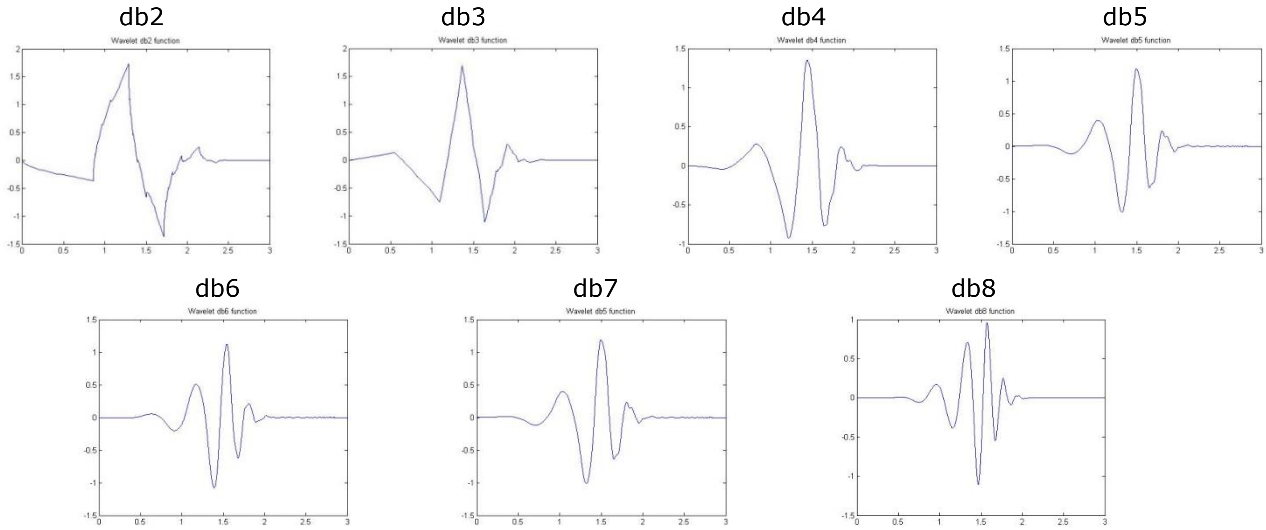

Figure 1. *Daubechies wavelets with different orders ('db2', 'db3', 'db4', 'db5', 'db6', 'db7' and 'db8' respectively)*

3. FEATURE EXTRACTION AND SPEECH RECOGNITION

For these experiments, a part of the Whi-Spe database [11] which contains numbers was used. The database itself contains 10.000 digital speech patterns which represent normal and whisper speech. All patterns are recorded with a frequency 22050 Hz, 16 bits per sample.

Figure 2 depicts a block diagram for feature extraction.

Firstly, the digital speech signal is coming to a block for "Framing/Overlapping". The size of the frame was 192 samples, and the overlap was 50%. The next block is the "Hamming window" and it weights the signal and puts the signal value to zero at the beginning and end of each frame. After that, the "Wavelet transformation" block is applied. For this transformation, the spectrum from 0 Hz to 11025 Hz is divided into 24 subbands following the Mel scale.

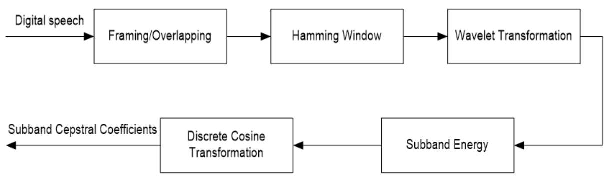

Figure 2. *Block* diagram for feature extraction

Based on a wavelet tree with six decompositions, an energy for each subband is calculated as [12]:

$$S_i = \sum_{mei}[(W_\varphi x)(i), m]^2 / N_i \qquad (4)$$

where $W_\varphi x$ is the Wavelet packet transformation of x; i – subband frequency index *(i= 1,2,3,…L); (*In this case L=24*);* N_i - number of coefficients in i^{th} subband.

The last step is the application of DCT (Discrete Cosine Transformation). The outputs are Subband Cepstral Coefficients (SBCC). They are obtained by using the following formula:

$$SBCC(k) = \sum_{i=1}^{L} \log S_i * \cos(\frac{k(i-0{,}5)}{L}\pi) \qquad (5)$$

where k=1,2,…N (N is a number of SBC coefficients, in this case N=12).

Hence, the feature vector which is used for speech recognition contains 12 SBCC elements, and all input signals are transferred into a set of these vectors.

For these experiments from the Whi-Spe database [11], two speakers are chosen: one female speaker (denoted as "Speaker1"), and one male speaker (denoted as "Speaker6"). The patterns of these speakers were in both modes (normal and whisper) and contain pronunciation of fourteen numbers (IPA notation): /nula/, /jedan/, /dva/, /tri/, /tʃetiri/, /pet/, /ʃest/, /sedam/, /osam/, /devet/, /deset/, /sto/, /hiʎadu/, /million/. Every word is repeated ten times in both modes (normal and whisper).

At the back-end of the recognition system, the DTW (Dynamic Time Warping) algorithm is applied [5]. It's an old and reliable system and it's based on dynamic programming.

The recognition is conducted in the following way (for example): one set of 14 patterns of "Speaker1" in the appropriate mode (normal or whisper) is compared with nine remaining sets of 14 patterns. If the first set is in the normal mode and the remaining nine sets in the normal mode – the results are called: Normal/Normal scenario ("N/N"). On a similar way, other three scenarios are produced: Whisper/Whisper ("W/W"), Normal/Whisper ("N/W") and Whisper/Normal ("W/N"). To make the experiment consistent, it was mandatory to use the first set of 14 patterns as a reference.

4. RESULTS

The results for these four scenarios are provided in the form of tables and histograms. The results are The Word Recognition Rate (WRR) is presented in percent (%).

Tables 1. to 7. show the results of these experiments.

Table 1. *WRR (%) for Daubechies 'db2' order*

	Speaker1	Speaker6	Average
N/N	83.30	73.81	78.56
W/W	71.43	65.08	68.26
N/W	27.78	32.54	30.16
W/N	24.60	19.05	21.83

Table 2. *WRR (%) for Daubechies 'db3' order*

	Speaker1	Speaker6	Average
N/N	90.48	80.16	85.32
W/W	80.95	76.19	78.57
N/W	30.16	35.71	32.94
W/N	22.22	19.84	21.03

Table 3 *WRR (%) for Daubechies 'db4' order*

	Speaker1	Speaker6	Average
N/N	90.48	82.54	86.51
W/W	79.37	71.43	75.40
N/W	28.57	34.92	31.75
W/N	25.40	20.63	23.02

Table 4. *WRR (%) for Daubechies 'db5' order*

	Speaker1	Speaker6	Average
N/N	90.48	84.92	87.70
W/W	80.95	75.40	78.18
N/W	30.16	31.75	30.96
W/N	25.40	22.22	23.81

Table 5. *WRR (%) for Daubechies 'db6' order*

	Speaker1	Speaker6	Average
N/N	93.65	85.71	89.68
W/W	83.33	76.19	79.76
N/W	31.75	37.30	34.53
W/N	23.02	23.81	23.42

Table 6. *WRR (%) for Daubechies 'db7' order*

	Speaker1	Speaker6	Average
N/N	91.27	90.48	90.88
W/W	84.13	75.40	79.76
N/W	30.16	35.71	32.94
W/N	26.19	26.19	26.19

Table 7. *WRR (%) for Daubechies 'db8' order*

	Speaker1	Speaker6	Average
N/N	92.86	85.71	89.29
W/W	82.54	76.98	79.76
N/W	30.95	35.71	33.33
W/N	25.40	23.81	24.60

From the tables above it is obvious that the female speaker produced better results than the male speaker for the match cases (Normal/Normal and Whisper/Whisper).

Figures 3.-6. describe WRRs in percent for all scenarios and all analyzed Daubechies orders.

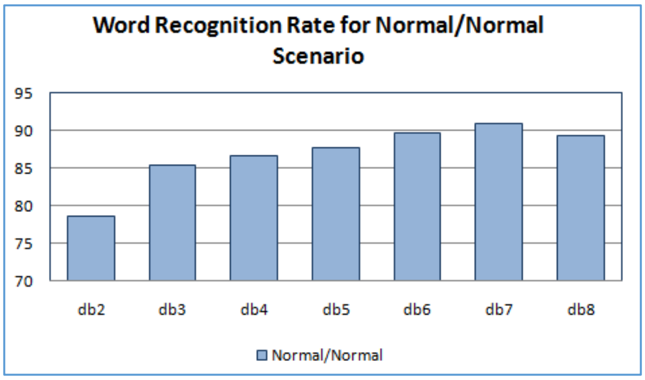

Figure 3. *Results for Normal/Normal scenario*

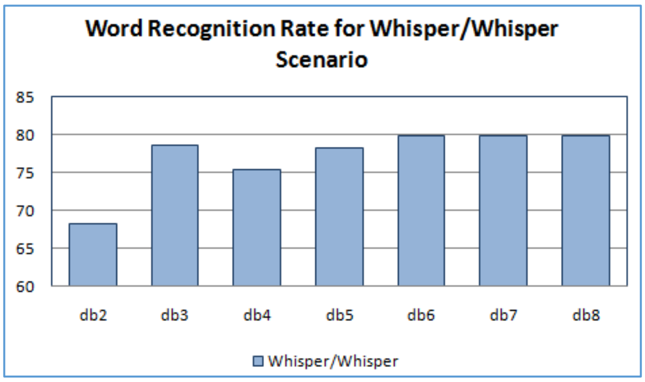

Figure 4. *Results for Whisper/Whisper scenario*

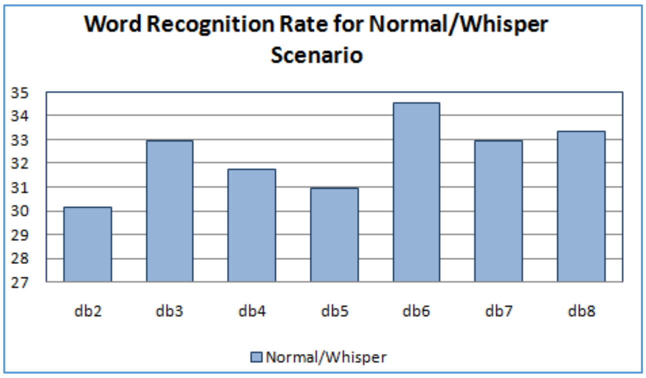

Figure 5. *Results for Normal/Whisper scenario*

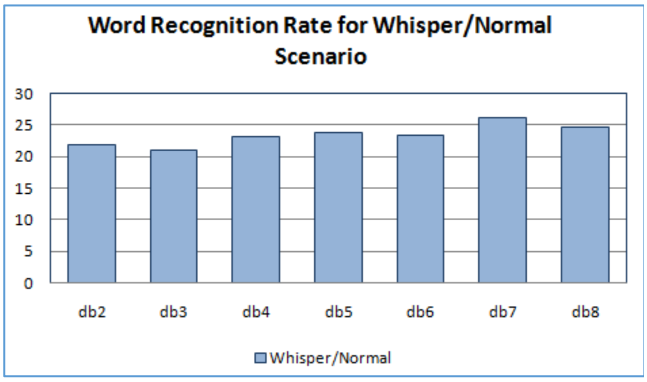

Figure 6. *Results for Whisper/Normal scenario*

Based on the histograms above it's obvious that 'db7' gives the best results for N/N (90.88%), W/W (79.76%) and W/N (26.19%) scenarios. After that 'db6' is a candidate for the second place (gives the best result for N/W (34.53%) scenario), but also 'db8' is very close.

5. CONCLUSION

The results of this research can be summarized in a few sentences:

- Usage of different Daubechies orders can impact the recognition of speech.
- The higher order consumes more computer's time.
- The experiments with orders from 2 to 8 suggest the best is to use 'db7'.

Further research may be focused on including all speakers and all patterns for the Whi-Spe database and make this result more reliable. Also, including vectors with delta coefficients, delta-delta coefficients and applying the cepstral normalization techniques (i.e. CMS) [13] the results for mismatch scenarios (N/W and W/N) should be improved. The research can incorporate speaker-independent scenarios and different methods on the back-end of ASR (i.e. HMM, DNN etc.) and also may take in consideration noisy environments.

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Effect of the Slope of Symmetric Saturated Activation Functions on Deep Learning

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Abstract: *It is presented how the slope of symmetric activation functions with saturation affects class detection using symbolic analysis. Different activation functions can be used to increase the most likely detected classes. The main result is the determination of the highest slope of the activation function and the lowest slope of the activation function in terms of the number of neurons in the layer.*

Keywords: *class detection; probability; automated drawing; symbolic solving of the neural network*

1. INTRODUCTION

The activation function is usually the same during the training phase with known images and the detection of an unknown class. The training phase can take longer because it usually starts with randomly generated weighted coefficients until they reach a steady state for the second phase.

It is not necessary to use the same activation function in the training phase and the class detection phase because it approaches the steady state very slowly for known images. This paper presents a slope analysis of symmetric saturated activation functions on deep learning for a faster training phase.

An overview of the symbolic analysis of neural networks is presented in [1]. Also, the code can be downloaded from the same site [1]. The same numerical example is used to demonstrate the proof of concept as in [2].

In this paper, we start with an application package [3] in an environment based on the Wolfram language [4]. We initialize the primary palette which loads the built-in drawing knowledge as presented in [3]. We use the palette for non-linear schemes. Element options are changed using the palette extension. The graphical user interface (GUI) enables fine-tuning of the presentation of elements.

The original software may be embedded with additional functions, such as copy-move-paste, left-to-right, or up-down, or rotating elements several times for 90^0. Any element of the schematic description can be easily replaced by another element. The system solution is obtained in the time domain by simply calling the solve button.

Any element from the system specification in the netlist can be replaced by one or more related components as in [5]. Schematic description is adapted to specific analysis [5].

A symbolic analysis of neural networks is also presented in [6]. The advantages of symbolic analysis of neural networks are shown in [7].

Tips and tricks for fixed point implementation are presented in [8] and [9].

The second section presents the properties of activation functions. The third part discusses the symbolic design method. It continues with the main results and achievements of the proposed original method.

2. ACTIVATION FUNCTIONS

There are a number of activation functions, such as the most popular sigmoid, hyperbolic tangent, ReLU and Leaky ReLU. In this paper, we analyze only symmetric saturated activation functions; which are hyperbolic tangents and a modified sigmoid with symmetric properties. ReLU and Leaky ReLU functions are not symmetric. We expect that positive and negative values of the input signal contribute equally to the detected classes. This is the main reason why we do not consider ReLU or classical sigmoid functions.

As explained in [8] and [9], to speed up the computation, we use a small number of binary shifts and adders. To find the best function, we analyze a linear function from some input signal range and with saturation to ensure non-linearity.

We do not consider the training phase, but consider the existing trained network to find what happens to the discovered classes if we change the activation function. Initial training classes consist of 19 type 1 classes, 3 type 2 classes, 18 type 3 classes, and 60 type 4 classes. The main achievement we expect is to find a symmetric activation function with saturation and linear properties for values around 0 of the input signal.

Note that in this paper we use the term linear activation function for a symmetric activation function with linear behavior from -1 values to 1 over 0, and with saturated values of -1 and 1 outside that region.

The first step is to determine the properties of the activation functions.

2.1. Properties

Let us denote the activation function by the symbol *f*. The symmetric activation function satisfies the following conditions:

$$f(-x) = -f(x). \tag{1}$$

The symmetric activation function satisfies the zero condition:

$$f(0) = 0. \tag{2}$$

The saturated activation function is bounded by an upper value of 1:

$$f(x) \leq 1. \tag{3}$$

The first derivative of the activation function is always positive or 0:

$$f'(x) \geq 0. \tag{4}$$

The maximum slope of the activation function is 1, which is equal to the slope of tanh'(0):

$$\max(f'(x)) = 1. \tag{5}$$

The maximum slope is 1, because for an input to the activation function that can be 1, the saturated value must be 1. A large slope is not expected because the saturation will become 1 before the maximum input value of 1.

The minimum slope of the activation function depends on the number of neurons in the layer:

$$\min(f'(x)) = \frac{1}{1+\#\mathrm{Neurons\ In\ Layer}}. \tag{6}$$

For a neural network with 4 neurons per layer, the minimum slope is 1/(4+1)=1/5. The maximum input value of the activation function is 4 for each neuron in the layer multiplied by the maximum weight parameter, which is also 1, plus one for the bias parameter. For a maximum input value to the activation function of 5, the activation function must reach a maximum value of 1. The slope can be lower, but the activation function cannot reach the maximum value of 1.

2.2. Examples

For a neural network with four neurons per layer, we present the possible activation functions from lowest to highest slope. The most popular feature is the tanh shape. A linear activation function that has the same slope for *x*=0 has the largest slope. Of course, the non-linearity is ensured by saturation for input values greater than 1 and less than -1. The main characteristics of the activation function with the highest slope are shown in Table 1.

Table 1. *The function with the highest slope*

Function	$\tanh_q$
f(*x*)	$\begin{cases} f=-1, & x<-1 \\ f=x, & -1\leq x\leq 1 \\ f=1, & 1<x \end{cases}$
f′(*x*)	$\begin{cases} f'=0, & x<-1 \\ f'=1, & -1\leq x\leq 1 \\ f'=0, & 1<x \end{cases}$

The characteristics of the most popular activation function are shown in Table 2. The maximum value is 0.9999 because the input value cannot be greater than 5. Also, the slope of the function is slightly greater than 0 for extreme input values.

Table 2. *The most popular function*

Function	tanh(x)
f(*x*)	$\begin{cases} -1<f<-0.9999, & x<-5 \\ -0.9999<f<0.9999, & -5\leq x\leq 5 \\ 0.9999<f<1, & 5<x \end{cases}$
f′(*x*)	$\begin{cases} 0<f'<0.0002, & x<-5 \\ 0.0002<f'<1, & -5\leq x\leq 5 \\ 0<f'<0.0002, & 5<x \end{cases}$

Table 3 presents the linear activation function for input values between -2 and 2, as well as the slope of the modified logistic sigmoid activation function. Nonlinearity is provided by saturation for input values greater than 2 and less than -2.

Table 3. *A function with a slope of 0.5*

Function	$(2\sigma(x)-1)_q$
f(*x*)	$\begin{cases} f=-1, & x<-2 \\ f=0.5x, & -2\leq x\leq 2 \\ f=1, & 2<x \end{cases}$
f′(*x*)	$\begin{cases} f'=0, & x<-2 \\ f'=0.5, & -2\leq x\leq 2 \\ f'=0, & 2<x \end{cases}$

The main features of the very popular Logistic Sigmoid activation function are presented in Table 4. The maximum value is 0.9866 because the input value cannot be greater than 5; the slope of the function is slightly greater than 0 for extreme input values.

Table 4. *The modified Logistic Sigmoid function*

Function	(2σ(x)-1)
f(*x*)	$\begin{cases} -1 < f < -0.9866, & x < -5 \\ -0.9866 \le f \le 0.9866, & -5 \le x \le 5 \\ 0.9866 < f < 1, & 5 < x \end{cases}$
f'(*x*)	$\begin{cases} 0 < f' < 0.0133, & x < -5 \\ 0.0133 < f' < 0.5, & -5 \le x \le 5 \\ 0 < f' < 0.0133, & 5 < x \end{cases}$

The main characteristics of the linear activation function, which has a smaller slope, are shown in Table 5. Nonlinearity is provided by saturation for input values greater than 5 and less than -5. Saturation will never happen because input values are never greater than 5. So this is actually an activation function with linear behavior for all input values.

This means that the activation function with the smallest slope is determined by the number of neurons plus 1 (for the bias parameter).

Actually, the case with the activation function with the lowest slope is no longer the activation function of the neuron because it never has nonlinear behavior, but this is the limiting case that occurs with the network in the limiting case.

Table 5. *The function with the least slope*

Function	x/5
f(*x*)	$\begin{cases} f = -1, & x < -5 \\ f = x/5, & -5 \le x \le 5 \\ f = 1, & 5 < x \end{cases}$
f'(*x*)	$\begin{cases} f' = 0, & x < -5 \\ f' = 0.2, & -5 \le x \le 5 \\ f' = 0, & 5 < x \end{cases}$

All introduced activation functions are illustrated in Fig. 1.

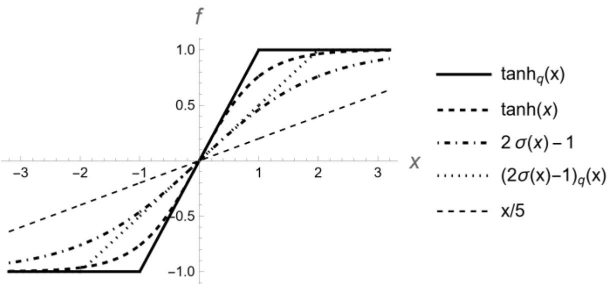

Figure 1. *Activation functions f.*

The slope of all activation functions is shown in Fig. 2. A better overview is for inputs between -3 and 3, because the other values are rare in practical examples.

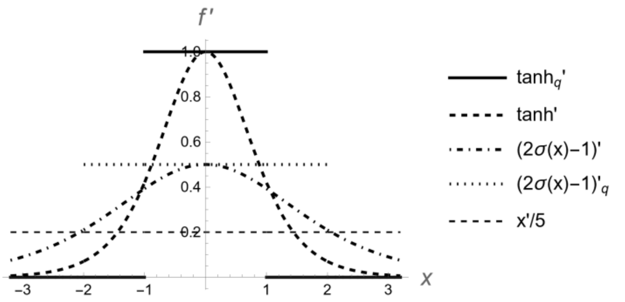

Figure 2. *Slope of activation functions f.*

The slope of the symmetric saturated activation function with linear behavior around 0 is between 1/(1+number of neurons in one layer) and 1. Note that the slope of popular activation functions (tanh and logistic sigmoid) is less than 1/(1+number of neurons in one layer) for input values greater than 1 and less than -1.

3. RESULTS

The training strategy can be based on a random number generator instead of zero initial weights and bias parameters. Assume that these initial parameter solutions correspond to the exact values of the expected classes. Initial training classes according to [2] consist of 19 type 1 classes, 3 type 2 classes, 18 type 3 classes, and 60 type 4 classes. We assume two nonzero input parameters and four the expected classes.

For simplicity, we generate a neural network with 4 inputs, 4 neurons per layer, two hidden layers (for deep learning) and one output layer with four detected classes. For the two unnecessary inputs, we specify zero weight and bias parameters, so that these zero parameters do not change during training. The results of processing with five activation functions are shown in Table 6.

Table 6. *Activation functions, integral of slope, and probability* {p1, p2, p3, **p4**}

Function	$\int_0^1$	$\int_0^{1.5}$	Probability
$\tanh_q$	1.00	1.00	{0.16, 0.02, 0.16, **0.65**}
tanh	0.76	0.91	{0.18, 0.03, 0.18, **0.60**}
$(2\sigma-1)_q$	0.50	0.75	{0.22, 0.05, 0.24, **0.49**}
2σ-1	0.46	0.64	{0.26, 0.06, 0.28, **0.40**}
x/5	0.20	0.30	{0.33, 0.10, 0.34, **0.24**}

The integral of the first derivative is used to illustrate the slope.

It is evident from Table 6 that a higher slope gives a higher probability of the fourth class.

Table 7 gives the expected classes versus the exact known classes during training. We assume that tanh corresponds to the correct detection of all classes as in [2].

Table 7. *Number of discovered classes*

Function	Class 1	Class 2	Class 3	Class 4
Exact	**19**	**3**	**18**	**60**
$\tanh_q$	17(-2)	2(-1)	16(-2)	65(**+5**)
tanh	19(+0)	3(+0)	18(+0)	60(**+0**)
$(2\sigma\text{-}1)_q$	22(+3)	5(+2)	24(+6)	49(**-11**)
2σ-1	26(+7)	6(+3)	28(+10)	40(**-20**)
x/5	32(+13)	10(+7)	34(+16)	24(**-36**)

If we use a large slope of the activation function, the detected most likely class is larger than the exactly known classes. Smaller slopes of the activation functions produce a smaller number of most likely classes. The smallest slope gives half the expected class, while the first and third classes are almost double the known classes.

This is the explanation why the nonlinear activation function is important for neural networks.

4. DISCUSSION

The proposed original method establishes a relation between the most likely detected classes with respect to the slope of activation functions for neural networks that have equally expected positive and negative input values. Another achievement is the determination of the slope of the activation function with saturation for two limiting cases, one for the highest slope and the other for the lowest slope that depends on the number of neurons in the layer.

During the training phase of the neural network, for known classes, the activation function can be chosen to best fit certain classes. If the number of detected classes is less than the number of test cases, the slope of the activation function should be increased. If the number of discovered classes is greater than the number of test cases, the slope of the activation function should be reduced.

During the training phase, we can know the exact number of each possible class. So, after the training phase, we can know the accuracy of the detected classes, and therefore choose the most appropriate activation function.

The main advantage of the proposed approach is faster training and faster detection of unknown classes because the calculation of the activation function consists only in using the input value for slope 1, i.e. the binary shift (multiplying by 1/2) for the lowest slope of the symmetric saturated activation function with linear behavior around 0. The class detection accuracy is very similar to the corresponding hyperbolic tangent or modified logistic sigmoid function with the same slope at 0.

5. CONCLUSION

The paper shows the influence of the slope of the symmetric activation function with saturation for more precise detection of the tested known classes. Future work will be to find the impact of asymmetric activation functions for asymmetric inputs, such as inputs that are all positive. Appropriate choice of symmetric saturated activation function with linear behavior around 0 ensures faster computation and consequent power reduction in hardware implementations.

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Application of the YOLO algorithm for Medical Purposes in the Detection of Skin Cancer

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Abstract: *Skin cancer is one of the most common forms of cancer worldwide. Exposure to ultraviolet (UV) radiation increases the risk of its development. Early preventive examinations and early detection of suspicious skin changes are key factors for successful treatment. Due to the rapid development of AI technologies, neural networks have found application in various fields, including medicine. Neural networks can be used to create various applications, which would facilitate self-examination for patients and alert them to potential problems. This method would further save time and reduce healthcare costs. The paper presents the application of a neural network using the YOLO (You Only Look Once) algorithm on a dataset of mole images with the aim of identifying and classifying moles, which facilitates early intervention and improves treatment outcomes.*

Keywords: *skin cancer; yolo; neural network*

1. INTRODUCTION

Skin cancer has emerged as a significant health issue in modern society, particularly among young people. The rise in the incidence of this disease in recent decades can be attributed to various factors, including increased exposure to UV radiation due to frequent sun exposure and the use of tanning beds. Although skin cancer is the most common form of cancer, it is often preventable and treatable if detected early.

Young people are especially vulnerable due to the growing trend of spending time outdoors without adequate sun protection. Many are unaware of the risks associated with excessive UV exposure, which can lead to serious skin damage and an increased risk of developing malignant conditions. Education and prevention are crucial components in the fight against skin cancer, as raising awareness about the importance of skin protection can significantly reduce the number of affected individuals.

In 2020, there were an estimated 325,000 new cases of melanoma diagnosed globally, resulting in 57,000 deaths. Incidence rates vary significantly by region. Melanoma is generally more common in men than women in most regions. The highest incidence rates per 100,000 people were recorded in Australia and New Zealand (42 in men and 31 in women), followed by Western Europe (19 in both men and women), Northern America (18 in men and 14 in women), and Northern Europe (17 in men and 18 in women). In contrast, melanoma remains rare in most African and Asian countries, with incidence rates typically below 1 per 100,000. Based on global population trends, scientists predict that by 2040, there could be over 500,000 new melanoma cases and nearly 100,000 deaths annually [1].

Determining whether a mole is dangerous can be challenging, especially for someone without medical training. However, there are certain criteria and characteristics that can help assess the risk. The most commonly used method is the ABCDE rule:

- A (Asymmetry): Asymmetrical moles, where one half doesn't look like the other, can be a warning sign.
- B (Border): Irregular, jagged, or unclear borders of the mole can indicate malignancy.
- C (Color): Different colors or shades within the same mole (brown, black, red, white, blue) can be suspicious.
- D (Diameter): Moles larger than 6 mm (approximately the size of a pencil eraser) often warrant attention.
- E (Evolving): Changes in size, shape, color, or symptoms (such as itching or bleeding) of the mole are important to monitor.

For a definitive diagnosis and assessment, it is necessary to consult a dermatologist. Dermatologists use dermoscopy, a technique that allows for a detailed examination of the skin, to better evaluate moles. A dermatological examination cannot definitively determine if a mole is dangerous with complete certainty. Due to busy lifestyles, many people rarely find the time to visit a dermatologist. Additionally, these examinations can be costly and need to be conducted multiple times if changes in the mole are observed. Regular monitoring and follow-up appointments are often necessary to keep track of any developments, making it challenging for individuals to maintain consistent check-ups. As a result, early detection and treatment of potentially malignant moles can be delayed, underscoring the need for accessible and affordable dermatological care. In most cases, a biopsy may be needed to definitively determine whether a mole is benign or malignant.

With the accelerated advancement of technology, people now have the opportunity to monitor their health using various applications, which can be useful for initial self-monitoring. These apps can serve as a starting point for later consultations with a doctor. It is important to note that for accurate diagnosis, seeking the opinion of a specialist such as a dermatologist is always necessary. This innovative approach to healthcare not only increases the accessibility of medical services but also empowers individuals to take proactive steps in monitoring their health. By using these applications, individuals can potentially identify concerning symptoms or changes in moles at an early stage, facilitating timely intervention and medical attention when needed.

One example of this is the use of the YOLO algorithm in dermatology for the early detection of skin cancer. The YOLO algorithm in medicine is utilized for the detection and classification of medical objects in images or video recordings. This technology enables rapid and precise identification of pathological changes, such as tumors on X-ray images, anomalies on MRI scans, or skin alterations that may indicate diseases like skin cancer. The application of the YOLO algorithm in medicine promises more efficient diagnostics and early disease detection, potentially enhancing healthcare and reducing the number of missed cases.

The aim of this scientific study is to train a model using the YOLO v8 algorithm, which could accurately assess whether a mole belongs to one of two categories with as high precision as possible.

2. LITERATURE REVIEW

Various studies have been conducted on the topic of skin cancer, employing older versions of the YOLO algorithm or alternative combinations of neural networks. These are showcased below.

Ünver et al. (2019) introduced a robust methodology for segmenting skin lesions in dermoscopic images, which merges the GrabCut algorithm with the YOLO deep convolutional neural network. Their approach underwent testing on the PH2 and ISBI 2017 datasets, both widely utilized public datasets within the domain of Skin Lesion Analysis Towards Melanoma Detection Challenge Dataset. The proposed method achieved an impressive accuracy rate of 93.39% [2].

In a study [3], a YOLO-based deep neural network was proposed for classifying nine types of skin cancer. Both YOLOv3 and YOLOv4 versions were analyzed and compared objectively for improved skin cancer diagnosis. The proposed neural network achieved a mean average precision score of 88.03% for YOLOv3 and 86.52% for YOLOv4. Experimental analysis indicated that both YOLOv3 and YOLOv4 are well-suited for classifying various skin diseases, with YOLOv4 generally outperforming YOLOv3 in most cases. YOLOv4 demonstrated its superiority by achieving the highest scores across all evaluation metrics when compared to conventional methods.

In a study [4], the authors proposed a deep learning CNN model utilizing AlexNet as a pre-trained model. This transfer learning approach was chosen because AlexNet has been extensively trained for object recognition, which is closely related to skin lesion classification. The last three layers of AlexNet—the final fully connected layer, softmax layer, and classification layer—were replaced with layers suitable for binary classification. All images were resized to 227×227 to match the input size of AlexNet. The model was trained using the training set with the SGDM algorithm, an initial learning rate of 0.0001, a mini-batch size of 30, and 40 epochs. The proposed model achieved an area under the receiver operating characteristic (ROC) curve of 0.91. With a confidence score threshold of 0.5, the model obtained a classification accuracy of 84%, sensitivity of 81%, and specificity of 88%. The authors suggested that the proposed approach could be deployed to assist dermatologists in skin cancer detection and could also be integrated into smartphones for the self-diagnosis of malignant skin lesions. They concluded that this could expedite cancer detection, which is critical for effective treatment.

In a study [5], the authors introduced a novel approach integrating YOLO v3 with a deep convolutional neural network (DCNN) for the purpose of skin lesion detection and classification... The authors reported that their YOLO v3-DCNN technique achieved a remarkable accuracy rate of 95% when evaluated on the HAM10000 dataset, demonstrating superior performance compared to earlier methodologies.

3. YOLO (You Only Look Once)

YOLO is an object detection algorithm introduced in 2015 by Joseph Redmon, Santosh Divvala, Ross Girshick, and Ali Farhadi. YOLO's architecture brought a significant revolution in real-time object detection, surpassing its predecessor – the Region-based Convolutional Neural Network (R-CNN). YOLO is a single-pass algorithm, where one neural network predicts bounding boxes and class probabilities using a full image as input [6].

3.1. Architecture of YOLO v8

Figure 1 depicts the architecture of YOLOv8, which encompasses three key components: backbone, neck, and head. The configuration of these components may vary across different versions of YOLO, and improvements in each of them have led to significant enhancements in accuracy and prediction speed. The latest versions of YOLOv8 introduce enhancements in all three components to achieve better performance [7].

- **Backbone**: It plays a crucial role in extracting significant features from the input image. Typically, a convolutional neural network trained on large datasets such as ImageNet is used. The backbone is responsible for feature extraction and generating feature maps from input images. Within YOLO, some commonly used backbone networks include VGG16, ResNet50, CSPDarknet53, and EfficientNet [7].
- **Neck** It represents the connection between the backbone and head in the YOLO architecture. It utilizes advanced techniques of feature pyramid aggregation, such as PANet, to combine features from different layers. The role of the neck is to fuse feature maps from various layers of the backbone network and pass them to the head. Popular options for the neck in YOLO include Spatial Pyramid Pooling (SPP), Feature Pyramid Network (FPN), NAS-FPN, and Rep-PAN [7].
- **Head** It's a part of the architecture consisting of predictive layers that generate final classifications. Each level (P2 to P5) is connected to specific detection blocks that predict bounding boxes and object classes [7].

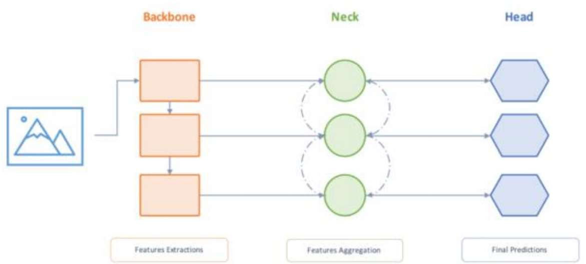

Figure 1. *The architecture of YOLO consists of a backbone, neck, and head [7]*

3.2. Comparison of YOLO Versions

The YOLO algorithm has gone through several versions, with each bringing significant improvements in object detection accuracy and speed. YOLOv2 introduced techniques such as batch normalization and anchor boxes, enhancing precision and processing speed. YOLOv3 added feature extraction at multiple scales and a new backbone network, allowing for a better balance between speed and accuracy. Versions YOLOv4 and YOLOv5 improved backbone networks, data augmentation, and training strategies, increasing accuracy without significant loss in real-time performance. PP-YOLO, developed by Alibaba Group, introduced a new backbone network and spatial attention module, making it faster and more accurate than YOLOv5. YOLOv6 implemented the EfficientNet architecture, resulting in even faster and more precise results. YOLOv7 reduced parameters and computational costs while maintaining high speed and accuracy. YOLOv8 improved feature aggregation and introduced a model without anchor boxes, directly predicting object centers [7].

3. METHODOLOGY

During the training of the model, a private dataset consisting of two classes (benign and malignant) was used, with each class containing 1500 images. The dataset was carefully collected and annotated in accordance with ethical standards. Figure 2 shows the appearance of the dataset.

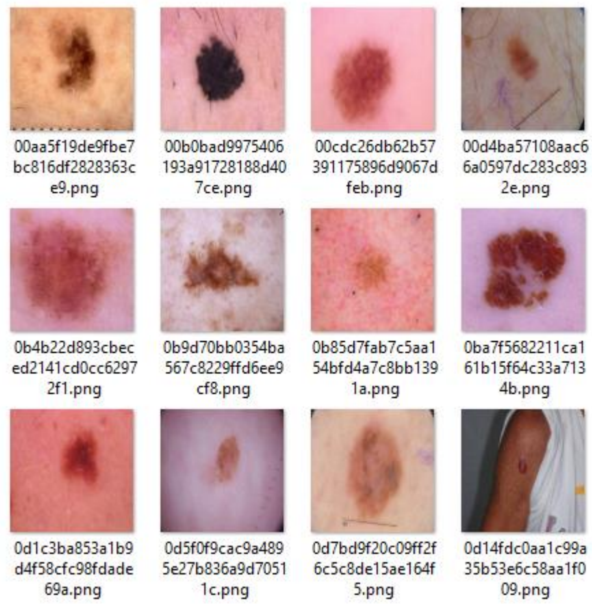

Figure 2. *Dataset*

The images were pre-processed to ensure size and quality. This step involved resizing the images to 224x224 pixels. To enable the application of the YOLO algorithm for classification, it was necessary to annotate the images. Each image was individually labeled using the Labelme tool, which is available as a Python package. After annotation, each image has a corresponding JSON file that matches its name. The JSON file consists of coordinate points that indicate the relevant parts of the image. Figure 3 shows the annotation of an image in the Labelme tool.

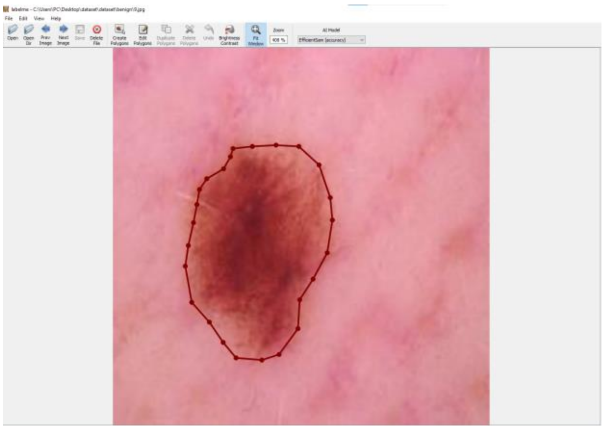

Figure 3. *Annotated image in the Labelme tool*

Images that were not suitable for annotation were excluded from the dataset. Since YOLO does not use JSON files for training, but rather TXT files, the annotations were converted from JSON to TXT format using the labelme2yolo tool. The dataset was then divided into three parts: training, testing, and validation in a ratio of 80:10:10.

After preparing the dataset, the YOLO algorithm was trained using this data.

Model was trained using NVIDIA GeForce 1080. During training, the following parameters were used: 100 epochs and a batch size of 16. The total training duration was 4 hours and 10 minutes.

4. RESULT AND INTERPRETATION

In this chapter, the results and their interpretations obtained after training the YOLO model are presented. Based on the confusion matrix shown in Figure 4 and Table 1, performance metrics were analyzed. The matrix illustrates how the model classifies images into three categories: benign, malignant, and background. Background represents parts of the image that were not annotated. Each cell of the matrix displays the number of instances correctly or incorrectly classified by the model.

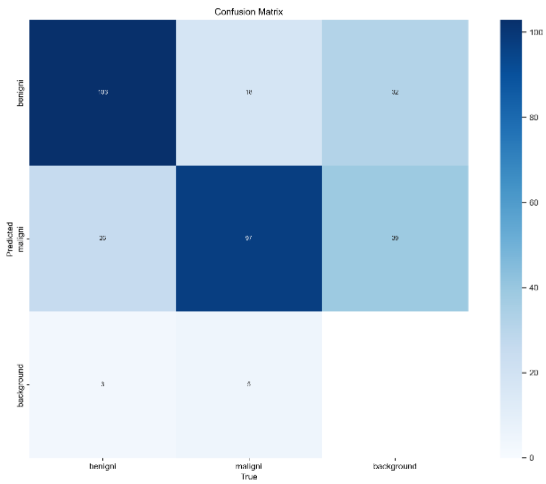

Figure 4*. Confusion Matrix*

In this example, the model correctly classified 103 instances as benign, but made an error by classifying 26 malignant instances as benign and 3 background instances as benign. As for malignant instances, the model correctly identified 97, but misclassified 18 benign and 5 background instances as malignant. The model did not identify any background instances, which is acceptable. Based on the obtained confusion matrix, it can be concluded that the model provides good and acceptable results for preliminary screening, where positive findings will be further reviewed by dermatologists.

Table 1. *Confusion Matrix*

	Benigni (True)	Malignant (True)	Background (True)
Benigni (Pred.)	103	18	32
Malignant (Pred.)	26	97	39
Background (Pred.)	3	5	0

Figure 5 displays a chart for all classes, precision reached a value of 1.00 when the confidence threshold was 0.848. This means that all predicted positive instances were correctly classified when the model had a precision of 84.8%. Precision is defined as the ratio of true positive predictions to the total positive predictions. It is particularly useful in scenarios where the false positive rate is high.

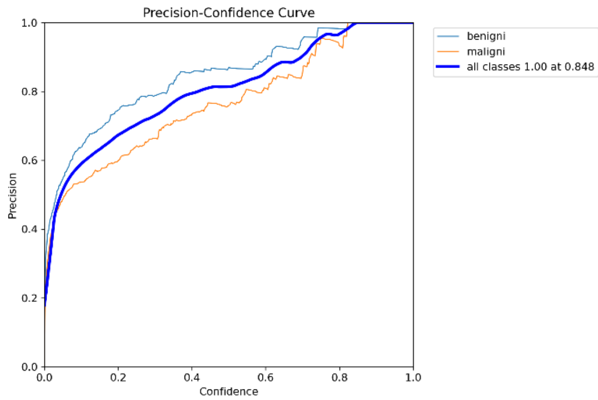

Figure 5*. Precision Confidence Curve*

This metric is expressed by formula (1):

$$Precision = \frac{TP}{TP+FP} \quad (1)$$

where:

- TP (True Positive) is the number of correctly identified positive predictions by the model.
- FP (False Positive) is the number of predictions that are incorrectly classified as positive by the model.

At this confidence threshold, the model achieved 100% precision, meaning there were no false positive predictions. This result demonstrates that the model exhibits a high level of reliability and accuracy at high confidence thresholds, which is crucial for applications where false positive results are unacceptable.

Figure 6 displays the recall, which measures the model's ability to identify all positive instances. This metric becomes particularly significant when the false negative rate is high. In the example, the model achieves a recall of 0.99 (99%) when the confidence threshold is 0.000. This means that the model successfully identifies 99% of true positive instances, practically missing almost none of the actual positive instances.

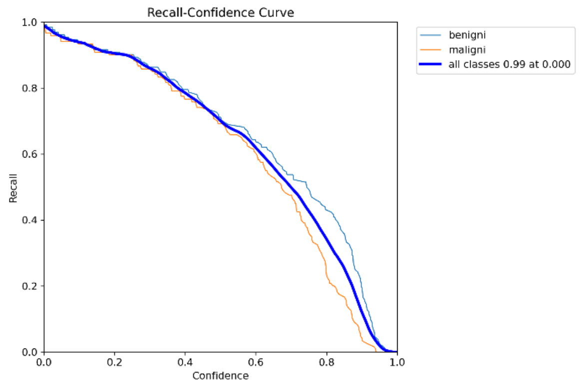

Figure 6. *Recall-Confidence Curve*

It is calculated by the following formula (2):

$$Recall = \frac{TP}{TP + FN} \tag{2}$$

where:

- TP (True Positive) is the number of correctly identified positive instances by the model.
- FN (False Negative) is the number of instances that are actually positive but incorrectly classified as negative by the model.

On Figure 7, a graph is shown indicating that the F1-score for all classes reached a value of 0.80 when the confidence threshold was 0.357.

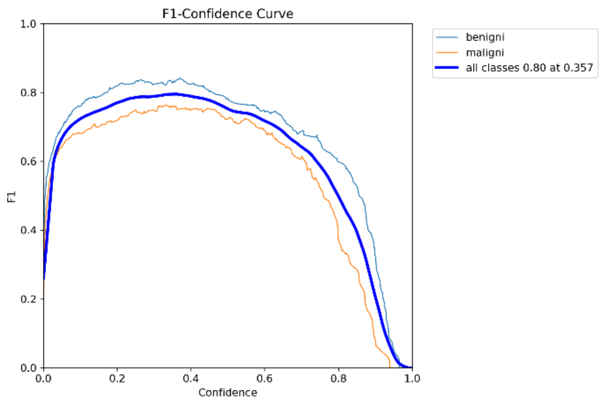

Figure 7. F1 Confidence curve

The F1-score is the harmonic mean between precision and recall and is used as a measure of overall model performance, especially when there is class imbalance. It is calculated by the following formula (3).

$$F1 - score = 2\,x\left(\frac{Precision\ x\ Recall}{Precision + Recall}\right) \tag{3}$$

The F1-score value indicates that the model has good overall performance in classifying instances when the confidence threshold is relatively low. This result is useful for evaluating the model in situations where both precision and recall are important.

Validation was performed on the validation dataset consisting of 248 images, as shown in Table 2, achieving an overall precision of 78.2%. This result is considered acceptable for preliminary screening, as dermatologists will further examine positive findings.

Table 2. *Results at the validation set*

Class	Instances	Precision	Recall
All	252	0.782	0.816
Benign	132	0.845	0.826
Malignant	120	0.718	0.807

In the following figure, Figure 8, lesion detection during the validation process is depicted.

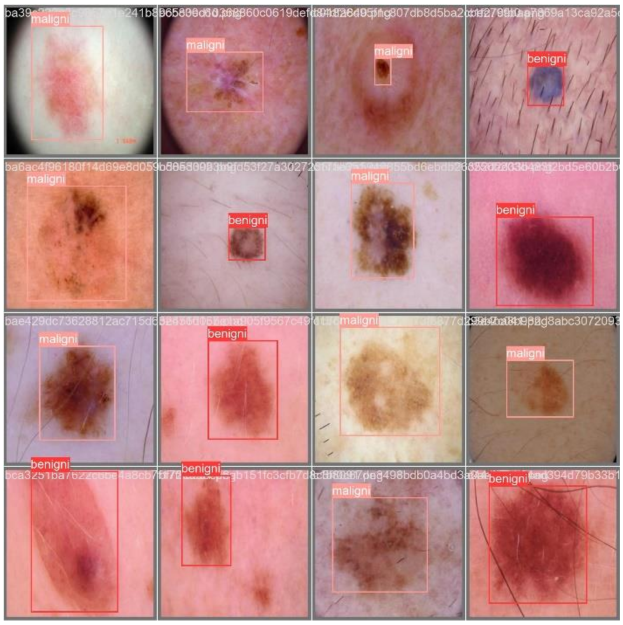

Figure 8. *Lesion Detection during Validation*

5. CONCLUSION

One of the purposes of this study is to raise awareness about the importance of regular mole checks and to find a solution that allows for simpler monitoring accessible to all classes of the population. In this study, the Yolo v8 algorithm was applied for the first time to detect two types of moles (benign and malignant). The theoretical foundation of the YOLO algorithm was comprehensively presented, along with an analysis of its architecture and the evolution of previous versions, emphasizing the advantages of the new versions. The methodology described the dataset and its preparation for the application of the YOLO algorithm. In the results section, the results with metrics Precision, Recall, and F1 score were presented. The achieved precision on the validation set for predicting benign lesions is 84.5%, for malignant lesions 71.8%, while the overall precision is 78.2%. Although the results are not impressive in terms of precision, we emphasize that the goal of the application is preliminary screening, where dermatologists will further review the findings. This algorithm cannot be entirely relied upon without the supervision of dermatologists and medical assessment, as even the examination by dermatologists alone is not always precise without additional analysis.

Further improvements include tracking new versions of the YOLO algorithm, as well as considering other datasets to achieve higher precision, and the obtained model should be used to create some type of application.

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Privacy-Preserving in Machine Learning: Differential Privacy Case Study

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Abstract: *The burgeoning field of Machine Learning (ML) has revolutionized various aspects of our lives. However, the reliance on vast amounts of data, often containing personal information, raises concerns about individual privacy. Striking a balance between effective ML model training and protecting sensitive data is crucial for responsible development and ethical implementation. This paper explores the challenges and potential solutions for preserving privacy in ML training, focusing on differential privacy (DP). The advantages of implementing DP in ML training include robust protection of individual data, enabling meaningful insights from large datasets while maintaining privacy. This is essential for ethical and responsible data usage in machine learning applications. However, DP in ML training presents challenges including scalability issues and trade-offs between utility and privacy. The paper also covers the mathematical mechanisms of Laplace and Gaussian* and their *noise addition, followed by a comparative analysis of their efficiency within the dataset.*

Keywords: *ML;* Differential privacy*; Gaussian Mechanism; Laplace Mechanism; data privacy*

1. INTRODUCTION

Machine learning (ML) models, powered by intricate algorithms, require copious amounts of data for training and optimization. While this data fuels innovation, it often necessitates the use of personal information, encompassing details like demographics, health records, or financial transactions. This raises significant concerns about individual privacy, as breaches or misuse of such data can lead to discrimination, profiling, and even identity theft [1].

DP is an advanced technique designed to safeguard individual data while still allowing meaningful insights to be gleaned from large datasets. By introducing precisely controlled noise into the data, DP ensures that the presence or absence of any single individual's data has a minimal impact on the overall analysis results. This method provides a strong privacy guarantee, enabling organizations to analyze and disseminate data without violating individual privacy. In our current era, where data-driven decision-making is paramount, the application of DP is increasingly important. It is especially significant across sectors such as healthcare and finance, where protecting sensitive information while extracting value from data is crucial [2].

It should also be noted that the General Data Protection Regulation (GDPR) has been defined in 2016, which can be found at the following link: https://gdpr-info.eu/. Here are defined main requirements in data privacy laws across Europe.

1.1 Dangers of exposing private data

The consequences of exposing private data in ML training extend far beyond simple inconvenience. Here's a breakdown of some key dangers [3]:

- **Identity Theft:** Exposed data like names, Social Security numbers, or addresses can be weaponized by criminals for impersonation. This can lead to financial losses through fraudulent credit card use, opening new accounts in the victim's name, or even tax return theft.
- **Financial Fraud:** Personal financial information like bank account details or investment holdings, if compromised, can be used for unauthorized transactions, draining savings or incurring significant debt.
- **Discrimination and Social Stigma:** ML models trained on biased or incomplete data can perpetuate discrimination in areas like loan approvals, job hiring, or insurance eligibility. Exposed health records might lead to social stigma or hinder access to insurance.
- **Reputational Damage:** Private information leaks, especially sensitive details, can damage an individual's reputation and cause emotional distress. Public embarrassment or loss of trust could arise from the misuse of personal data.

- **Security Risks:** Data breaches can expose individuals to targeted phishing attacks or malware scams. Criminals might use leaked information to gain the victim's trust and launch further cyber attacks.
- **Reduction of Physical Safety:** Exposing private data like home location, travel and work schedule can lead to theft or vandalism of property. This also can lead to physical assaults on individuals.
- **Diminishment of Freedom of Speech:** Leaks of sensitive information like political or religious beliefs can be used against individuals by revealing unpopular opinions resulting in their hesitation to engage in expressive activities or discouragement in having personal opinion.

Employing security measures is crucial for mitigating the exposure of private data. These measures play a vital role in ensuring a certain level of confidentiality, as safeguarding credentials and controlling access to data are fundamental components of a robust security infrastructure.

2. TECHNIQUES FOR PRIVACY-PRESERVING ML TRAINING

Several techniques offer promising solutions for mitigating privacy risks in ML training [4-6]. In the following sections we provide brief preview of such techniques.

2.1 Anonymization

This technique involves removing or obfuscating personally identifiable information (PII) from the data before training. Common anonymization methods include:

- **Suppression:** Removing sensitive attributes entirely from the data.
- **Generalization:** Replacing specific values with broader categories (e.g., replacing zip code with city).
- **Perturbation:** Adding controlled noise to the data to obscure individual values while preserving statistical properties.
- **Pseudonymization:** Replacing PII with fictitious but unique identifiers, allowing for some re-identification risk.

While anonymization offers a straightforward approach, it comes with limitations:

- **Information Loss:** Removing or modifying data can lead to information loss, potentially impacting the accuracy or generalizability of the trained model.
- **Re-identification Risks:** Depending on the anonymization method and the dataset characteristics, there might still be a possibility of re-identifying individuals, especially when combining anonymized data with other sources.
- **Limited Applicability:** Anonymization may not be suitable for all data types or scenarios. For instance, anonymizing medical records while preserving their utility for analysis can be challenging.

2.2 Differential Privacy

This approach adds controlled noise to the data in a way that guarantees a mathematical bound on the privacy leakage, even if an adversary observes the training data and the trained model. This ensures that learning from the data does not reveal any more information about specific individuals than what can be learned from statistical summaries of the data. DP offers strong privacy guarantees but might lead to a slight reduction in model accuracy, as the added noise can obscure some of the signal in the data.

2.3 Federated Learning

This technique distributes the training process across multiple devices or servers, keeping the raw data decentralized. Only the model updates, not the individual data points, are shared among participants. This significantly reduces the privacy risks associated with sharing sensitive data, as the central server never directly observes the raw data. However, federated learning poses challenges in terms of communication overhead and coordination across distributed devices, and can also be susceptible to privacy attacks if not implemented carefully.

2.4 Homomorphic Encryption

Fully enabling computation on encrypted data, permits basic operations like addition and multiplication, serving as the foundation for more complex functions. However, the expense of frequently bootstrapping the cipher text (refreshing it due to accumulated noise) has led to the predominant use of additive homomorphic encryption schemes in privacy-preserving ML approaches. These schemes support addition operations on encrypted data and multiplication by plaintext.

2.5 Garbled Circuits

This cryptographic technique employed in scenarios involving multiple parties seeking to compute a function on their private inputs. In this process, the function is transformed into a garbled circuit, which is then transmitted along with the corresponding garbled inputs. The key feature is that the party providing the circuit remains unaware of the specifics of the other parties' inputs, achieved through techniques like oblivious transfer. The recipient, upon receiving their garbled input, can employ it with the garbled circuit to calculate the desired function's outcome.

This approach is often integrated with additive homomorphic encryption in privacy-preserving ML methodologies, ensuring secure computation and model creation.

2.6 Secure Processors

This technique is based on processors that are initially designed to safeguard sensitive code from unauthorized access by rogue software at elevated privilege levels like Intel SGX processors which are now being harnessed for privacy-preserving computation. The fundamental concept revolves around collaborative efforts among multiple data owners to execute various ML tasks, with the computation party leveraging an SGX-enabled data center. In such scenarios, even if adversaries gain control over all hardware and software within the data center, they remain unable to compromise the SGX processors utilized for computation.

2.7 Secure multi-party computation (SMPC)

This technique facilitates secure collaboration without the need to trust a third party, as computations are performed on encrypted data without revealing any information about the data or the computed results. SMPC allows organizations like hospitals, research centers, and universities to jointly analyze data for various purposes, such as ML model training or statistical analyses for anti-money laundering efforts. By keeping the data encrypted during transfer, SMPC preserves data usability while providing robust privacy protection, making it a valuable tool for secure and privacy-preserving data analysis across institutions.

2.8 Model Distillation

Introduced as a method for compressing large models into smaller ones while preserving their accuracy, knowledge/model distillation facilitates knowledge transfer between models. This process involves training the smaller model on data labeled with probability vectors generated by the initial model, encapsulating the knowledge derived from training data. This decentralized approach minimizes the risk of data breaches and unauthorized access while still allowing for effective model training and inference.

2.9 Privacy-preserving Generative Adversarial Networks

This technique preserves privacy by incorporating the principle of DP into the training process of Generative Adversarial Networks (GANs). During training, PPGAN adds carefully designed noise to gradients, ensuring that sensitive information in the training data remains obscured. This noise prevents the model from memorizing specific details of the training data, thus safeguarding individuals' privacy. Additionally, by controlling the amount of noise added, PPGAN allows for a balance between privacy protection and the utility of the generated data. Through these mechanisms, PPGAN enables the creation of high-quality synthetic data while minimizing the risk of privacy breaches.

3. ETHICAL CONSIDERATIONS IN ML

Balancing progress with protection in the development and deployment of ML systems requires careful consideration. It involves weighing the potential impact of algorithms on individuals, communities, and society at large. Addressing concerns surrounding privacy, transparency, accountability, and the broader ethical implications of ML technologies is essential to ensure responsible innovation [7].

Alongside potential benefits, there's growing recognition that the utilization of ML carries risks and may result in harm, prompting various ethical inquiries. This segment offers a concise outline of notable concerns during the development of ML models.

3.1 Algorithmic Bias

Data used for training can introduce biases, mirroring societal prejudices and reinforcing existing inequalities. For instance, a hiring algorithm trained on biased historical data may perpetuate discriminatory practices. Identifying and addressing these biases is crucial for achieving fair and equitable outcomes. Identifying and addressing these biases is crucial for achieving fair and equitable outcomes.

3.2 Transparency and Explainability

ML algorithms frequently function as opaque systems, making decisions without offering transparent explanations for their rationale. This opacity can present difficulties in comprehending decision-making processes and undermine confidence in the technology. Guaranteeing transparency and explainability in ML systems is paramount for accountability and mitigating potential harm.

3.3 Privacy

Privacy concerns emerge when sensitive data is gathered, stored, and handled without appropriate consent or security protocols. Given that algorithms handle vast amounts of personal data, there's a looming threat of privacy breaches and unauthorized utilization of sensitive information. Protecting individual privacy rights while leveraging the capabilities of ML necessitates robust data security practices and meticulous adherence to legal and ethical standards.

3.4 Accountability

Achieving a balance between progress and protection in deploying ML systems is paramount, particularly in critical sectors like healthcare and criminal justice. As these systems become more autonomous, ensuring clear accountability for harmful or biased decisions is essential, with stakeholders such as developers and regulatory bodies playing crucial roles. Robust risk assessment processes and adherence to ethical frameworks are vital for maintaining accountability and safeguarding individuals' rights in the face of evolving technology.

4. FUNDAMENTALS OF DP

DP offers a promising method for safeguarding data privacy [8]. Its primary goal is to shield an individual's sensitive data from inference attacks that target the statistics or aggregated data related to that individual. It is widely recognized that simply releasing aggregated data or statistics from a dataset often does not guarantee privacy protection.

DP introduces the concept that statistical outputs or aggregated data (including ML models) should not disclose whether any specific individual is part of the original dataset. DP ensures that the probability of generating certain statistics or aggregate values remains almost unchanged whether the dataset includes an individual's information or not.

In practical terms, DP involves a trusted data curator collecting data from various sources and performing computations on this data, such as calculating mean values or identifying the maximum and minimum values. To prevent anyone from deducing individual data points from the results, the curator adds random noise to the outcomes. This noise ensures that the released data remains stable even if any single sample in the dataset is altered. Since no individual sample can significantly impact the overall distribution, it becomes challenging for adversaries to determine any specific individual's information. Therefore, a mechanism is considered differentially private if the results of computations on the data remain consistent despite changes to any individual sample.

DP has garnered significant attention within the privacy research field over the past few decades. It evaluates the risk of revealing individual data points when computations are performed on a dataset. Refer to Fig. 1. for illustration in a typical DP framework, a trusted data curator collects data from various data owners to create a dataset. The aim is to conduct computations or analyses on the compiled dataset, such as calculating the mean value (e.g., the average salary), ensuring that data users can obtain this information without compromising the privacy of the data owners.

To guarantee that no one can accurately deduce a person's details from the computation outcome, the curator introduces random noise (i.e., DP sanitizer) to the result. This modification ensures that the published result remains unchanged even if a person's information in the underlying data is altered. Because the data of a single person does not substantially impact the distribution, adversaries are unable to confidently deduce information about any specific individual.

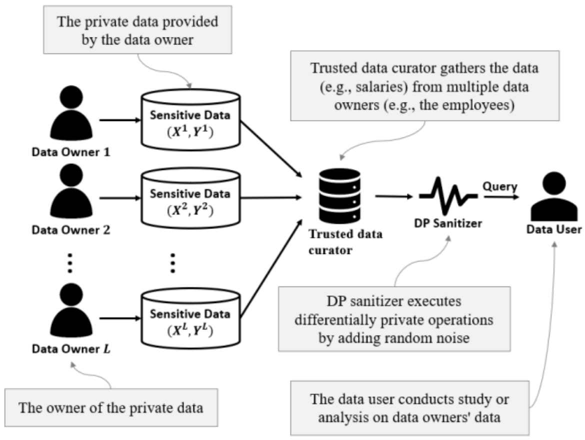

Figure 1. *Differential Privacy framework [1]*

5. MECHANISMS FOR DP

This part covers two widely-used mechanisms in DP, which serves as the foundation for numerous differentially private ML algorithms Laplace and Gaussian mechanism [9].

5.1 Laplace Mechanism

Laplace mechanism achieves DP by adding random noise from a Laplace distribution to the target queries or functions. In the previous section, we introduced the Laplace mechanism through the scenario described in Fig. 1. This section will provide a more systematic explanation of the Laplace mechanism and present additional examples that utilize it.

Based on the Laplace mechanism's design, given a query function f(x) that returns a numerical value, the following perturbed function [10]:

$$\mathrm{M_L}(\mathrm{x}, \mathrm{f}(\cdot), \epsilon). \tag{1}$$

meets ϵ-DP requirements:

$$\mathrm{M_L}(\mathrm{x}, \mathrm{f}(\cdot), \epsilon) = \mathrm{f}(\mathrm{x}) + \mathrm{Lap}(\triangle \mathrm{f}/\epsilon) \tag{2}$$

where $\triangle f$ is the sensitivity of query function $f(x)$, and $Lap(\triangle f/\epsilon)$ denotes the random noise drawn from the Laplace distribution with center 0 and scale $\triangle f/\epsilon$.

A histogram query can be viewed as a distinct type of counting query, in which the entirety of the data is segregated into separate sections, and the inquiry is regarding the quantity of database entries within each section.

In the example presented in Fig. 2, it can be seen a histogram with ranges for the number of employees in organizations based on specified boundaries and intervals with the number of organizations in each range without using DP.

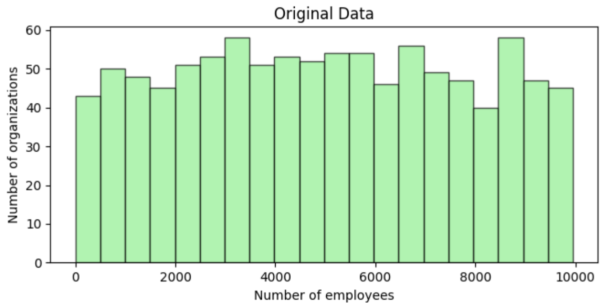

Figure 2. *Histogram of organizations by number of employees without using DP*

In order to implement DP on such a histogram query, it becomes necessary to compute the sensitivity initially. In case where the sensitivity equals 1, incorporating perturbation from $Lap(1/\epsilon)$ into each of the histogram sections before disclosure is imperative, with ϵ representing the privacy allocation stipulated by the data proprietors.

In example presented on Fig. 3, a histogram illustrates the incorporation of DP by showcasing data with added noise. The epsilon value used in this instance is 0.5.

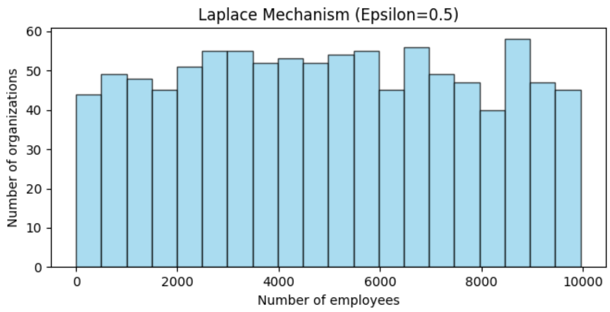

Figure 3. *Histogram of organizations by number of employees with using DP Laplace mechanism*

5.2 Gaussian mechanism

The Gaussian mechanism presents an alternative to the Laplace mechanism. Instead of introducing Laplace noise, it introduces Gaussian noise, offering a somewhat eased privacy assurance.

Given a numerical query function f:

$$\mathbb{N}^{|x|} \rightarrow \mathbb{R}^k \tag{3}$$

for all pairs of databases, $x \in \mathbb{N}^{|x|}$, and the privacy budget ϵ and δ, the Gaussian mechanism is defined as:

$$M_{GM}(x, f(\cdot), \epsilon, \delta) = f(x) + (Y_1, Y_{2,}, \dots, Y_k) \tag{4}$$

In this scenario, Y_i represents a set of random variables that are independent and identically distributed, originating from a Gaussian distribution:

$$N(0, \tau^2), \tau = \Delta f \sqrt{2 \ln(1.25/\delta)} / \epsilon \tag{5}$$

and Δf is the sensitivity of query function f.

In comparison to alternative arbitrary sounds, incorporating Gaussian disturbance offers two benefits:

- Gaussian interference aligns with numerous other noise origins (for instance, the white noise present in communication channels)
- The aggregate of Gaussian stochastic variables yields a fresh Gaussian stochastic variable. These benefits facilitate the examination and rectification of privacy-preserving ML methodologies employing the Gaussian mechanism.

In the following instance, the Gaussian mechanism is evidently observable, showcasing its inherent effectiveness in preserving privacy while maintaining data utility.

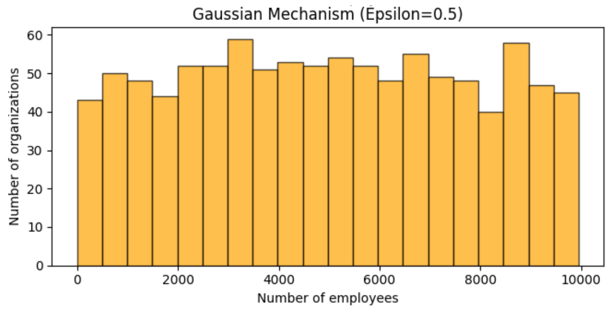

Figure 4. *Histogram of organizations by number of employees with using DP Gaussian mechanism*

5.3 Comparison

From examples above, it's apparent that both the Gaussian and Laplace mechanisms play crucial roles in privacy-preserving data analysis. While the Gaussian mechanism operates based on a normal distribution, the Laplace mechanism relies on a Laplace distribution. Despite these foundational differences, the ultimate results achieved in the given example remain notably similar, highlighting the versatility of both methods in ensuring privacy without compromising analytical outcomes.

Using MSE (Mean Squared Error) as a measure, different epsilon values are applied to the privatized data obtained from the original dataset. For each epsilon value, a data sample is generated from the original dataset, followed by applying the Laplace and Gaussian mechanisms to the sample. Then, MSE values for privatized data are calculated for both mechanisms. Finally, the results are displayed in the console, allowing for comparison of privacy mechanisms' performance across different epsilon values. This process helps understand how DP parameters affect the quality of privatized data and provides insights into the effectiveness of various privacy protection mechanisms.

In the analysis of DP mechanisms, the MSE of the Laplace and Gaussian mechanisms was conducted using different epsilon values. The results, as presented in the Table 1 for Laplace mechanism and in Table 2 for Gaussian mechanism, offer a detailed view of the MSE for each mechanism across various epsilon values. Below is a summary of the MSE for epsilon values from 0.1 to 1 with increment of 0.05.

The data illustrates a distinct difference between the Laplace and Gaussian mechanisms for different epsilon values (Fig. 5) measured by MSE.

Based on the results from the previous illustration detailing the MSE values for the Laplace mechanism demonstrate a notable fluctuation as epsilon increases. Specifically, at epsilon values of 0.1 and 0.25, relatively low MSE values. However, a significant escalation in MSE occurs at epsilon values of 0.2, 0.45, and 0.7, where the MSE peaks. Notably, at epsilon 0.8 and 0.95, the MSE diminishes to 0.0. This erratic pattern suggests that the Laplace mechanism's performance is particularly sensitive to changes in epsilon, with certain values leading to significantly increased error rates, while others result in minimal error.

Table 1. *Detailed view of the MSE for Laplace mechanism across various configuration*

MSE values for Laplace mechanism	
EPSILON	**MSE**
0.1	0.42
0.15	2.12
0.2	15.07
0.25	0.25
0.3	1.6
0.35	4.69
0.4	3.38
0.45	15.7
0.5	14.08
0.55	4.95
0.6	2.85
0.65	2.8
0.7	19.72
0.75	3.61
0.8	0.0
0.85	0.36
0.9	3.21
0.95	0.0
1	2.04

On the other hand, the MSE values for the Gaussian mechanism exhibit a more gradual increase with epsilon. Notable deviations occur at epsilon 0.2, 0.5 and 0.85. However, the overall trend indicates a relatively stable performance compared to the Laplace mechanism, with fewer instances of drastic fluctuations in error rates.

When epsilon is set to 0.5, both mechanisms exhibit relatively high MSE values, with the Laplace mechanism recording almost double MSE than the Gaussian mechanism. That difference can be seen in Fig. 3. and Fig 4.

Table 2. *Detailed view of the MSE for Gaussian mechanism across various configuration*

MSE values for Gaussian mechanism	
EPSILON	**MSE**
0.1	7.47
0.15	0.75
0.2	27.86
0.25	10.1
0.3	4.41
0.35	0.14
0.4	0.11
0.45	1.45
0.5	7.15
0.55	2.0
0.6	0.1
0.65	0.61
0.7	0.06
0.75	0.27
0.8	0.25
0.85	4.29
0.9	0.01
0.95	0.03
1	0.12

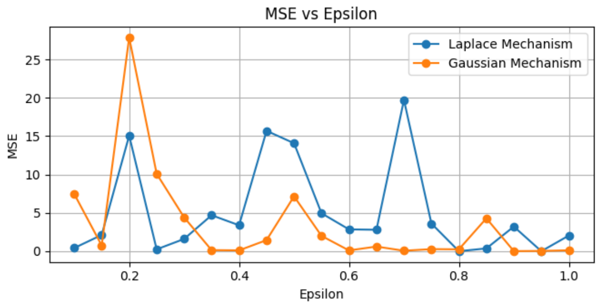

Figure 5. *MSE for different epsilon values*

As shown in Table 3 the Laplace mechanism demonstrates a higher average MSE of 5.1 compared to the Gaussian mechanism's average of 3.54. This suggests that, on average, the Gaussian mechanism provides more accurate data in contrast to Laplace mechanism which provides slightly higher privacy protection.

Table 3. *Comparison the results of Laplace and Gaussian MSE gain for different epsilon values*

Laplace and Gaussian MSE comparison	
MSE for Laplace mechanism	5.1
MSE for Gaussin mechanism	3.54

6. CHALLENGES AND LIMITATIONS

6.1 Scalability issues

Privacy-preserving algorithms like DP often need to be more accurate than their non-private counterparts, which can be particularly challenging when scaling up data processing [11].

6.2 Utility vs. privacy trade-offs

- **Multiple Queries**: With DP, the privacy guarantee for a database weakens as an algorithm is run multiple times over it. As a result, it can be difficult to maintain a reasonable balance between privacy and accuracy when multiple queries are required.
- **Dataset Size**: The inaccuracy introduced by DP through noise addition can be manageable for large datasets but problematic for small ones. This trade-off between privacy and utility becomes more pronounced with varying dataset sizes.
- **Adding Noise**: Adding noise to ensure privacy can decrease the accuracy of results. Finding the right balance between privacy and utility can be complex.
- **Suitability for Data Types**: DP may not be suitable for all types of data or queries, as some data characteristics may make it difficult to achieve a good privacy-utility balance.

6.3 Potential weaknesses

As with any definition, DP also has some weaknesses.

Its weaknesses include:

- **Data Insight Limitation**: The restructured data resulting from the application of DP algorithms can hinder organization analysts from extracting valuable insights, potentially limiting the practical usefulness of the data.
- **Accuracy Cost for Specific Queries**: Ensuring privacy often results in decreased accuracy compared to the non-private version of an algorithm. For some queries, this accuracy cost can be very large. For instance, releasing the maximum value in a database with a large possible range can lead to significant accuracy loss when made private.
- **Weakened Guarantees with Repeated Queries**: Running an algorithm multiple times over the same database weakens the privacy guarantees, complicating the balance between privacy and accuracy when multiple queries are necessary.

7. CONCLUSION

The integration of ML into various sectors has transformed data-driven decision-making but also introduced significant privacy risks. Exposing sensitive information during ML training can lead to identity theft, financial fraud, and discrimination. DP addresses these risks by adding controlled noise to datasets, ensuring individual data protection while enabling meaningful analysis. Techniques like anonymization, federated learning, and homomorphic encryption complement DP but come with their own challenges. The Laplace and Gaussian mechanisms within DP effectively balance privacy and utility, with the Laplace mechanism often preserving data quality better. However, scalability issues, utility versus privacy trade-offs, and accuracy costs for specific queries remain significant challenges. The ongoing development of privacy-preserving techniques is essential to overcome these limitations. By refining these methods, we can protect individual privacy while leveraging ML's potential. Achieving this balance is crucial for fostering trust and enabling responsible innovation in data-driven technologies. Continuous research and improvement are necessary to maintain this balance and address emerging challenges.

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Development of an Algorithm for Forecasting Inflation in the Economy Using Regression Models

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Abstract: *This paper investigates the development of an efficient algorithm for forecasting inflation, using regression models with key macroeconomic parameters as input variables. The reason for this research is based on the increasingly rapid changes in financial indicators, which are conditioned both by the corona virus epidemic and by the ubiquitous economic sanctions caused by military conflicts. By analyzing the impact of the unemployment rate, GDP, interest rates on loans, then crude oil prices and the exchange rate on inflation, we can identify the optimal approach for forecasting inflationary trends. Experimental testing of various regression models allows for a deeper understanding of the factors that shape inflation, providing a basis for making better economic decisions. Moreover, the proposed methodology is adaptable and can be applied to other economies, broadening the scope and impact of the research. Through iterative testing of regression models, we obtain a model that has the highest precision, thus creating the possibility of maintaining stability and balance on the financial market.*

Keywords: *algorithm; inflation; regression; macroeconomy; forecasting*

1. INTRODUCTION

In today's dynamic economic environment, accurate inflation forecasting is critical to strategic decision-making at all levels, from central banks and governments to individual investors and consumers. Inflation, defined as an increase in the general price level of goods and services in a certain period of time, has a significant impact on the stability and growth of the economy. Its unpredictability can lead to instability in financial markets, erosion of purchasing power and general economic uncertainty.

In the context of increasingly rapid changes in financial indicators, caused by the corona virus pandemic and geopolitical conflicts, traditional inflation forecasting methods face significant challenges. A robust and flexible methodology is required that can adapt to these dynamic conditions and provide reliable forecasts of inflationary trends.

This paper deals with the development of an efficient inflation forecasting algorithm using regression models with key macroeconomic parameters as input variables. The goal of the research is to identify the optimal approach for forecasting inflationary trends through the analysis of the impact of the unemployment rate, GDP, interest rates on loans, crude oil prices and exchange rates on inflation. Experimental testing of various regression models and iterative improvement of their performance tend to create models with the highest forecasting accuracy. Such a model would make it possible to make better economic decisions and maintain stability on the financial market.

This paper contributes to the existing knowledge in this field in the following ways:

- It proposes an innovative approach to inflation forecasting using regression models with key macroeconomic parameters.
- It looks at the impact of various factors, including the coronavirus pandemic and geopolitical conflicts, on inflation.
- By using iterative testing and improving regression models, higher forecasting accuracy is achieved.
- It provides a robust and flexible inflation forecasting methodology that can adapt to dynamic conditions.

The results of this research can be of significant benefit to central banks, governments, financial institutions, investors and consumers in making informed decisions about inflation and its impact on the economy.

2. A REVIEW OF RELATED RESEARCH

In this chapter, we focus on relevant research related to inflation forecasting using regression models, with a particular emphasis on Ridge, Lasso, Decision Tree, and Random Forest models, which have been identified as the most accurate in this field. The aim is to identify studies that confirm the superiority of these models in predicting inflation trends compared to other models.

One of the most relevant types of research in this field is a study titled "Forecasting and Analyzing Predictors of Inflation Rate: Using Machine Learning Approach". In this study, researchers applied machine learning models, including Ridge, Lasso, Elastic Net, Random Forest, and artificial neural networks, for predicting the inflation rate. The analysis was carried out using a dataset with 56 features and 132 monthly observations from January 2012 to December 2022. The Random Forest (RF) model showed higher accuracy in predicting the inflation rate than other machine learning models. In addition, it was shown that nonlinear machine learning models are more successful than linear machine learning models or time series, mainly due to unpredictability and variable interactions [1].

Another study titled "Predicting Inflation with Recurrent Neural Networks" also provides valuable insights. Although this study focuses on the application of recurrent neural networks for predicting inflation, it also highlights the importance of machine learning in economic forecasts [2].

The third study "Inflation Forecasting Using Machine Learning Methods" also highlights the use of basic machine learning methods, including LASSO, Ridge, Elastic Net, Random Forest, and Boosting, for predicting inflation [3].

Finally, the study "Forecasting of Inflation Rate Contingent on Consumer Price Index" highlights the application of various machine learning algorithms, including Decision Tree and Random Forest, for predicting the inflation rate [4].

These studies together confirm the superiority of Ridge, Lasso, Decision Tree, and Random Forest models in predicting inflation trends. These models have demonstrated the ability to accurately predict inflation, even in the presence of complex, nonlinear relationships inherent in economic data.

In the following chapters, the theoretical part of regression will be presented, as well as its methods that are now listed and based on which the path to the methodology of further research was developed.

3. REGRESSION MODELS

Regression analysis is a collection of statistical techniques that serve as a basis for drawing conclusions on the relationships between interrelated variables. Since these techniques are applicable in almost all fields of study, including social, physical and biological sciences, business and engineering, regression analysis is now perhaps the most used of all methods of analysis data [5]. To determine whether and to what extent these phenomena are dependent, it is necessary to make a regression model.

The regression technique contains several methods, based on which the analysis and discussion of the achieved results over the data can be performed, and they are:

- Linear regression
    - Simple linear regression
    - Multiple (complex) linear regression
- Non-linear regression
- General linear model
    - Poisson model
    - Logistic model
- Log-linear models
- Regression tree and tree model

The following subchapters provide the theoretical basis for regression methods that will be used for further research.

Ridge regression is a method for estimating the coefficients of multiple regression models in scenarios where independent variables are highly correlated. This method is used in many fields, including econometrics, chemistry, and engineering. The formulation of Ridge regression is given as:

$$Y = \beta 0 + \beta 1X1 + \beta 2X2 + \cdots + \beta pXp + \varepsilon + \lambda \Sigma \beta j^2$$

where λ is the regularization parameter [6].

Lasso (Least Absolute Shrinkage and Selection Operator) is a regression analysis method that performs variable selection and regularization to enhance the predictive accuracy and interpretability of the resulting statistical model. The formulation of Lasso regression is given as:

$$Y = \beta 0 + \beta 1X1 + \beta 2X2 + \cdots + \beta pXp + \varepsilon + \lambda \Sigma \mid \beta j \mid$$

where λ is the regularization parameter [7].

Decision Tree regression uses a decision tree to predict a continuous target variable. This method is particularly useful when the data is nonlinear or when there is interaction among predictor variables [8].

Random Forest is a meta estimator that fits several decision tree regressors on various sub-samples of the dataset and uses averaging to improve the predictive accuracy and control overfitting [9].

In the following chapter, we will consider each of these models in more detail, their methodology, and applications.

4. RESEARCH METHODOLOGY

In this chapter, we will describe in detail the research methodology used in the development of an algorithm for forecasting inflation in the economy using regression models.

At the beginning of the research, the necessary data were collected from January 2007 to December 2023 on a quarterly basis from several sources, including the Statistical Office of Serbia [10], the National Bank of Serbia (NBS) [11] and Trading Economics [12]. These sources provide reliable data on macroeconomic parameters such as gross domestic product (GDP), the euro exchange rate, the unemployment rate, interest rates and the price of crude oil, which are key factors in the analysis of inflation.

After the collected data, there are detailed steps that follow the development of the algorithm.

4.1. Data loading and cleaning

The first step in the research methodology is to load data from an Excel file. After loading, the data is subjected to a cleaning process to ensure data quality. This process includes:

- checking and correcting data types and
- creating a column that combines years and quarters for further analysis

4.2. Exploratory Data Analysis (EDA)

Exploratory data analysis is a key step in understanding the distribution of data and the interrelationships between variables. Graphs were used here to visualize the relationship of inflation with key economic parameters such as GDP, the euro exchange rate, the unemployment rate, interest rates and the price of crude oil. These graphs help understand the potential links between inflation and other factors.

4.3. Data preparation

After the exploratory data analysis, the data were prepared for further analysis. This step includes:

- selection of relevant attributes for analysis,
- data scaling for normalization and
- division of data into training and test sets.

4.4. Model training and evaluation

In this phase, different regression models are trained and evaluated. Ridge regression, Lasso regression, Decision Tree regression and Random Forest regression models were used. For each model, the RandomizedSearchCV technique was used to find the optimal parameters. Model performance was measured using Mean Squared Error (MSE) and Cross-Validation Mean Squared Error (CV MSE).

4.5. Visualization of model results and performance

Visualization of the results and performance of the model is an important step for easier interpretation of the results. In this step, graphs are created showing the MSE, CV MSE, and execution time for each model.

4.6. Ranking list of models

After visualizing the results, a model ranking list is created that is generated based on model performance, showing which model has the lowest MSE and CV MSE.

4.7. Error analysis

The model ranking is followed by an error analysis that was conducted to better understand the model's performance. A graphical display is used to compare predictions with actual values, which helps identify areas where the model can be improved.

4.8. Inflation forecast for 4 quarters ahead

Finally, the best model was used to predict inflation for the next four quarters. The predictions are visualized to allow an easier understanding of future inflation trends.

4.9. Documentation process

As part of the final process, we have documentation, where the research results will be summarized and presented in the form of a PDF report. This report contains detailed information on the methodology, the results of the analysis as well as the interpretation of the results, where the user can create a picture of inflation trends based on them.

This methodology provides a clear framework for the development of an inflation forecasting algorithm and allows detailed examination of various aspects of the model.

5. RESULTS AND DISCUSSION

The presented methodology is followed by the collection of results through the steps provided by the algorithm. In the following subsections, the scenario for three iterations, that is, for 10, 1000 and 5000 iterations in the algorithm, will be presented.

5.1. Exploratory Data Analysis (EDA)

In this section, we first analyze the results of exploratory data analysis to gain insight into the basic characteristics of our data set and the interrelationships between variables. In the next pictures from no. 1 to no. 6, we show the results of the exploratory analysis.

In every picture, we compare inflation with a macroeconomic indicator to see how inflation correlates with various aspects of the economy, including GDP, unemployment rate, interest rates, exchange rates, oil prices, and years and quarters of the data set that is provided to the algorithm.

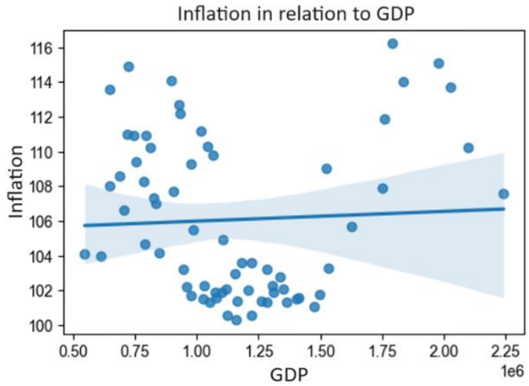

Figure 1. *EDA - Inflation in relation to GDP*

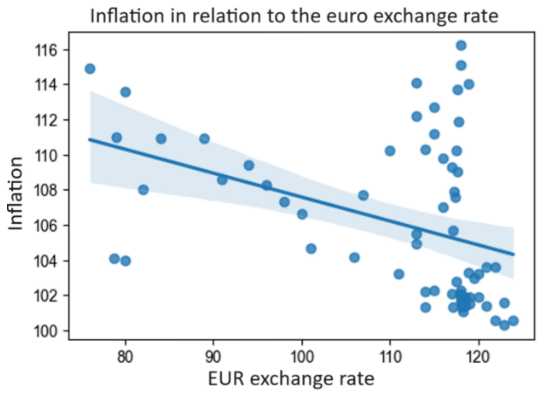

Figure 2. *EDA - Inflation in relation to EUR exchange rate*

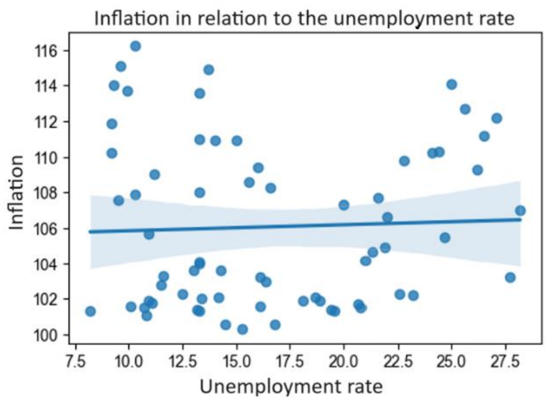

Figure 3. *EDA - Inflation in relation to unemployment rate*

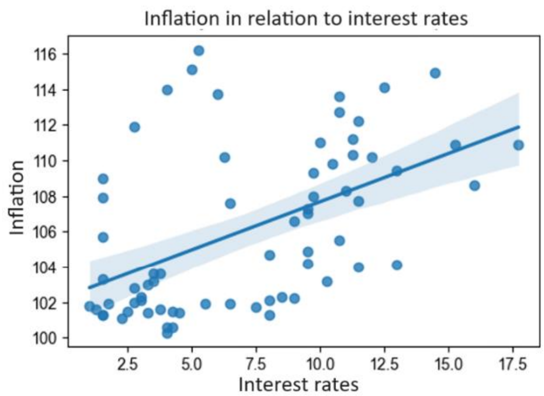

Figure 4. *EDA - Inflation in relation to interest rates*

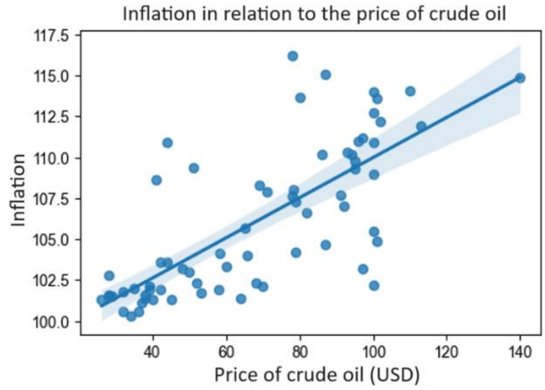

Figure 5. *EDA - Inflation in relation to crude oil (USD)*

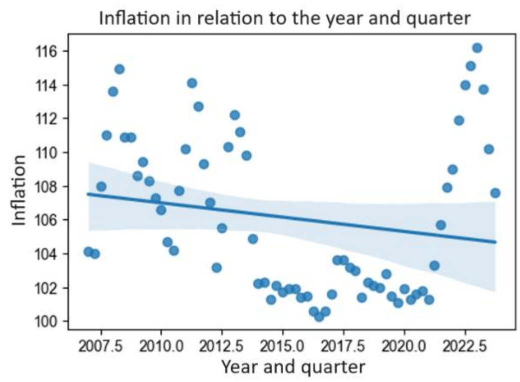

Figure 6. *EDA - Inflation in relation to year and quarter*

From the given picture, it can be clearly seen that the change in inflation is strongly influenced by the exchange rate of the euro, interest rates on loans, and the price of crude oil in dollars. The rest of the variables do not have a concrete and strong influence on the change in inflation, and accordingly the further steps of the analysis in the algorithm are approached.

5.2. Iteration of the algorithm

After the exploratory analysis, the number of iterations is defined. As already explained in the methodology, three scenarios will be used:

1. First scenario 10 iterations
2. Second scenario 1000 iterations
3. Third scenario 5000 iterations

For each scenario, we will compare their performance and results in the following chapters. What is important to point out is that it is necessary to find the optimal number of iterations for the algorithm to be accurate. This means that sometimes the highest number of iterations does not mean the most accurate model.

5.3. Model performance

After defining the scenario, the performance analysis of the model follows according to the number of iterations. The following images will show the results, that is, the performance for the second scenario. The second scenario is the one in which the most accurate prediction algorithm was found.

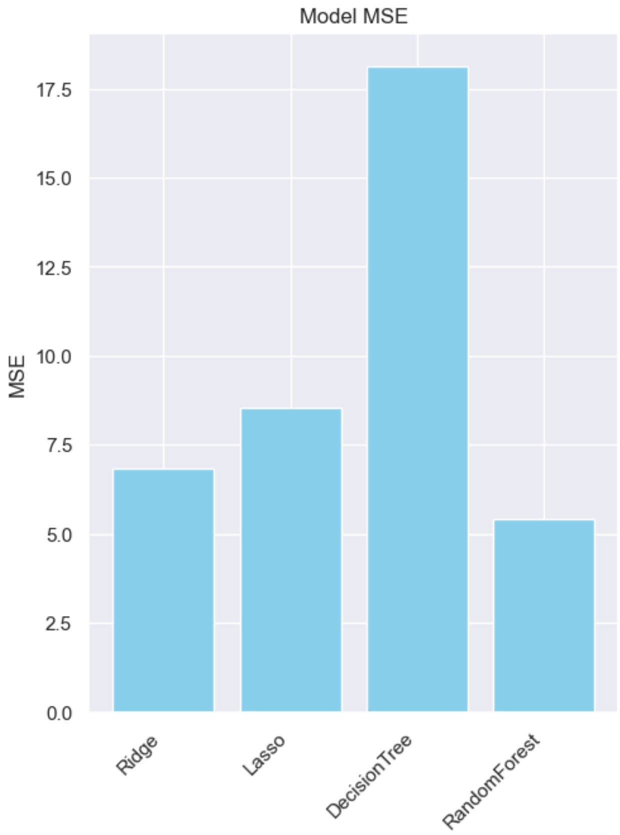

Figure 7. *Scenario 2 MSE*

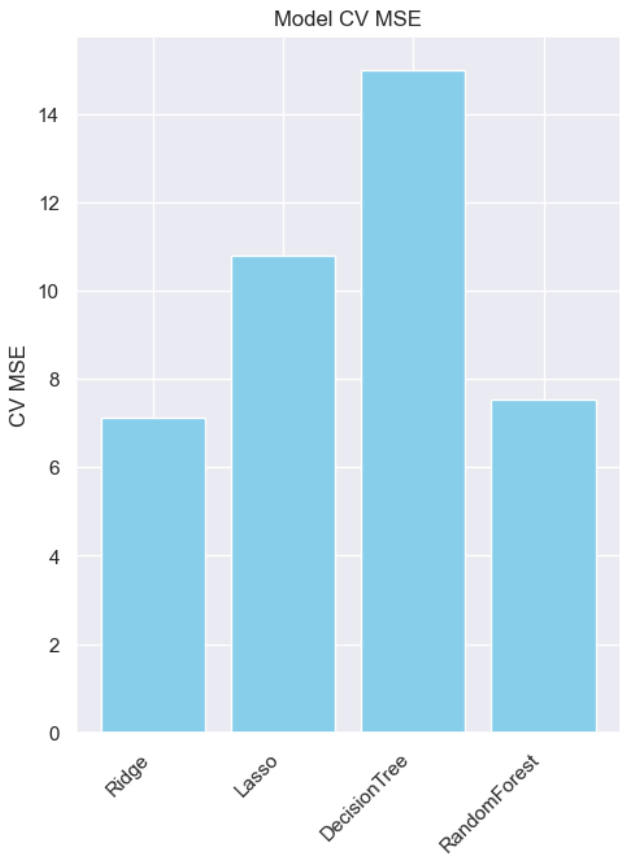

Figure 8. *Scenario 2 CV MSE*

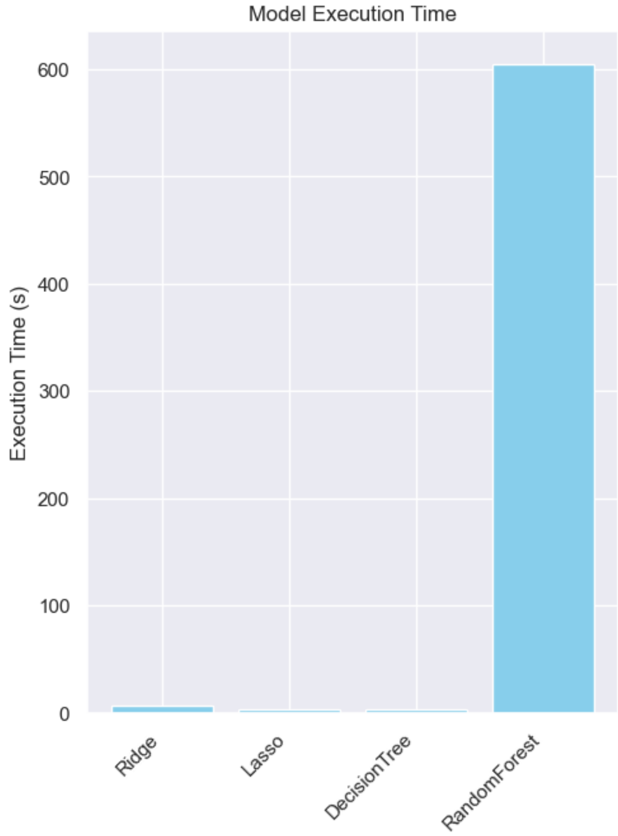

Figure 9. *Scenario 2 Execution Time*

From the above figures, it can be observed that in all three scenarios, the Random Forest model had the lowest MSE, but also an approximately low CV MSE. However, the execution time was significantly longer than the time it took other algorithms to perform the analysis.

5.4. Model ranking after analysis

After analyzing the performance of the models, the ranking of them follows, where the first model in the table is the one with the highest accuracy and can be seen in the next table.

Table 1. *Ranking models*

Model	MSE	CV MSE	EXECUTION TIME
Random Forest	5.4187	7.5414	605.0663
Ridge	6.8284	7.1246	6.9150
Lasso	8.5299	10.7951	3.2944
Decision Tree	18.1328	15.0057	3.1714

The results in the table are taken from the second scenario because it achieved the highest accuracy of the model. From the given table, the most accurate model is **Random Forest**.

5.5. Error analysis for the most accurate scenario

After ranking the model, error analysis is started. Error analysis was done through a graph where the ratio of actual and predicted values was shown.

Those values that are closest to the red diagonal are those that the algorithm predicted best, which can be seen in the following image no. 10.

Figure 10. *Error Analysis*

From the given picture, it can be concluded that the model predicts precisely in most cases, while in a smaller number of cases it makes an approximate prediction.

5.6. Forecasting four quarters ahead according to the most accurate scenario

The error analysis is followed by the inflation forecast four quarters ahead. Since the second scenario was found to achieve the highest accuracy of the model, it will be used for forecasting four quarters ahead of 2024. In the next picture, no. 11 the results of the analysis can be seen.

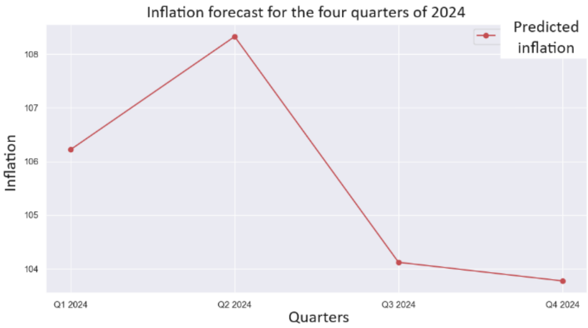

Figure 11. *Predicted inflation for four quarters of 2024*

Based on the predicted values, it is likely that inflation will peak in the second quarter of 2024 and begin to decline in the third and fourth quarters by the end of the year.

5.7. Broader economic context

While this study focuses on the Serbian economy, the methodology and findings have broader implications. The regression models and algorithmic approach developed here can be adapted to other economies with relevant adjustments. By customizing the input variables and tuning the models to local economic conditions, this approach can provide accurate inflation forecasts in diverse economic environments. This adaptability enhances the value of the research and demonstrates its potential for wider application in global economic analysis.

6. CONCLUSION

This research presents the development of an algorithm for forecasting inflation in the economy of the Republic of Serbia using regression models with key macroeconomic parameters as input variables. The primary motivation for this research stemmed from the increasingly rapid changes in financial indicators, driven by the coronavirus pandemic and economic sanctions caused by military conflicts.

Through exploratory data analysis (EDA) and iterative testing of various regression models, it was determined that the key factors influencing inflation are the euro exchange rate, loan interest rates, and crude oil prices. Experimental testing of different regression models such as Ridge, Lasso, Decision Tree, and Random Forest allowed for a detailed understanding of the factors shaping inflation, providing a basis for better economic decision-making.

A key finding of the research is that increasing the number of iterations in the algorithm leads to more accurate predictions, but it is essential to find the optimal number of iterations to achieve the highest model accuracy. The most accurate model, based on performance rankings (MSE, CV MSE, and execution time), was the Random Forest model, which provided the lowest prediction errors and the most precise inflation forecasts.

Inflation forecasts for the four quarters ahead, based on the Random Forest model, indicate that inflation will peak in the second quarter of 2024 and then begin to decline in the third and fourth quarters. These results can be significantly beneficial to central banks, governments, financial institutions, investors, and consumers in making informed decisions about inflation and its impact on the economy.

In addition to its applicability to the Serbian economy, the methodology developed in this study can be adapted to other economies. By modifying the selection of macroeconomic parameters and tuning the regression models, the proposed algorithm can provide accurate inflation forecasts for a variety of economic contexts. This flexibility makes the research valuable not only for local economic planning but also for global economic analysis, offering a robust tool for policymakers and financial institutions worldwide.

Further development of the research would focus on continuous monitoring of the current economic situation, ongoing data collection, and comparison with previous data to predict which segments of information are crucial for economic planning and decision-making in the Republic of Serbia. Additionally, improving algorithms and optimizing hyperparameters could further enhance the accuracy of predictions, contributing to the stability of economic planning and decision-making.

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Association Rules Mining for Educational Recommender Systems

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Abstract: *Evaluation of e-learning systems has led to many systems based on recommending courses, teaching materials, etc. In addition to the traditional collaborative filtering, content-based filtering, and hybrid recommendation methods, this paper presents a methodology based on data mining technologies. The paper introduces a methodology for mining associative rules using the access logs of students in a Moodle course. After accessing student Moodle logs, it is necessary to clean and select the data relevant to the research, specifically the learning objects. Additionally, a query must be created to obtain transactions and discover the context of the events, which includes a list of learning objects. Based on the transaction table, we can then use an a priori algorithm to generate rules. The rules obtained using the presented methodology enable the simple creation of a system for recommending teaching materials aimed at improving the success of students.*

Keywords: *recommendation system; apriori; learning materials; Moodle*

1. INTRODUCTION

In the rapidly evolving landscape of education, the effective use of technology to recommend personalized educational resources has become paramount. Distance learning systems have become an irreplaceable part of modern educational systems. Evaluation of e-learning systems has led to many recommendation-based systems, which have improved the modern learning process. Also, these systems can be supported in different forms, like web-based learning, computer-based learning, or virtual classrooms and content delivery via e-networks, video conferencing, e-mails and mobile technology.

These systems use advanced algorithms to analyze user interactions, preferences, and learning behaviors, supplying personalized recommendations that cater to the unique needs of each learner. Traditional recommendation approaches often rely on collaborative filtering (CF) or content-based methods, proving effectiveness but with certain limitations in capturing intricate relationships within educational datasets.

According to [1], recommender systems represent software tools to help users in the decision-making process by applying information filtering, data mining, and prediction algorithms. There are several types of recommender systems [2]: collaborative, content-based, knowledge-based and hybrid. A hybrid recommender system gives the possibility of combining techniques to overcome problems such as the cold-start.

As an alternative to traditional recommendation methods, it is possible to apply Association Rules Mining (ARM) methods. Unlike traditional methods, ARM discovers associative rules and correlations between different elements. It focuses on identifying rules that can predict the appearance of an object in a transaction [3].

ARM involves the use of data analysis algorithms based on statistical and data mining methods. It was first proposed by R. Agrawal, and it is primarily used to identify interesting relationships between various data items [4].

The paper presents the methodology for generating associative rules in the field of education. The most well-known algorithms for discovering associative rules are: Apriori, Eclat, Clikue, FP-Growth [5]. In this paper, the classic Apriori algorithm will be used for discovering frequentitem sets and mining association rules over transactional datasets [6]

By using Moodle records and applying the Apriori algorithm, it is possible to create rules for recommending teaching materials. The goal is to improve student success by providing personalized suggestions based on their interaction with the learning platform. Through this approach, the work aims to encourage better outcomes for students.

2. RELATED WORK

The integration of ARM into Educational Recommender Systems (ERS) is a dynamic area of research that builds upon the latest advancements in recommender systems, educational data mining, and personalized learning experiences.

ERS has been the subject of extensive research, aiming to enhance the adaptability and personalization of learning experiences. While traditional collaborative filtering and content-based approaches have proven effective, they often face challenges in capturing intricate relationships within educational datasets. The application of data mining techniques in education has gained significant attention, as researchers exploring ways to extract meaningful patterns and insights from educational datasets.

In the paper [7], authors conducted pioneering work on the use of data mining for predicting student performance, highlighting the potential of these techniques to inform instructional strategies. This broader context provides the backdrop for using ARM in the specific domain of educational data. Combined with traditional recommendation techniques, association rule mining has been successfully applied in various domains, including e-commerce, healthcare and technology [8]. In an educational context, the application of ARM to find patterns in student behavior and preferences has proven its potential to uncover valuable associations in educational datasets [9].

In paper [10], the authors describe the process of association rule mining in Moodle LMS. They analyzed students' login frequency, the number of accessed resources, forum messages, and average performance on quizzes. The research demonstrates the potential of association rules to predict student performance and identify students who need more attention.

In paper [11], the authors introduced a system designed to support learners by offering personalized recommendations. This system suggests which learning objects within a course are most beneficial for each student. The recommendations consider the specific learning object a student is currently exploring, as well as the learning objects previously visited by other learners with similar profiles. Essentially, the system tailors its suggestions based on the individual learner's current activity and the historical preferences of other learners with comparable characteristics. This approach aims to enhance the overall learning experience by providing relevant and personalized guidance to each user.

3. METHODOLOGY

In this research, we utilized logs from the Moodle course at the School of Railroad Transport of Applied Studies, which is part of the Academy of Technical and Art Applied Studies in Belgrade. Data collection involved downloading logs from the Moodle Technical Drawing course. The dataset, stored in a CSV file, includes information such as time stamps, user full names, affected users, event context, component, event names, descriptions, origin, and IP addresses. The dataset comprises 24,965 rows of student log records from the Technical Drawing course.

The second stage of the methodology involves data preprocessing. During this stage, we utilize horizontal data selection, a fundamental operation in data analysis that plays a crucial role in filtering and obtaining relevant information. From the collected data, we exclude all records related to course teachers, guests, and system administrators. Additionally, we eliminate rows that are deemed irrelevant and could potentially impact the accuracy of the results negatively.

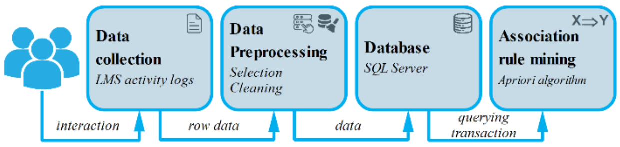
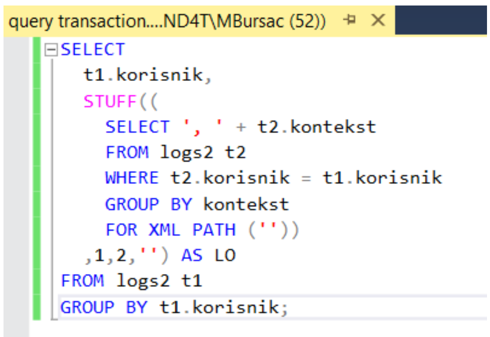


Figure 1. *Research methodology*

Following the collection and preprocessing of data, the dataset is stored in a SQL Server database with the name "logs2." This dataset encompasses information about all students who enrolled in the course and successfully passed the exam for the observed subject. Before implementing the Apriori algorithm, a query is employed to extract and organize the relevant data into a transaction table.

By applying the query (Figure 2), each user (student) can discover the context of the event, including the names of the learning objects they accessed in the observed course.

This table serves as the basis for applying the Apriori algorithm, capturing the interactions and associations between different items or elements within the dataset.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    t1.korisnik,
    STUFF((
      SELECT ', ' + t2.kontekst
      FROM logs2 t2
      WHERE t2.korisnik = t1.korisnik
      GROUP BY kontekst
      FOR XML PATH (''))
    ,1,2,'') AS LO
FROM logs2 t1
GROUP BY t1.korisnik;
```

Figure 2. *Querying transaction*

The transaction table (table 1) represents all students who accessed the Technical Drawing course and for each student the learning objects they accessed. The transaction table contains 226 rows (students) listing the different learning objects they have accessed (from 1 to a maximum of 65). In the transaction table, each student represents a unique transaction that has accessed one of the learning objects at least once.

Table 1. *Transaction table*

Transaction Student ID	Learning objects
Student 1	{Exercise 1 (AutoCAD file), Exercise 2 (AutoCAD file), Exercise 2 (picture), U/I test AutoCAD, Exercise 1 (video), Exercise 12 (video), Exercise 2 (video)…}
Student 2	{Forum, AutoCAD 2016 and AutoCAD LT 2016 ESSENTIALS, Exercise 1 (AutoCAD file), Exercise 2 (AutoCAD file), Exercise 2 (picture), U/I test AutoCAD, Exercise 1 (video), Exercise 10 (video), Exercise 11 (video), Exercise 12 (video)…}
Student 3	{Lectures, Template - A3, Exercise 1 (AutoCAD file) Exercise 1 (picture), Exercise 10 (AutoCAD file), Exercise 10 (picture), Exercise 11 (AutoCAD file)…}
...	...
Student 226	{Lectures, Homework, Course intro, Exercise 1 (pdf), Exercise 1 (AutoCAD file), Exercise 1 (picture), Exercise 10 (pdf)…}

The final stage in the methodology involves association rule mining. As described in [5], association rule mining comprises two primary stages: frequent item generation and rule generation. Frequent itemsets refer to sets of items or elements that recurrently appear together in the dataset. The Apriori algorithm is employed during this process, using an iterative approach to identify these frequent itemsets based on the apriori property concept [11]. This property assists in efficiently uncovering combinations of items by exploiting the knowledge that if a set of items is frequent, its subsets are also frequent. Both stages, frequent item generation and rule generation, play crucial roles in the association rule mining process, ultimately revealing meaningful associations within the dataset.

A rule is defined as if *x* then *y*, where *x* is the antecedent and *y* is the consequent. In the rule generation stage, the calculation of the values of support, confidence, and lift ratio is carried out on each rule [5]. Given the potentially large number of rules generated, it becomes necessary to establish threshold values for support and confidence.

According to [12], support (1) is defined as the percentage of the transactions containing both *x* and *y* among all transactions:

$$support(x => y) = \frac{number\ of\ transaction\ containing\ (x \cup y)}{total\ number\ of\ transaction} \quad (1)$$

Support is a measure of the number of times an itemset (a combination of items) appears in a dataset and it is calculated by dividing the number of transactions containing an item set by the total number of transactions. Support is often used with a threshold to identify itemsets that occur frequently enough to be considered significant or of interest.

Confidence (2) is defined as the percentage of transactions that contain *x* among transactions that contain *y* [12].

$$confidence(x => y) = \frac{number\ of\ transaction\ (x \cup y)}{number\ of\ transaction\ containing\ x} (2)$$

Confidence is a measure of the likelihood that an itemset will appear if another itemset appears and it is calculated by dividing the number of transactions containing both itemsets by the number of transactions containing the first itemset. Also, confidence is often used with a threshold to identify rules that are strong enough to be of interest.

According to related work, the minimum support and confidence thresholds were between 0,3 and 0,7. In this research, we use a minimal support threshold 0,35 and a minimal confidence threshold 0,7. The Apriori algorithm in this research was implemented in Python.

4. RESULTS AND DISCUSSION

In this study, association rule mining was applied to analyze student interaction patterns within the Technical Drawing course using Moodle logs. The dataset consisted of 226 student records and their interactions with various learning objects. The Apriori algorithm was employed to generate association rules based on predefined thresholds for support and confidence.

After applying the Apriori algorithm, 14 associative rules are obtained with support (Sup) and confidence (Con), table 2.

Table 2. *Rules*

Antecedents =>	Consequents	Sup	Con
Exercise 2	Exercise 1	0,361	0,966
Student exercise, Graphics	Exercise 2	0,357	0,944
Graphics, Exercise 1 (video)	Student exercise	0,357	0,944
Student exercise	Exercise 1	0,387	0,939
Student exercise, Exercise 1	Graphics	0,357	0,924
Lectures, Student exercise	Graphics	0,378	0,918
Exercise 1	Student exercise	0,387	0,868
Student exercise	Graphics, Exercise 1	0,357	0,867
Exercise 1	Graphics	0,378	0,849
Graphics, Homework	Student exercise	0,378	0,826
Exercise 11	Exercise 10	0,378	0,826
Exercise 1	Exercise 2	0,361	0,811
Exercise 1 (AutoCAD file)	Student exercise, Graphics	0,357	0,802
Course intro	Student exercise, Exercise 1	0,357	0,78

The table 2 illustrates association rules discovered through association rule mining. Each rule is represented in the form "*x* => *y*" where *x* is the antecedent and *y* is the consequent.

The analysis of association rules provides valuable insights into student behavior and preferences within the Technical Drawing course. Rules with high support and confidence values indicate strong associations between specific learning objects or activities. These associations rules can inform instructional strategies and personalized learning approaches.

The following figures show the relationship between frequency of the rules and confidence (figure 3), as well as frequency and support (figure 4). Figure 5 show relationship between confidence and support.

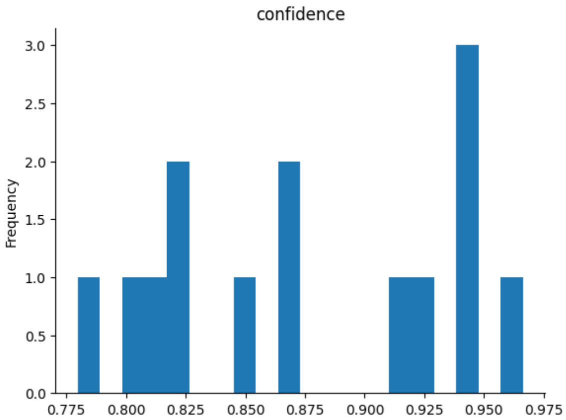

Figure 3. *Association rules - frequency and confidence*

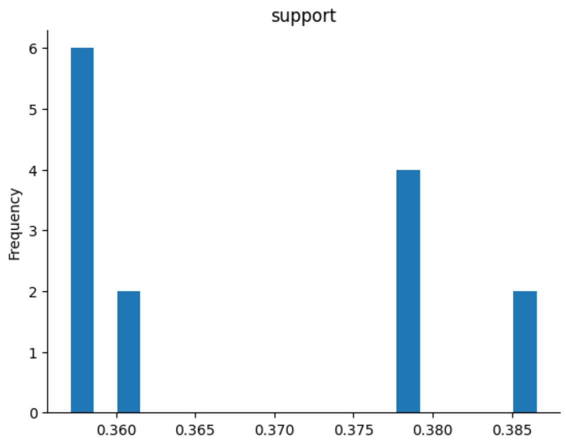

Figure 4. *Association rules - frequency and support*

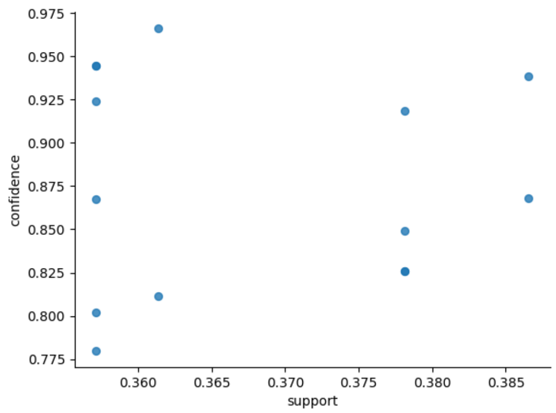

Figure 5. *Association rules - support and confidence*

5. CONCLUSION

Many educational recommendation systems rely on established methods like collaborative and content-based systems. The methodology discussed in this paper offers a straightforward approach to creating rules for recommending learning (objects) materials. Association rules obtained in this way can be used to create a system for recommending teaching materials, which in the case of related research [8, 9, 10, 12] led to the improvement of the educational process.

Future work will focus on developing and implementing a Moodle block that recommends teaching materials to the right group of students. This approach aims to help students enhance their knowledge and achieve greater success.

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Natural Language Processing in Meaning Representation for Sentiment Analysis in Serbian Language

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Abstract: *This paper explores machine learning algorithms that contribute to meaning representation and context modeling in sentiment analysis. Language preprocessing techniques are described in detail. The study also discusses string distance calculations and the application of Naive Bayes for classification, emphasizing important model metrics such as accuracy. The final section of the paper presents a practical example encompassing the process of data collection, analysis, preprocessing, classification using machine learning algorithms, and model evaluation. Testing demonstrated the system's ability to classify sentiments in Serbian Language.*

Keywords: *Naive Bayes; Model Metrics; Meaning; Context; Sentiments*

1. INTRODUCTION

In recent decades, the world has witnessed an explosion of textual data from various platforms, ranging from social media to blogs and news articles. This influx of data has necessitated advanced methods for processing and analyzing it, driving the development of Natural Language Processing (NLP). NLP has become crucial for understanding and exploiting textual data. Initially, NLP deals with text preprocessing, which includes processes such as tokenization, normalization, and lemmatization, essential for preparing the text for further analysis. These processes serve as the foundation for applying various machine-learning algorithms that enable the extraction of meaning from text. Besides preprocessing, NLP encompasses the development of models capable of understanding and generating text. In this context, machine learning algorithms are of paramount importance. From Naive Bayes classifiers to advanced techniques, these models facilitate sentiment analysis, emotion recognition, and context modeling. This paper explores a dataset collected from confession forums, aiming to apply machine learning algorithms for sentiment classification in confessions. The first step in the research is to analyze the distribution of sentiments in the data using a classification based on the number of approvals and disapprovals. Following this, the WordCloud tool is used to examine the most prevalent words in the confessions. The accuracy of the classifiers in different languages is also analyzed, and the challenges of processing text in multiple languages are considered. Through various metrics and analyzes, this paper provides deeper insights into the sentiments and emotional states expressed in the confessions. Finally, the most successful classifiers for sentiment analysis in different languages are identified, and recommendations for future research in the field of NLP based on these confessions are provided.

2. RELATED WORK

In recent years, the development and application of NLP techniques in sentiment analysis have gained significant attention, particularly in less-resourced languages such as Serbian. Sentiment analysis involves the extraction and analysis of subjective information from textual data, which is crucial for various applications.

The task of sentiment analysis in the Serbian language presents unique challenges due to its linguistic characteristics, including the complex morphology which can significantly influence the overall sentiment value of a text. Jahić and Vičič [14] explored these challenges in the context of the Bosnian language, a closely related South Slavic language, highlighting the impact of negation on sentiment classification. Their findings underscore the importance of addressing these linguistic features in sentiment analysis models to enhance their accuracy and reliability.

Building on the foundation of multilingual sentiment analysis, Draskovic et al. [15] developed a multilingual model for machine sentiment analysis specifically tailored to the Serbian language. Their research demonstrated the potential for cross-linguistic approaches in enhancing sentiment analysis capabilities for Serbian, emphasizing the need for models that can effectively capture the nuances of the language across different domains.

Further advancements in NLP for the Serbian language are illustrated by Laković et al. [16], who conducted an exploratory analysis of text using available NLP technologies. Their study provided insights into the current state of NLP tools for Serbian, highlighting both the opportunities and limitations in applying existing technologies to sentiment analysis tasks. The results of their work suggest a need for continued refinement and adaptation of NLP tools to better serve the specific requirements of Serbian language processing.

One of the significant contributions to Serbian NLP is the development of SRBerta, a Transformer-based language model specifically designed for Serbian Cyrillic legal texts by Bogdanović et al. [17]. While their work primarily focused on legal documents, the underlying technology of SRBerta holds promise for broader applications, including sentiment analysis. The use of such advanced models represents a critical step forward in the creation of robust, domain-specific NLP tools for Serbian, capable of handling the intricacies of the language in various contexts.

Sentiment analysis for the Serbian language illustrates a growing interest and progress in the field, driven by the development of both general and domain-specific models. These efforts reflect the ongoing challenges and opportunities in adapting NLP techniques to effectively process and analyze text in the Serbian language.

3. MEANING REPRESENTATION IN THE FIELD OF NLP

Meaning representation in NLP is the process of representing words, sentences, or text in a way that allows computers to understand and implement systems. It involves capturing information or concepts as they are represented in the human brain or in a computational system. Meaning representation is crucial in various NLP applications, including machine translation, sentiment analysis, text classification, text generation, automatic detection of inappropriate content, detection of emotional tone in text, and automatic identification of text authorship.

A collection of text or speech that a computer can process and read is called a corpus. Sentences contain words and punctuation marks. Punctuation determines the boundaries of elements and uses marks like question marks and quotation marks to identify context. Punctuation is highly significant in sentiment analysis. Sometimes sentences contain words that are not important for a particular system, such as interjections, which can be excluded. The distinction between capitalized and lowercase words depends on the task; for tasks like speech representation and recognition, it is not very important. According to "Serbian Dictionary" by Vuk Stefanović Karadžić [1], there are 26,270 words in the Serbian literary language. The dictionary of the Serbian Academy of Sciences and Arts predicts it will have over 35 books with about 500,000 entries [2]. However, the exact number of words is hard to determine due to loanwords, archaisms, etc.

The larger the corpus analyzed, the more word types we find. The number of word types is denoted as |V|, and the number of occurrences N is defined by Herdan's law with the formula (1).

$$|V| = kN^{\beta} \tag{1}$$

Where k and β are positive constants within $0 < \beta < 1$. The value of β depends on the corpus and genre, and the vocabulary size significantly increases, more than the square root [3].

2.1. Lemmatization

Lemmatization is the task of determining whether two words have the same root despite all differences. For example, the holiday *„Spasovdan"* has the root word *„spas"* (salvation) in its name. Lemmatization involves the complete morphological parsing of words. Words consist of smaller units called morphemes, which carry meaning. For instance, the word *„knjiga"* (book) or *„knjige"* (books) has the lemma *„knjiga"*, which is the base form. Significantly, words are morphologically different because they have singular and plural forms. For example, in the name of the town *„Bratunac"*, lemmatization would yield the words *„brat"* (brother) and *„unac"*.

2.2. Stemming

Trimming the endings of words is called stemming. Porter introduced a precursor to stemming in his work from 1980 [4]. An example of stemming according to Porter would be as in the text:

„Постоји још неколико теорија о настанку имена Братунац. Наиме, према причи старијих становника општине Братунац, име Братунац је настао тако што је неки бег, који је био најзначајнији у то вријеме на том простору звао свог сестрића: „Ходи амо, дајџи мој братунац…", (син од сестре-братанац-братунац)."[5]

This text would look like this:

"Постоји још неколико теорија о настанку име Братунац. Наиме, према причи стариј становник општин Братунац, им Братунац је наста так што је неки бег, кој је био најзначајни у то вријем на том простор зва свог сестрић: „Ход амо, дај мој

братунац…", (син од сестре-братанац-братунац)."

2.3. Minimal distance changes in strings

The distance in changes provides a way to express sentences at different distances. The minimal distance between two arrays gives the minimum number of change operations (insertion, deletion, substitution) required to convert one array into another.

Levenshtein distance or edit distance is a measure used to calculate the similarity between two character arrays, also known as cost. It is defined as the minimum number of simple operations required to transform one character into another. The operations are inserting a new character, deleting existing characters, or replacing one character with another [6].

Levenshtein distance between the words „Сребро" and „Сребреница" is 5 because it requires 5 insertions of 'еница' after the word сребро.

Сребро -> Сребре – Transition о to е

Сребре -> Сребрен – Adding the letter н after е

Сребрен -> Сребрени – Adding и after н

Сребрени -> Сребрениц – Adding ц after и

Сребрениц -> Сребреница – Adding а at the end

The distance between the words „ПОДРИЊЕ" and „ПОДРИЊСКИ" is 1.

ПОДРИЊЕ -> ПОДРИЊС – Transition е to с

ПОДРИЊС -> ПОДРИЊСК – Adding the letter к after с

ПОДРИЊСК -> ПОДРИЊСКИ – Adding the letter к after и

The distance between the words Братанац and Братунац is 1.

БРАТ**У**НАЦ -> БРАТ**А**НАЦ"

2.4. Naive Bayes

The Naive Bayes classifier is a probabilistic classification model that applies Bayes' rule. The basic idea is represented by formula (2), where d from the class set C is assigned to the class with the highest posterior probability [7].

$$\hat{C} = arg \max_{c \in C} P(c|d) \tag{2}$$

By applying Bayes' rule, we arrive at formula (3), which maps the posterior probability based on the model and prior probability. Of course, these formulas make assumptions about the independence of word identity, i.e., that the position of words is not important, which is a characteristic of the naive Bayes approach [8].

$$P(c|d) = \frac{P(d|c)P(c)}{P(d)} \tag{3}$$

The training process of the naive Bayes classifier is crucial for probability modeling. Formula (4) represents the prior probability of class c, where the assumption of maximum probability is applied [9].

$$P(c) = \frac{N_c}{N_{doc}} \tag{4}$$

Training involves calculating probabilities based on the training dataset, but Laplace's formula (5) is used to avoid problems with zero probabilities when data is sparse [10].

$$\hat{P}(w_i|\ c) = \frac{count(\ w_i, c)+1}{(\sum_{w \in V} count(w,c))+|V|} \tag{5}$$

By incorporating word positions, formula (6) further modifies the classification process.

$$\hat{C}_{NB} = \arg\max_{c \in C} P(c) \prod_{i \in \text{positions}} P(w_i|c) \tag{6}$$

Finally, to represent documents as a set of features, formula (7) is used.

$$\hat{c} = \arg\max_{c \in C} P(f1, f2, \dots, fn\ |c)\ P(c) \tag{7}$$

2.5. Application of Naive Bayes in Sentiment Analysis

In the example in Table 1, different sentences are given for classifiacation using Naive Bayes.

Table 1. *The example values are given in column X, and the classes are given in column Y.*

X	Y
Братунац бисер Републике Српске.	*1*
Сребреница град са богатом културном баштином.	*1*
Подриње, представља идеално место за релаксацију и одмор.	*1*
Братунац, место са трагичном претходном историјом.	*0*
Сребреница, име које је постало симбол масовног страдања.	*0*
Подриње напомиње на последице ратних сукоба.	*0*
Подриње је познато по рату.	*0*
Сребреница бисер источне Српске.	***?***

Based on Table 1, we conclude that the ratio of probabilities of positive elements is given by formula (8), and the ratio of probabilities of negative elements is given by formula (9).

$$P(positive) = \frac{3}{7} \tag{8}$$

$$P(negative) = \frac{4}{7} \tag{9}$$

According to the formula, the total number of words in the corpus is determined as:

$$|V| = 43 - 7 \tag{10}$$

Free examples of sentiment analysis on forums are given in Table 2.

Table 2. *Statistical values of words in the corpus*

Query	Value (corpus in %)
подриње	3 / 7
братунац	2 / 4.7
сребреница	2 / 4.7
са	2 / 4.7
место	2 / 4.7
је	2 / 4.7
Positive words	**18**
Negative words	**25**
Sum of all words	**43**

In the sentence S="Сребреница бисер источне Српске", the word "источна" is not in the training corpus and that word is removed.

The procedure for determining the probability of whether a sentiment is positive or negative is given by formulas: (11 - 18).

$$P(\text{"Сребреница"}|pos) = \frac{1+1}{18+36} \quad (11)$$

$$P(\text{"Сребреница"}|neg) = \frac{1+1}{25+36} \quad (12)$$

$$P(\text{"бисер"}|pos) = \frac{1+1}{18+36} \quad (13)$$

$$P(\text{"бисер"}|neg) = \frac{0+1}{25+36} \quad (14)$$

$$P(\text{"Српске"}|pos) = \frac{1+1}{18+36} \quad (15)$$

$$P(\text{"Српске"}|neg) = \frac{0+1}{25+36} \quad (16)$$

$$P(neg)P(S|neg) = \frac{4}{7} \times \frac{2\times1\times1}{61\times61\times61} \approx 4.707 \times 10^{-8} \quad (17)$$

$$P(pos)P(S|pos) = \frac{3}{7} \times \frac{2\times2\times2}{54\times54\times54} \approx \mathbf{7.742 \times 10^{-7}} \quad (18)$$

For sentiment analysis, the standard Naive Bayes text classification can be adapted to improve performance. The key modification is to focus on the presence of a word in the document rather than its frequency. **Limiting the number of occurrences of a word to 1 in each document can significantly improve results. This preprocessing is known as binary multinomial Naive Bayes**, which is based on the same algorithm as the regular Naive Bayes. During training, duplicate words are removed before merging into a single document, both in the training and test documents.

Negation plays a significant role in sentiment analysis, for example, "Дринска регата ми се свидела" (I liked the Drina Regatta) versus "Дринска регата ми се није свидела" (I did not like the Drina Regatta). **Negation completely changes the conclusion and gives a different output**. In some algorithms where negation appears, such as "није" (is not), "не" (no), "никако" (by no means), "никакво" (no kind of), and similar words, the particle НЕ (NO) is usually added in place of these words!

2.7. Model Metrics in Machine Learning

The basic metrics for evaluating machine learning models are: Accuracy, Precision, Recall, and F1-Score.

Accuracy - This is a general measure of model performance, defined as the ratio of correctly classified instances (TP and TN) to the total number of instances (19). Accuracy is useful when the classes in the dataset are relatively balanced but can be misleading otherwise [11].

$$Accuracy = \frac{TP+TN}{TP+FP+TN+FN} \quad (19)$$

Precision - This metric measures the accuracy of the model's positive predictions, i.e., the ratio of correctly predicted positive instances to all instances that the model labeled as positive (TP / (TP + FP)) (20). Precision is important in scenarios where minimizing the number of false positive predictions is crucial, such as in medical diagnostics [11].

$$Precision = \frac{TP}{TP+FP} \quad (20)$$

Recall: Also known as sensitivity or the true positive rate (TPR), recall measures the model's ability to identify all actual positive instances in the dataset (TP / (TP + FN)) (21). High recall indicates that the model rarely misses positive instances, which is important in tasks where it is critical to find all positive examples [11].

$$Recall = \frac{TP}{TP+FN} \quad (21)$$

F1 Score: This measure represents the harmonic mean between precision and recall, and is useful when a balance between these two metrics is needed. The formula for the F1 score is 2 * (precision * recall) / (precision + recall) (22). A high F1 score indicates a good balance between precision and recall [11].

$$F = \frac{1}{(\alpha\frac{1}{Precision}+(1-\alpha)\frac{1}{Recall})}, \alpha \in [0,1] \quad (22)$$

When the parameter α < 1/2, the formula emphasizes recall; when α = 0, the F-measure is equal to recall, specifically F = Recall. When α > 1/2, the formula highlights precision; for α = 1, F = Precision. In the case where α = 1/2, the formula represents the harmonic mean of precision and recall and is referred to as the balanced measure. **This measure is also referred to as the Macro F1 measure.** (23)

$$F = \frac{2*Precision*Recall}{Precision+Recall} \quad (23)$$

2.8. ROC/AUC curve

The ROC (**Receiver Operating Characteristic) curve** is a graphical representation of classifier performance, illustrating the relationship between **True Positive Rate (TPR)** and **False Positive Rate (FPR)** for different decision thresholds. It is based on binary classification problems. TPR, also known as sensitivity, represents the ratio of true positives to the total number of positive instances in the dataset. It is given by the expression (24).

$$TPR = \frac{TP}{TP+FN} \quad (24)$$

FPR represents the ratio of false positives to the total number of negative instances in the dataset. The ROC curve is a graph where the x-axis represents FPR and the y-axis represents TPR [12]. The closer the ROC curve is to the upper-left corner of the graph, i.e., closer to the ideal case (TPR=1, FPR=0), the better the classifier. It is given by the expression (25).

$$FPR = \frac{FP}{TN+FP} \quad (25)$$

AUC (Area Under the Curve) represents the area under the ROC curve and is used as a measure of classifier performance. The AUC value ranges between 0 and 1, where a value of 1 represents the ideal situation (perfect classifier), while a value of

0.5 indicates random guessing. The closer the AUC is to 1, the better the classifier performs. AUC can also be used to compare multiple models [12].

2.9. Boxplot

Boxplot is a graphical representation of data distribution that enables visual analysis of the statistical characteristics of a dataset. This graph is used to display the distribution of numerical data through five basic statistical parameters: minimum, first quartile (25th percentile), median (50th percentile), third quartile (75th percentile), and maximum [13].

The main purpose of a boxplot is to provide insight into the central tendency, dispersion, and presence of any extreme values in the dataset. The central line in the boxplot represents the median (the value that divides the dataset into two halves of 50% each), while the lower and upper edges of the rectangle (the "box") represent the first and third quartiles, respectively. Vertical lines extending from the boxes indicate the range of data values outside the interquartile range, and any points beyond these lines represent extreme values or outliers.

Boxplots are useful for comparing distributions of different datasets or for analyzing changes in data distribution over time or between different groups. Additionally, they assist in identifying any outliers and provide insight into the symmetry or asymmetry of the data distribution. Boxplot visualization on the training and testing datasets for sentiment analysis in the Serbian language (Fig 1).

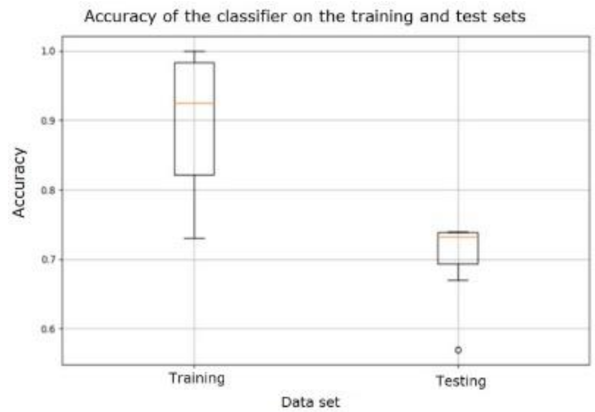

Figure 1. *Boxplot visualization on the training and testing data sets*

2.10. Matrix confusion

Evaluation of machine learning models provides a detailed overview of the performance and quality of machine learning algorithms. To evaluate a machine learning model, an appropriate model metric must be chosen. In machine learning classification for spam detection, accuracy is often chosen as the metric; however, in some situations, this metric may not be the most suitable.

The evaluation of a machine learning model is conducted exclusively on the test dataset, never on the training dataset. For example, in sentiment detection on social networks, a binary classifier is used to classify as spam or not spam.

The first step in model evaluation is the confusion matrix. The confusion matrix is mainly used in classification tasks (Table 3). The confusion matrix is a square matrix used for model evaluation and has the following dimensions as in equation (26):

$$\mathrm{Dim}_{\mathrm{confusion\_matrix}} = N \times N \tag{26}$$

The confusion matrix provides a detailed insight into how the model classifies data and how well it performs compared to the actual values. The matrix is used in binary classification but can also be used in multiclass classification. The matrix compares the actual target values with the values predicted by the machine learning model.

Table 3. *Confusion matrix 2 x 2*

		Actual values	
		positive	negative
Predicted values	positive	**TP**	**FP**
	negative	**FN**	**TN**

The confusion matrix is commonly used in sentiment detection with two possible outcomes: whether the sentiment is positive or negative. It is defined as a 2x2 square matrix with the following possible outcomes:

True Positives (TP): The number of sentiments correctly classified as positive (predicted value is the same as the actual value).

False Positives (FP): The number of instances incorrectly classified as positive (sentiments that are negative but classified as positive). The predicted value is incorrectly predicted.

True Negatives (TN): The number of instances correctly classified as negative (predicted negative value is the same as the actual negative value).

False Negatives (FN): The number of instances incorrectly classified as negative (positive sentiments incorrectly marked as negative). The predicted value is incorrectly predicted.

Based on these four values, various performance evaluation metrics for the model can be calculated, such as Accuracy, Precision, Recall, and F1-Score.

For example, the dataset contains 5000 instances to be classified, primarily confessions from the website. The dataset is shown in Table 4. When the model is defined and trained, the confusion matrix obtained from the example is significantly imbalanced. There is a much larger number of correctly classified positive sentiments compared to correctly classified negative sentiments. The minority class is negative, and the majority class is positive. When the data is balanced by classes, we obtain accuracy as the model metric.

Table 4. *Dataset with the distribution of values*

3851	**152**
54	**943**

Accuracy is calculated using formula (27)

$$Accuracy = \frac{3851+943}{3851+152+54+943} \approx 0{,}96\% \tag{27}$$

When, as in the given example, there are many more data points of one class than the other, accuracy ceases to be a useful metric. When working with imbalanced data, the most commonly used measure is the **F-measure**. This measure is defined as the harmonic mean of precision and recall.

From this model, it can be seen that the accuracy is approximately 96%, which indicates that the accuracy is 96% regardless of whether the sentiment is positive or negative. Based on accuracy, there is no information on how many of the total number of actual positive sentiments are correctly predicted to be positive.

Given the seriousness of the problem, accuracy is not a good metric in this case, and another metric needs to be used. The calculated accuracy from the table is given by formulas (28) and (29) respectively:

$$Precision = \frac{3851}{3851+152} = 0{,}962 \approx 0{,}96 \tag{28}$$

$$Recall = \frac{3851}{3851+54} = 0{,}986 \approx 0{,}99 \tag{29}$$

The Macro F1 score is the harmonic mean of the precision and recall, calculated separately for each class and then averaged:

$$F1 = 2 \times \frac{0.96 \times 0.99}{0.96 \times 0.99} \approx 0.974 \tag{30}$$

The Micro F1 score aggregates the contributions of all classes to compute the average metric. For binary classification, the Micro F1 score is the same as the accuracy, precision, and recall when they are calculated across all instances:

$$Micro\ F1 = 2 \times \frac{0.962 \times 0.986}{0.962 \times 0.986} \approx 0.975 \tag{31}$$

4. DATA COLLECTION AND IMPLEMENTATION OF PRACTICAL EXAMPLE

The popular website "Confessions" https://ispovesti.com/ where users can anonymously share their personal stories, secrets, confessions, and reflections. The most significant features of the website include anonymity, confessions, voting, comments, categories, search, popularity, and the latest news. The dataset consists of 1000 confessions downloaded from the Confessions website, and the main characteristic is that the dataset itself comprises various emotional states, punctuation marks, emoticons, and the like. The downloaded dataset has sentiment distribution and a target column determined based on the "approve" and "condemn" fields. The distribution of sentiments is shown in Fig 2.

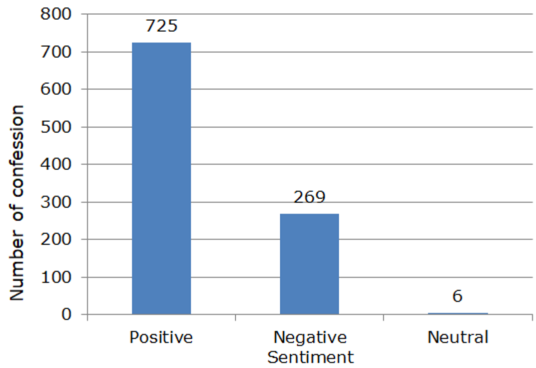

Figure 2. *Distribution of sentiments*

WordCloud is a visualization technique that displays words from a text dataset, with the size of each word indicating its frequency or importance within the dataset. The word cloud visualization for positive sentiments is shown in Fig 3 and in Fig 4 is the word cloud for negative sentiments.

Figure 3. *The Word Cloud in Positive Classes*

Figure 4. *The Word Cloud in Negative Classes*

In Table 5 various results for the model metric are presented. This may indicate overfitting of the model to the training set, which is a common issue when working with machine learning. The best models, such as Random Forest and Decision Tree, should be further investigated to determine whether their performance on the test set is truly based on their general capabilities or if the results are due to overfitting.

Table 5. *Training and test set values*

Model metric	Training	Test
Random Forest	1.0	0.73
Gradient Boosting	0.92125	0.675
SVC	0.9275	0.74
Multinomial NB	0.73	0.74
Logistic Regression	0.82125	0.72
K-Neighbors	0.765	0.735
Decision Tree	1.0	0.56
Random Forest 100	1.0	0.73
Gradient Boosting 100	0.9225	0.685
Linear SVC	0.82375	0.74

ROC/AUC curves and solutions obtained for the Serbian language. For each language group, the best model that provides the highest AUC can be identified, while the **Decision Tree** classifier is less effective in all analyzed cases. This information can be useful in selecting models for specific language tasks in the future. **Decision Tree** has the weakest performance. For the Serbian language, the AUC is 0.72. **SVM** and **Logistic Regression** classifiers show good results for the Serbian language, while **Decision Tree** shows significantly worse results compared to other classifiers.

The **poor decision** to use the Decision Tree model can be attributed to its tendency for **overfitting, instability, and limited** ability to model complex patterns in the data.

Multinomial NB achieves the best result for Serbian language of 0.91 AUC, as shown in Fig 5.

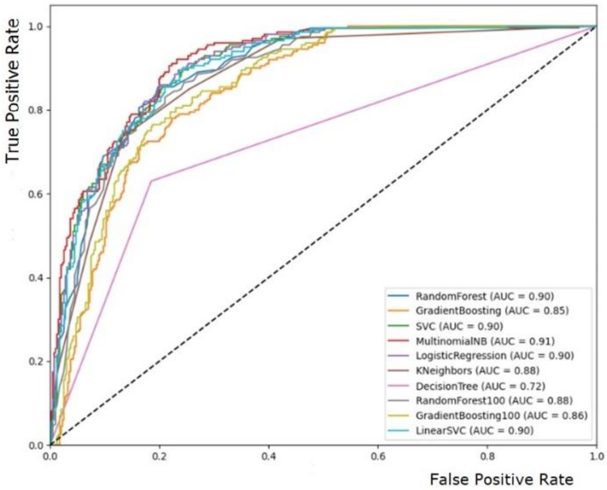

Figure 5. *ROC curve for different classifiers*

The overview of values provided is located in the lines below:

- **RandomForest: AUC = 0.90**
- **GradientBoosting: AUC = 0.85**
- **SVC: AUC = 0.90**
- **MultinomialNB: AUC = 0.91**
- **LogisticRegression: AUC = 0.90**
- **KNeighbors: AUC = 0.88**
- **DecisionTree: AUC = 0.72**
- **RandomForest100: AUC = 0.88**
- **GradientBoosting100: AUC = 0.86**
- **LinearSVC: AUC = 0.90**

5. CONCLUSION

Based on a detailed and systematic approach to processing and analyzing textual data, this paper provides significant insights into the field of NLP and its potential for understanding, interpreting, and exploiting textual information. By applying a wide range of text preprocessing techniques, including tokenization, normalization, and lemmatization, the paper demonstrates crucial methodological aspects necessary for effective textual data analysis. Notably, the use of various metrics to evaluate the performance of machine learning models is emphasized. Precision, recall, F-measure, ROC/AUC curve, and other metrics enable a comprehensive analysis and assessment of different models' performances, which is essential for selecting the best model for a specific application.

Additionally, by exploring machine learning algorithms for sentiment classification in confessions from the "Confessions" website, the paper provides insights into various aspects of sentiment and emotional state modeling in text. Through the application of different metrics and analytical methods, the paper achieves a deeper understanding of sentiment in confessions and identifies the most effective classifiers for sentiment analysis in the Serbian language.

The paper not only contributes to the advancement of methods and techniques in NLP but also paves the way for future research in this field, offering valuable recommendations for further investigation and development in NLP. We conclude that in order to achieve better performance we have to proceed with enlarging dataset for model training.

One of the most significant constraints in this research is the linguistic complexity of the Serbian language. The availability of high-quality, large-scale datasets in the Serbian language is limited. Most existing datasets are either too small for robust machine learning model training or not specifically designed for sentiment analysis tasks. This limitation affects the generalizability and performance of the models trained on such data. The application of Naive Bayes algorithm can lead to lower accuracy and precision in classification tasks, particularly when dealing with complex sentence structures or context-dependent sentiments. This constraint limits the ability to experiment with and deploy more sophisticated models that could potentially offer better performance.

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Natural Language Processing in Contextual Modeling for Sentiment Analysis in Serbian and Languages of the Germanic-Romance Language Group

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Abstract: This paper explores context modeling concepts for comparing natural language processing (NLP) of Serbian with the Romance-Germanic language group, focusing on Serbian, English, German, and French. The study delves into vector semantics and embedded representations, utilizing term-document and term-context matrices, cosine similarity measures, TF-IDF, and Pointwise Mutual Information matrices. A special emphasis is placed on the psychological context in defining affective computing and emotions. The research concludes with a sentiment analysis of forum texts originally in Serbian, translated into English, French, and German, highlighting the model's varying results based on language complexity. Finally, the paper presents model metrics, including comparisons of the ROC/AUC curves, accuracy across various classifiers, and a detailed analysis using SVM classifiers.

Keywords: *Context Modeling; Natural language processing; Vector Semantics;* Sentiment Analysis*;* Affective Computing.

1. INTRODUCTION

This paper describes concepts of context modeling for comparing the NLP of languages such as Serbian with the Romance-Germanic language group. The focus is particularly on Serbian, English, German, and French. Context modeling is based on defining vector semantics and embedded representations, defining matrices such as term-document matrix and term-context matrix, defining the cosine similarity measure of strings, as well as matrices like TF-IDF and Pointwise Mutual Information. The psychological context of defining affective computing and emotions is particularly emphasized. The review concludes with a sentiment analysis of forum texts originally in Serbian and translated into English, French, and German. Significantly, the model provides different results depending on the natural language and its complexity. At the end, model metrics are provided, along with comparisons of the ROC/AUC curve, accuracy on different classifiers, and on a selected classifier such as SVM.

2. RELATED WORK

In recent years, the application of NLP techniques in sentiment analysis for less-resourced languages, such as Serbian, has seen substantial growth. Sentiment analysis aims to extract and evaluate subjective content from textual data, which is crucial for various fields like social media monitoring, customer feedback, and market analysis. However, performing sentiment analysis in the Serbian language presents unique challenges due to its complex linguistic features, including intricate morphology and syntax, which can greatly affect sentiment interpretation.

For example, research by Draskovic et al. developed a multilingual model for sentiment analysis tailored to Serbian. The study utilized multiple datasets, including reviews translated into Serbian, and explored various machine learning algorithms to optimize sentiment classification in the context of a low-resource language environment [1].

Additionally, a comparative study on cross-lingual sentiment analysis using large language models, such as mBERT and XLM-R, highlighted the advantages of using pre-trained models for sentiment analysis across different languages, including those from the Germanic and Romance language groups. This research emphasized the importance of zero-shot and few-shot learning techniques, which allow these models to perform well in languages with limited labeled data by transferring knowledge from languages with richer resources [2].

These studies collectively underscore the ongoing challenges and opportunities in developing effective NLP techniques for sentiment analysis in Serbian and highlight the potential of cross-lingual and multilingual approaches to improve performance in less-resourced languages.

3. CONTEXT MODELING

Context modeling represents the process of creating a model that takes into account the circumstances or context in which information appears. Context can include various aspects such as time, place, situation, or prior information. In some NLP models, context is used to better understand ambiguous words or phrases, or to get more accurate representation of what a sentence truly means.

3.1. Vector Semantics and Embedded Representations

The most significant term in linguistics and the basic unit is the word. Words often appear alongside words with similar meanings, a concept known as the distributional hypothesis. The task of the distributional hypothesis is to determine that words frequently appearing in the same or similar contexts tend to have similar meanings. For example, the word "phone" is usually found alongside the word "mobile," or the abbreviation "radio" can be associated with "Radio Television of Serbia." This hypothesis stems from the observation that similar words tend to appear near each other in a text.

Vector semantics deals with the linguistic hypothesis of similarity between words, sometimes referred to as **embedding**. It analyzes the arrangement of sentences in texts. The best model for representation in texts based on meaning is chosen as a conclusion.

The models for representing meaning are expected to have key aspects such as: semantic relationships, contextual understandings, lexical and syntactic connections, directed analyses, customized word representations, inferential capabilities, word contrasts, and word associations.

Semantic relationships should enable connections between words such as **synonyms** (words that have similar or identical meanings, used to express the same or very similar concept, idea, or notion. For example, "happiness" and "joy" are synonyms because both words express the concept of a positive emotional state), **antonyms** (words that have opposite or contrasting meanings. In other words, they represent words expressing opposing concepts, ideas, or emotions. For example, "good" and "bad" are antonyms because they express opposite qualities or states), **hyponyms** (words that represent a subclass or subcategory of other words, known as hypernyms. In essence, a hyponym is a more specific term that fits within the more general term represented by the hypernym. For example, in the order "man" is a hyponym for "person," because "man" falls within the category of "person"), **hypernyms** (words that represent a more general concept or category to which other words known as hyponyms belong. For example, in the order "person" is a hypernym for "man" and "woman").

Contextual understandings represent the ability to adapt the meaning of words depending on the context in which they appear.

Connotations include distinguishing between different connotations such as positive, negative, and neutral. Connotation encompasses aspects of emotions, attitudes, and opinions associated with words. Some words have positive connotations, while others have negative. Sentiment is a concept encompassing evaluative language, which is important for sentiment analysis and other tasks in natural language processing. This research has found that words vary along three important dimensions of affective meaning: **valence (happy, annoyed), arousal (excited, calm), and dominance (controlling, astonished).** Using these dimensions, words can be represented as points in a three-dimensional space, which is the basis for vector semantic models.

Lexical and syntactic connections need to encompass all words, dictionaries, phrases, and expressions used in the language. These are the basic units of language that carry meaning. The lexicon includes dictionaries, synonyms, antonyms, idioms, phrases, and all other forms of expression used for communication. Syntax refers to the rules and structure that define how words are organized into sentences and phrases in a language. It encompasses rules for the grammatical structure of sentences, including word order, verb forms, subject and object identification, and the use of different types of sentences.

Directed analyses often reveal that words have directed meanings, such as **polysemy** (a linguistic concept indicating the existence of multiple distinct meanings or senses for the same word. Essentially, a polysemous word has more than one meaning or use in different contexts. Polysemous words have meanings that depend on the context in which they are used, for example, the word "bank" can refer to a financial institution or the side of a river) and **ambiguity** (a concept used when there are multiple different interpretations or understandings of an expression, sentence, or text. For example, "The representative from Bratunac is on the Serbian national team" can mean a sports team representing Serbia in an international competition or a group of individuals representing the town of Bratunac).

Customized word representations can often refine a model for various tasks in the field of natural languages. Inferential capabilities and conclusions are drawn based on the meaning of words in different contexts.

Word contrast defines that a difference in linguistic form is always associated with some difference in meaning. For example, errors reported by a web application are technically called exceptions, but a user tells the developer that an error occurred, not an exception. Word association is defined as a connection. For example, when thinking of the word "Bratunac", it is often associated with war (thinking of Bratunac reminds us of Serbian victims in the mid-Drina region). Thus, these two nouns do not have a common meaning but are connected.

A very important feature is the thematic word model based on a model **like LDA (Latent Dirichlet Allocation),** which aims to apply supervised learning on corpora to derive sets of related words, based on similar words, usually called semantic fields [3].

A semantic field includes a group of words related to the same topic or area, such as words related to hospitals or restaurants. A semantic frame represents a set of words describing perspectives or participants in a particular type of event, such as a commercial transaction. The roles of words in context are important as they help understand how a sentence functions and how it can be paraphrased or analyzed.

3.2. Vector word representation and word embedding

In natural language processing, vector semantics is most commonly used to represent words. There are two significant approaches to natural language processing. The first approach uses points in a **three-dimensional** space to represent the connotation of words. The second approach is based on the work of linguists and represents words by their distribution in language use. **The simplest** way to represent a word is as a point in a multidimensional semantic space based on the distribution of embedded words. The concept of embedding itself denotes a mathematical model of mapping one space or structure into another space, although the meaning has evolved [4].

3.3. Term-Document Matrix

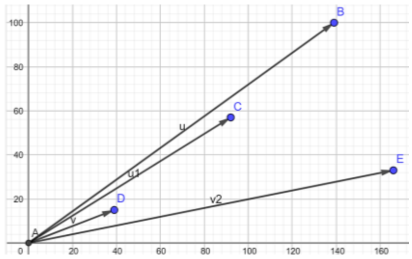
The term-document matrix is a matrix where each **row represents a word in the vocabulary, each column represents a document from a collection of documents, and each cell represents the frequency of a specific word (row) in a particular document (column).** Similar documents have similar vectors, and likewise, similar documents share similar words. The term-document matrix, in its structure, allows for the representation of word meaning based on the documents. In **Table 1**, the works of the Serbian Nobel laureate Ivo Andrić are given: "The Bridge on the Drina" [5], "Bosnian Chronicle" [6], "The Woman from Sarajevo" [7], "The Damned Yard" [8], and the occurrence of certain words. For example, the word "life" appears 100 times in the novel "Travnicka Chronicle".

Table 1. *Literary works of Ivo Andrić and frequency of occurrence of certain words*

	Na Drini ćuprija	Travnička hronika	Gospođica	Prokleta avlija
most	399	**8**	14	0
ljudi	166	**139**	92	39
život	83	**100**	57	15
sreća	0	**0**	3	2
reka	12	**1**	0	1
vrijeme	8	**4**	18	1

The term-document matrix represents a document as a vector in space. A vector is a one-dimensional array or list of numbers [9]. The vector space represents a collection of vectors characterized by their dimensions. For example, the document "Bosnian Chronicle" can be represented by the following vector: [8, 139, 100, 0, 1, 4]. The document has a dimension of |V|, which is the size of the vocabulary. The order of the numbers indicates the different dimensions by which the document varies (Fig. 1).

The vector |V| has a dimension of 6, and since it is challenging to visualize vectors in a six-dimensional space, the visualization is often shown in two dimensions, where 2 words are selected from the entire vocabulary for display. The matrices were initially defined to extract information about similar documents. If documents are similar, they will have similar words, and their vectors will tend to be similar. This is a simple example, but in reality, the matrix and vocabulary size can be on the order of several thousand, and the number of documents can be enormous. In Fig. 1, a depiction of word vectors is given, where the word "people" is shown on the X-axis and the word "life" on the Y-axis.



Point	Coordinates
B	(139, 100)
C	(92, 57)
D	(39,15)
E	(166, 83)

Figure 1. *Display of coordinates with terms*

3.4 Term-Document Matrix (Word – word)

When words appear in the same context, this matrix has dimensions |V|×|V|. Here, |V| represents the size of the vocabulary, i.e., the number of different words in the text corpus. In this **matrix**, rows and columns are labeled with words, and each cell within the matrix contains information about how many times a particular word appears in the context of another word (Table 2).

Table 2. *Example matrix term – context*

Point	Coordinates
B	(50, 31)
C	(3, 3)
D	(3,0)

	varoš	**mesto**	**kraj**	**poreklo**
selo	21	50	31	3
tradicija	0	3	0	15
koliba	3	3	3	10
put	2	15	12	0

The primary purpose of the term-context matrix is to provide a record for each word in the vocabulary of the contexts in which it most commonly appears. An example is given in Table 2. The context can be defined in various ways, such as neighboring words in a sentence, words nearby within the same paragraph, or even within the same document. By using this matrix, it is possible to derive estimates of semantic relationships between words in the text, as well as to apply various machine learning techniques for text data analysis [10].

3.5. Similarity measure based on the cosine of the angle

The cosine similarity measure utilizes the cosine of the angle between two vectors as an indicator of their similarity. This measure is commonly employed in text analysis and natural language processing. To calculate the similarity between two vectors v and w, the cosine of the angle between their vector representations is first computed.

The scalar product (dot product) of two vectors is defined by formula (1).

$$a \cdot b = |a||b| \cdot \cos\theta \quad (1)$$

The cosine of the angle between two vectors is defined by formula (2).

$$\cos(v, w) = \frac{v \cdot w}{|v||w|} \quad (2)$$

where:

- $\boldsymbol{v \cdot w}$ is the dot product between vectors $\boldsymbol{v}$ and $\boldsymbol{w}$,
- $\|\boldsymbol{v}\|$ and $\|\boldsymbol{w}\|$ are the norms (lengths) of vectors v and w, respectively.

This cosine similarity measure provides a value between -1 and 1, where:

- Values close to 1 indicate high similarity between the vectors.
- Values close to -1 indicate high dissimilarity between the vectors.
- Values close to 0 indicate orthogonality or no significant similarity between the vectors [11].

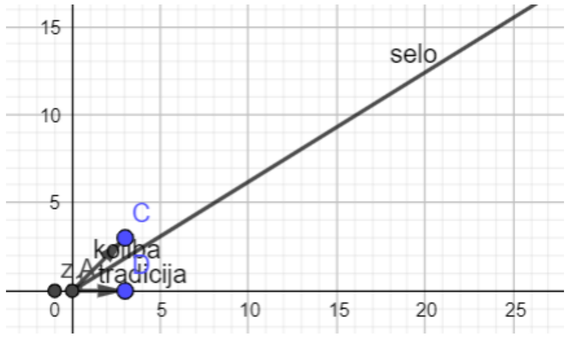


Figure 2. *Similarity measure based on the angle cosine trigonometric function*

The intensity of a vector is usually defined by formula (3).

$$|v| = \sqrt{\sum_{i=0}^{N-1} {v_i}^2} \quad (3)$$

According to this formula, the following expression (4) is obtained for calculating the cosine of the angle:

$$\cos(v, w) = \frac{v \cdot w}{|v||w|} = \frac{\sum_{i=0}^{N-1} v_i w_i}{\sqrt{\sum_{i=0}^{N-1} {v_i}^2}\sqrt{\sum_{i=0}^{N-1} {w_i}^2}} \quad (4)$$

According to Table 2, similarity could be calculated using the expressions (5 - 12).

$$\cos(selo, koliba) = \frac{selo \cdot koliba}{|selo||koliba|} \quad (5)$$

$$\cos(selo, koliba) = \frac{\sum_{i=0}^{N-1} selo_i koliba_i}{\sqrt{\sum_{i=0}^{N-1} {selo_i}^2}\sqrt{\sum_{i=0}^{N-1} {koliba_i}^2}} \quad (6)$$

$$\cos(selo, koliba) = \frac{selo \cdot koliba}{|selo||koliba|} \quad (7)$$

$$\cos(selo, koliba) = \frac{21*3+50*3+31*3+3*10}{\sqrt{21^2+50^2+31^2+3^2}\sqrt{3^2+3^2+3^2+10^2}} \quad (8)$$

$$\cos(selo, koliba) \approx 0.425 \quad (9)$$

$$\cos(selo, tradicija) = \frac{selo \cdot tradicija}{|selo||tradicija|} \quad (10)$$

$$\cos(selo, koliba) = \frac{21*0+50*3+31*0+3*15}{\sqrt{21^2+50^2+31^2+3^2}\sqrt{0^2+3^2+0^2+15^2}} \quad (11)$$

$$\cos(selo, koliba) \approx 0.203 \quad (12)$$

The village and the cottage have a higher similarity, with a value closer to 1, indicating greater similarity!

3.6. Similarity measure based on the cosine of the angle

The TF-IDF matrix is an important tool in text processing. It is used to represent textual documents as vectors, where words from the text are represented as frequencies of occurrence in the documents. The TF-IDF matrix consists of terms (words) as rows and documents as columns. For each word and each document, the TF-IDF value represents the measure of importance of that word in that document, with a preference for words that are important for that document but rare in other documents. TF (term frequency) represents the number of occurrences of a given word in a document, while IDF (inverse document frequency) represents the inverse frequency of occurrence of that word in all documents in the dataset. The idea is that words that appear in more documents (i.e., more frequently in the corpus) have lower IDF values, while words that are rare in more documents have higher IDF values.

Combining TF and IDF measures highlights the significance of words in a specific document compared to the entire set of documents. Not every word has a TF matrix; it is only for words that have expressed meanings, such as "river," "water," "nature," while words like "and," "but," "then," "already," "while," "and," "so," "then," "nor," "neither" do not have a TF set. Term frequency is given by formula (13) for a word 't' and document 'd' as established by Lunh in his work from 1957 [12]. Basic counting is used to show the frequency of term occurrence.

$$tf_{t,d} = count(t, d) \tag{13}$$

TF according to formula (14) measures how many times a certain term appears in a document. It is calculated as the ratio of the number of times the term appears in the document to the total number of terms in the document.

$$TF(t, d) = \frac{f_{t,d}}{\sum_{t' \in d} f_{t',d}} \tag{14}$$

where:

- ***N*** is the number of times the term ***t*** appears in document ***d***. The numerator represents the total number of terms in document ***d*** .

IDF (Inverse Document Frequency) is given by formula (15) and represents a measure of how much information a term provides, or more precisely, how common or rare it is across documents [13].

$$IDF(t, d) = log\frac{N}{1 + |\{d : d \in D \text{ и } t \in d\}|} \tag{15}$$

Where **N** represents the total number of documents in the corpus. $N = |D|$, the number of documents where the term t appears. If the term is not in the corpus, it will lead to division by zero. Therefore, 1 is usually added to the denominator. TF-IDF combines TF and IDF to obtain the importance of a term in a document relative to the entire set of documents. It is calculated by multiplying TF and IDF for each term in the document. The formula for computing TF-IDF is given by expression (16):

$$TF - IDF(t, d, D) = TF(t, d) \times IDF(t, D) \tag{16}$$

The basic idea behind TF-IDF is that terms that appear frequently in a document but are rare across the entire set of documents are more important for determining the theme or content of the document. In other words, they are good indicators of term relevance for a given document compared to others.

This calculation aims to determine the representation of two documents given the procedure of calculating term occurrence according to expressions from formulas (17) - (26) as shown in Table 3.

Table 3. *Example of two documents with terms*

Document 1		Document 2	
Word	Number of words	Word	Number of words
Volim	1	*Volim*	1
Republiku	2	*Republiku*	3
Srpsku	1	*Srpsku*	1

$$TF(\text{'Volim'}, d1) = \frac{1}{4} = 0.25 \tag{17}$$

$$TF(\text{'Volim'}, d1) = \frac{1}{5} = 0.2 \tag{18}$$

$$TF(\text{'Volim'}, D) = log\frac{2}{2} = 0 \tag{19}$$

The word "Volim" is not informative and does not carry information because it appears in all documents.

$$\text{TF} - IDF\,(\text{'Volim'}, d1, D) = 0.25 \times 0 = 0 \tag{20}$$

$$\text{TF} - IDF\,(\text{'Volim'}, d2, D) = 0.2 \times 0 = 0 \tag{21}$$

$$TF(\text{'Srpsku'}, d1) = \frac{0}{4} = 0 \tag{22}$$

$$TF(\text{'Srpsku'}, d2) = \frac{1}{5} = 0.2 \tag{23}$$

$$TF(\text{'Srpsku'}, D) = log\frac{2}{1} = 0.301 \tag{24}$$

$$\text{TF} - IDF\,(\text{'Srpsku'}, d1, D) = 0 \times 0.301 = \mathbf{0} \tag{25}$$

$$\text{TF} - IDF\,(\text{'Srpsku'}, d2, D) = 0.2 \times 0.301 = \mathbf{0.0602} \tag{26}$$

3.7. Pointwise mutual information (PMI)

PMI (Pointwise Mutual Information) is a measure used in text processing and is one of the **fundamental measures for evaluating the relationship between two terms in textual documents**. PMI is used to assess how much two terms co-occur together compared to their occurrence when they appear independently.

PMI is defined between two terms A and B by formula (27) [14]:

$$PMI(A, B) = \log\left(\frac{P(A,B)}{P(A) \cdot P(B)}\right) \tag{27}$$

Where:

- $P(A, B)$ represents the probability of occurrence of term A and term B appearing together in the document.

- $P(A)$ *and* $P(B)$are the probabilities of occurrence of term A and term B in the document, respectively.

The PMI value is positive if terms A and B frequently occur together in the text, more than expected if their occurrences were $P(A, B)$ is greater than the product of $P(A)$ and $P(B)$. The PMI value is negative if terms A and B occur together less frequently than expected.

To focus only on positive PMI values, absolute negative values are ignored and replaced with zero. Additionally, if the focus is on strong associations between terms while ignoring weak associations or noise, the Positive Pointwise Mutual Information (PPMI) method, given by formula (28) [13], is used:

$$I(A, B) = \max\left(\log_2 \frac{P(A,B)}{P(A) \cdot P(B)}, 0\right) \tag{28}$$

4. AFFECTIVE COMPUTING

Affective computing, also known as affective computing, is a branch of computer science that focuses on developing systems and devices capable of recognizing, interpreting, and responding to human emotions. The goal of affective computing is to create machines that can understand and simulate human affective states, such as emotions and moods, in order to enhance human-computer interaction and improve the user experience. This field involves the integration of various disciplines, including computer science, psychology, cognitive science, and neuroscience, to develop algorithms and techniques for emotion recognition, affective modeling, and emotion-aware systems. Affective computing applications range from virtual assistants and social robots to emotion-aware user interfaces and affective gaming systems [16].

4.1. Defining Emotions

Emotions are complex psychological and physiological processes that play a crucial role in human communication and behavior. In the context of NLP, the recognition and analysis of emotions are becoming increasingly significant due to their application in various fields, including customer support, healthcare, education, and social media analysis. Examples of emotional expressions in animals are provided.

According to **Scherer**, emotions are defined as relatively short episodes of response to the evaluation of an external or internal event. Automatic detection of emotions in reviews or customer responses (anger, dissatisfaction, trust) could help businesses identify specific problematic areas or those that are functioning well. Emotions are often intertwined with mood, temperament, personality, disposition, or creativity [17].

Robert Plutchik emphasized that a similar method of accumulating primary emotions and combining them results in other emotions derived from the basic ones. According to Panksepp, there are seven biologically inherited primary affective systems known as seeking, fear, rage, lust, panic, and play. Meanwhile, according to Russell's theory, most of these models involve two basic dimensions: arousal and valence, with the addition of a third dimension, which is dominance [18].

According to Russell, these dimensions are defined as follows:

- **Valence**, or stimulus valence, refers to pleasantness. Valence maintains the response to a specific event or situation. Positive valence sustains pleasant emotions such as happiness or joy, while negative valence denotes unpleasant emotions such as sadness and anger.

- **Arousal** is a dimension related to the level of activity, alertness, or energy induced by a stimulus. High arousal is associated with emotions such as excitement or anger, while low arousal is associated with emotions like calmness or sadness.

- **Dominance** refers to the degree of control or influence exerted by a stimulus or emotion. High dominance emotions include feelings of control and power, while low dominance emotions involve feelings of helplessness or submission [19].

4.2. Lexicons of Affect

Lexicons of affect are sets of words and phrases that are associated with emotions and feelings. They serve as resources for text analysis in NLP, enabling computer systems to identify and classify emotional content in text. These lexicons typically include words labeled with different emotional categories, polarity (e.g., positive or negative), and often emotion intensity.

Applications of affect lexicons include sentiment analysis (detecting overall tone), emotion detection (emotion intensity), social media monitoring (analyzing user posts, comments, and reviews), and market research (analyzing customer feedback to gain insights into product or service perception).

The process of creating lexicons or sentiment dictionaries is a complex one involving several steps. The main goal is to determine the purpose for which the lexicon will be used, followed by identifying which sentiment categories it will cover. Data collection involves gathering a large corpus of text relevant to the domain being analyzed, such as movie reviews. Data is typically collected from the web using web scraping techniques. Text cleaning involves removing unnecessary elements and applying NLP techniques such as tokenization, lemmatization, or stemming.

Significant features are extracted, such as words or phrases carrying sentiment value. Sentiment values are assigned, which can be binary or scalar, for example, in the range from -5 to 5.

4.3. Using lexicons for sentiment and affect recognition

Lexicons are used when there is not enough data for supervised learning. Although it can often be inefficient to assign sentiment to each document manually for training classifiers. The most straightforward approach is to have only a ratio of positive and negative words in the document. If the document has more positive words than negative words, the lexicon used to define polarity determines that it is a positive sentiment, so a threshold denoted by λ is used.

Let N_{pos}, be the number of positive words in the document, N_{neg} be the number of negative words in the document and λ be the classification threshold. If $N_{pos} > \lambda \cdot N_{neg}$, the document is classified as positive.

In the case where the lexicon contains weights θ_{pos}^{ω} and θ_{neg}^{ω} for each word ω, the algorithm is based on formula (29):

$$Sentiment(D) = \frac{\sum_{\omega \epsilon D} \theta_{pos}^{\omega} - \sum_{\omega \epsilon D} \theta_{neg}^{\omega}}{|D|} \quad (29)$$

D - document being classified,

|D| - total number of words in the document.

If $Sentiment(D) > 0$, the document is classified as positive, if $Sentiment(D) < 0$, as negative.

Detecting emotions in text is often achieved using supervised classification. The training set is labeled for affective meanings, and the classifier is built based on features from that set. Similar to sentiment analysis, classifiers such as SVM or logistic regression are effective algorithms. For large datasets, it may be necessary to use parts of speech or lexicon selection.

This concept is based on formula (30)[20]:

$$PMI(phase) = log \frac{p(phrase)}{\prod_{w \epsilon phrase} p(w)} \quad (30)$$

The formula for the probabilities of expressions (31) within the given subject, used to calculate the probabilities of a certain phrase appearing in the context of the subject, such as emotional states and personalities [20].

$$p(phrase\,|subject) = \frac{\sum freq(phrase,subject)}{\sum freq(phrase,subject_0 \epsilon vocab(subject))} \quad (31)$$

$p(phrase\,|subject)$ - represents the conditional probability of the phrase occurring within a given set.

Formula (32) is used for the indicator function of a feature from the lexicon. This formula evaluates the presence of a specific lexicon in a given text [20].

$$fL(c,x) = \begin{cases} 1\ ako\ je\ \exists w: L\ i\ w\ \in x\ i\ klasa = C \\ 0 -\ other \end{cases} \quad (32)$$

5. DATA COLLECTION AND IMPLEMENTATION OF A PRACTICAL EXAMPLE

Table 4 shows the various results for the model metrics. This may indicate overfitting of the model on the training set, which is a common problem when working with machine learning. The best models, such as Random Forest and Decision Tree, should be further examined to determine whether their performance on the test is really based on their general abilities or is the result of overfitting.

For the English language, RandomForest performed best with an AUC of 0.90.For the French language, **SVC**, **LogisticRegression**, and **LinearSVC** perform best with an AUC of 0.88.For the German language, **SVC**, **LogisticRegression**, and **LinearSVC** are the most successful with an AUC of 0.90. For the Serbian language, MultinomialNB is the best with an AUC of 0.91. (Table 4 and Fig. 3, Fig. 4, Fig. 5, Fig. 6). **Decision Tree** consistently shows an AUC of around 0.72 to 0.76, which is well below the performance of other models, confirming that the model is likely overfitted on the training data and failed to generalize on the test set. Considering other models or using variance reduction techniques and controlling tree depth can improve the performance of Decision Tree models.

Table 4. *Overview of the performance of the classifier with the best accuracies by language*

Serbian language	**English language**
AUC za svaki klasifikator: RandomForest: AUC = 0.90 GradientBoosting: AUC = 0.85 SVC: AUC = 0.90 MultinomialNB: AUC = 0.91 LogisticRegression: AUC = 0.90 KNeighbors: AUC = 0.88 DecisionTree: AUC = 0.72 RandomForest100: AUC = 0.88 GradientBoosting100: AUC = 0.86 LinearSVC: AUC = 0.90	AUC za svaki klasifikator: RandomForest: AUC = 0.90 GradientBoosting: AUC = 0.88 SVC: AUC = 0.89 MultinomialNB: AUC = 0.87 LogisticRegression: AUC = 0.89 KNeighbors: AUC = 0.87 DecisionTree: AUC = 0.72 RandomForest100: AUC = 0.89 GradientBoosting100: AUC = 0.88 LinearSVC: AUC = 0.88
German language	**French language**
AUC za svaki klasifikator: RandomForest: AUC = 0.89 GradientBoosting: AUC = 0.89 SVC: AUC = 0.90 MultinomialNB: AUC = 0.89 LogisticRegression: AUC = 0.90 KNeighbors: AUC = 0.86 DecisionTree: AUC = 0.76 RandomForest100: AUC = 0.89 GradientBoosting100: AUC = 0.89 LinearSVC: AUC = 0.90	AUC za svaki klasifikator: RandomForest: AUC = 0.87 GradientBoosting: AUC = 0.85 SVC: AUC = 0.88 MultinomialNB: AUC = 0.86 LogisticRegression: AUC = 0.88 KNeighbors: AUC = 0.85 DecisionTree: AUC = 0.73 RandomForest100: AUC = 0.87 GradientBoosting100: AUC = 0.85 LinearSVC: AUC = 0.88

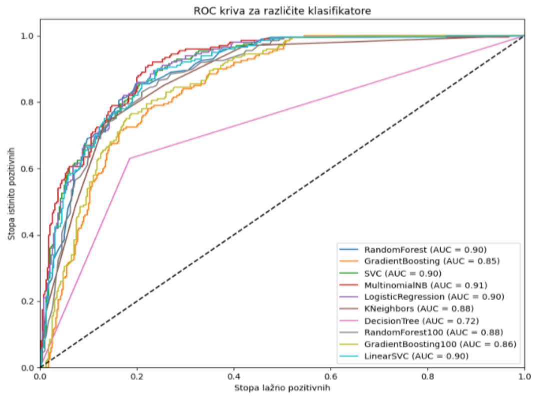


Figure 3. *ROC/AUC curve in Serbian language results*

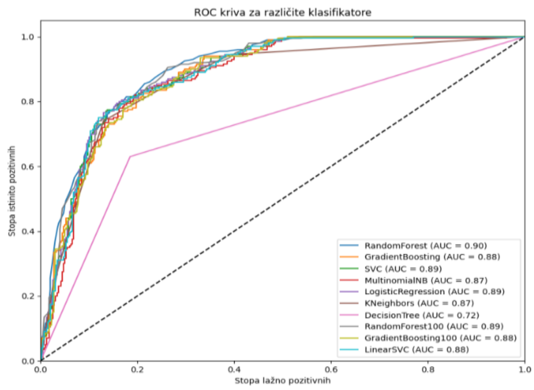


Figure 4. ROC/AUC curve in English language results

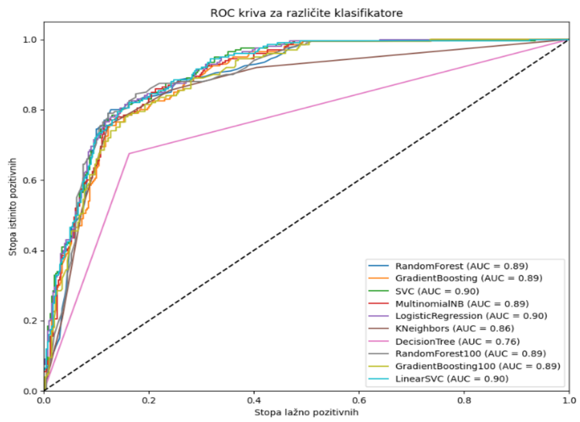


Figure 5. ROC/AUC curve in German language results

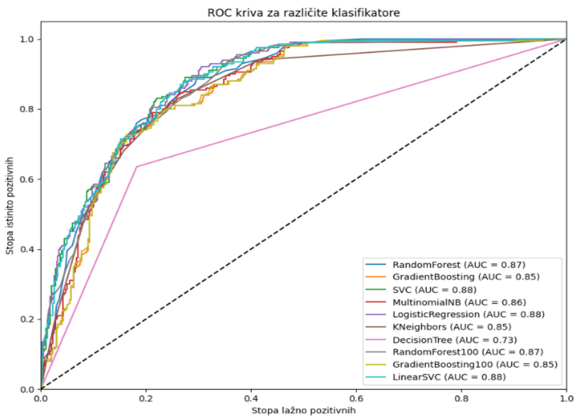


Figure 6. ROC/AUC curve in French language results

6. CONCLUSION

The text explores the concept of vector semantics and embedded representations in natural language processing (NLP). It emphasizes the importance of representing words as vectors in a semantic space to capture their meanings, contexts, and relationships. The distributional hypothesis suggests that words frequently appearing in similar contexts tend to have similar meanings, which forms the basis for many NLP models. The text discusses various models and measures used to represent and analyze word meanings, such as the term-document matrix, TF-IDF, and cosine similarity. It also highlights the significance of semantic relationships, contextual understanding, and lexical connections in understanding and processing natural language. Additionally, the text introduces the concept of affective computing, which focuses on developing systems capable of recognizing and responding to human emotions, thereby enhancing human-computer interactions. Overall, the text provides a comprehensive overview of key concepts and methods in vector semantics and their applications in NLP.

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Minimalistic User Interface Design and Dark Mode Usage in Human-Computer Interaction

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Abstract: *When it comes to minimalist design and dark mode, these are two very current topics in today's design, development, and implementation of web and mobile applications. Often heard is the phrase "Less is more," which will be explained in detail through this paper, both from a theoretical perspective and with practical examples. Minimalist design has numerous advantages from various perspectives, but it also presents a significant challenge for designers because it requires highlighting everything important in the right way without excessive decoration and too many details. On the other hand, dark mode also presents a challenge, but from a technical standpoint, it has many advantages, as well as from the perspective of user experience. In comparison to lighter themes, it facilitates viewing the screen during the night and contributes to energy savings. In summary, today, minimalism and dark mode, in combination, when creating design software, improve the user interface (UI) and user experience, and enhance application performance in various fields.*

Keywords: *dark mode; human-computer interaction; user experience; user interface; minimalism*

1. INTRODUCTION

In today's world, life without mobile phones, laptops, tablets, and other similar devices is unimaginable. The field of information technology is constantly evolving. New principles are being created, applications are being developed, all aimed at making life easier, solving problems more quickly, and accessing information, which is considered to have the greatest value today.

Everything is being digitized, and it is necessary to keep pace with the times. In line with this, consideration must be given to different generations of people who will use them, various levels of education, as well as the diverse psycho-physical abilities of people. In this regard, the implemented application must be accessible to as many people as possible in a simple way. This simplicity is achieved through the use of minimalist user interface design and dark mode.

Minimalist design is a concept in design that focuses on essential elements and a simple aesthetic, while dark mode provides a dark background that reduces eye strain and improves visibility, especially in low-light conditions, thus enhancing the user experience.

The aim of this paper is to illustrate what these two techniques represent, how they originated, what is gained by their implementation, but also the risks of achieving excessive complexity due to improper implementation of these techniques. As in everything, there are basic principles that should be followed to ensure that the end product is satisfactory.

The rest of the paper is organized as follows. The second section describes minimalist design, along with its advantages compared to classic design and its implementation in UX/UI design. The third section describes dark mode, its application, and its benefits. The fourth section presents a practical example of implementing the principles described in the previous sections. Finally, in the fifth section, a conclusion is provided in which opinions on everything mentioned and implemented in the paper are outlined.

2. MINIMALIST DESIGN

Minimalist design is an aesthetic principle that focuses on simplicity and reduction. It is characterized by clean lines, minimal ornamentation, and functionality. Minimalism exists on the spectrum between emptiness and presence, with a focus on removing excess and retaining only the most essential elements.

Decades before minimalism became a trend in web design, it was a movement in visual arts in the post-World War II era. It emerged as a reaction to chaotic colors, movements, and the pronounced subjectivity often found in the works of abstract artists [1].

The perspective behind minimalist art was expressed by the motto of the renowned 20th-century architect Ludwig Mies van der Rohe: "Less is more." This motto later became the spirit and unofficial mantra of minimalism in web design: fewer elements on the page result in less cognitive load for users [1].

By the end of the twentieth century, minimalism began to shape as a distinct trend in the field of human-computer interaction [2].

The emergence of Responsive Web Design (RWD) in 2010 prompted the broader users to appreciate a minimalist approach. To effectively utilize RWD techniques, organizations must carefully prioritize their content—distracting from primary content that can be overlooked on desktops becomes a significant issue on mobile devices [1, 2, 3, 4].

Starting from the mid-2000s, echoes of the minimalist art movement began to appear in web interfaces: smaller amounts of content and limited color palettes. Google is often considered a pioneer of minimalist web interfaces. Google has prioritized simplicity and rigor in its interfaces since its beta offering in the 1990s.

2.1. Minimalist design advantages

In 1995, Jakob Nielsen included minimalist design in his 10 usability heuristics. His use of the term was in line with Tufte's and Carroll's sense of minimalism, as he advocated for the elimination of irrelevant information from interfaces. The advantages of minimalist design according to Nielsen are [5]:

- *Simple Navigation*: Navigation remains consistent in terms of where it appears and how it appears on the website, facilitating users in quickly finding relevant information. If there are multiple sections, they should be categorized to maintain order and cleanliness. Additionally, if there is a dropdown menu for navigation, ensure that all links are clickable. Finally, if you have a search box embedded in your website, make sure it always provides relevant and fast results.
- *Usability*: Easier navigation is the basic pillar of improved usability. Minimalist design is trending as it focuses on enhancing and nurturing user experience. Product design should be user-oriented, employing limited colors and experimenting with fonts to create a minimalist design.
- *Assistance in Content Focus*: While writing content, it is essential to ensure that everything is in order and represents a visual hierarchy. Using the largest font size for headlines, the second-largest font size for subheadings, and the smallest font size for content can help in writing content for minimalist design.
- *Pleasant Atmosphere*: Adopting a minimalist approach and eliminating unnecessary elements ensures survival ahead of the competition and a user-friendly interface.
- *Faster Loading Times*: Minimalist design helps pages load faster because they have fewer but important elements for users. Modern users are impatient and won't hesitate to go to another page if your page takes time to load.
- *Responsive Design*: If there are fewer essential elements on the screen, it is easier to adapt the page to different screen sizes. By embracing minimalist design principles, responsive design can effectively simplify the user interface and eliminate excess elements that may disrupt optimal browsing experience on smaller screens or mobile devices, Fig. 1.

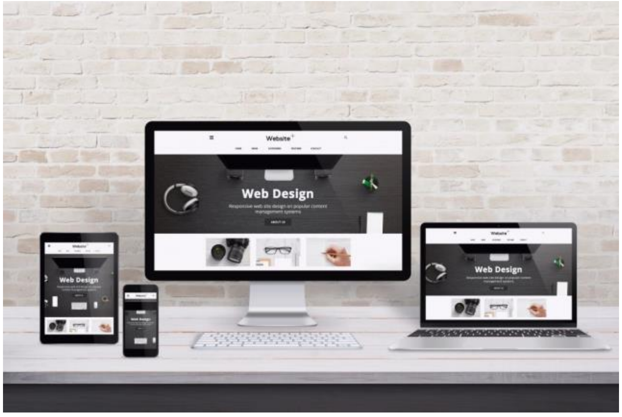

Figure 1. *Minimalism and responsive design [6]*

2.2. Minimalism in UX/UI design

UI refers to screens, buttons, switches, icons, and other visual elements with which you interact when using a website, application, or other electronic device. User Experience (UX) refers to the overall interaction you have with a product, including how you feel about the interaction. Although the user interface can certainly affect UX, these two are different, as are the roles of designers.

The minimalist user interface should be created with these three main principles in mind [3] – [5]:

- *Promotion of main content:* Many popular mobile applications achieve a minimalist design by following the principles of removing unnecessary images and distracting colors. Eliminating all additional components helps users focus on the actual functionality of the application or web page.
- *Strengthening the existing hierarchy:* White (or negative) space is the pillar of any minimalist design. What is left out of the design is equally important as what is inserted. Utilizing white space and size in a minimalist interface allows for maintaining a structured and clear page while adhering to the hierarchy of design components.
- *Less is more:* When there are fewer design elements, they may need to collide in size and width to provide equal emphasis. Less is more, and the goal is to create a significant impact with fewer design elements. It’s essential to consider details, as they carry more weight in the overall design.

In the world of digital design, minimalism is becoming an increasingly common approach. This strategy seeks to remove any unnecessary content from a website or application, with the ultimate goal of facilitating access to the most important components and providing users with an enhanced overall experience.

The concepts of minimalism that experts often mention are [3]:

- *Simple*
- *Clear*
- *Expressive*
- *Well-composed and proportional*
- *High functionality of elements*
- *Use of white and negative space* (space between components on the screen).

When it comes to UX and UI design, alluringly simple and clear "flat" websites or mobile applications are becoming more attractive, which, with a reduced number of clicks, accelerated interaction, or simplified user paths, quickly lead users to the desired goal or information about services or products.

Maintaining clear message conveyance and creating a recognizable brand while creatively using graphic elements such as colors, typography, and simple shapes is important.

3. DARK MODE

Dark mode represents a preference for using a dark color palette in software and device interfaces. This mode provides screen lighting that is easier on the eyes and less straining, especially in low-light conditions [7].

Dark mode is a user interface in low-light conditions that uses dark colors—usually black or shades of gray—as the primary background color. This is a departure from the default white user interface that designers have used for decades. In response to our increased screen time, programmers have discovered that interfaces with dark themes help reduce eye strain, especially in conditions of low lighting or at night. Less eye strain means less headaches and a better working experience.

Below are some best practices for creating dark mode applications [8]:

- *Not too dark*: Avoid pure black. It's hard for the eyes to look at a high-contrast screen. Good colors for dark mode are shades of gray combined with unsaturated colors.
- *Contrast*: Backgrounds in dark mode must be dark enough to display white text.
- *Desaturation of colors*: Stay away from completely saturated colors on a dark background. Instead, use unsaturated colors like pastels and muted colors—shades that have added gray and white.
- *Never use shadows*: In a light theme, everything is smooth because the white background and black shadow match perfectly. A black background and a black shadow won't have much contrast. Two common mistakes are trying to make the shadow more intense than the background or trying to place a shadow lighter than the object.

In the Fig. 2, the difference between light and dark mode in the Windows 11 operating system is shown.

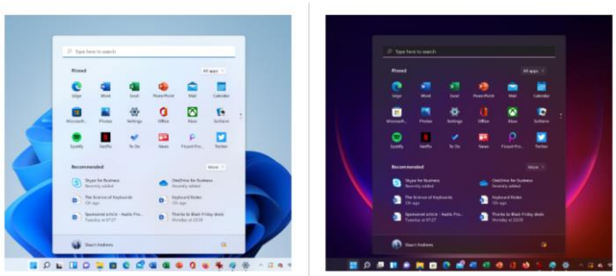

Figure 2. *Difference between light and dark mode in the Windows 11 operating system*

3.1. Dark mode advantages

Dark mode has several key characteristics and advantages [9]:

- *Reduces eye strain*: Using dark mode in user interface design helps improve overall content readability.
- *Increased visibility in low-light settings*: Another advantage of dark mode design is increased visibility, especially in low-light settings. In dark mode, we can see text and other items displayed on the screen more clearly.
- *Significantly saves battery*: Using the dark theme option on devices (whether it's a laptop or a mobile phone) significantly helps extend battery life. This is especially true for OLED screens because they can turn off black pixels when not in use.
- *Helps improve focus*: Another useful effect of dark mode in web page design is when you want to highlight a certain type of content. For example, brands like Spotify [10], Fig. 3, and Netflix want to draw attention to colorful and vivid album covers and video thumbnails. Dark mode makes these thumbnails pop in a specific way that light mode cannot achieve.

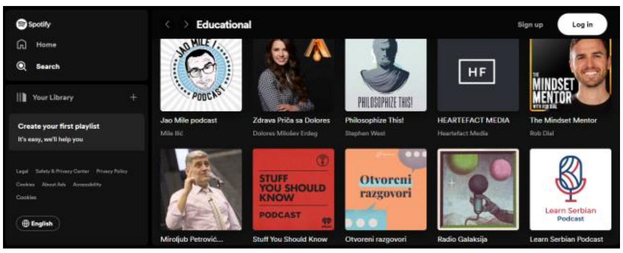

Figure 3. *Spotify in dark mode*

4. PRACTICAL REALIZATION

The application was created in Figma and is related to adding and tracking advertisements. Figma is a collaborative UI design tool based on the browser that allows users to work together to create vivid and interactive prototypes [11]. Through the application, minimalism is implemented in UI design along with examples of the first few pages in dark mode.

Fig. 4 depicts the login page where the user is required to log in. Basic information about the application is presented: its name and logo. Additionally, there are empty fields on the page that the user needs to fill in to access the application.

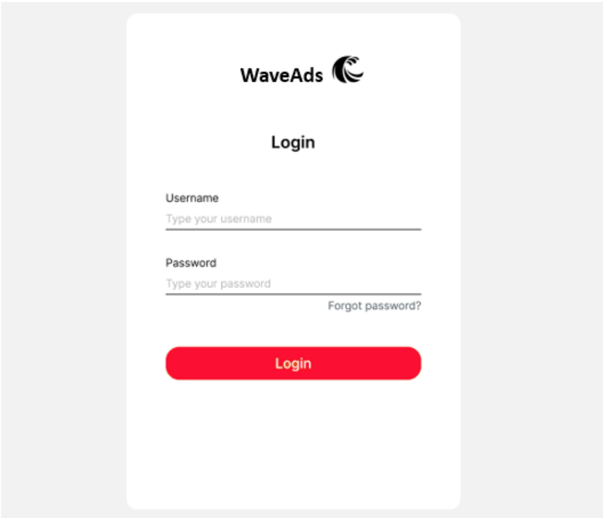

Figure 4. *Login page*

In Fig. 5, the homepage is displayed, featuring a header, sidebar, and the most popular and recently posted advertisements in the main section of the page.

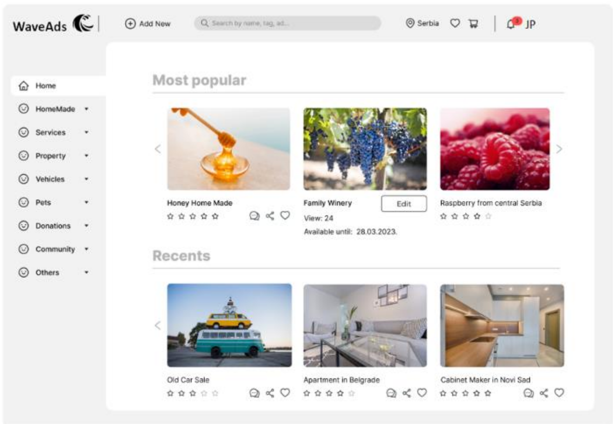

Figure 5. *Homepage – light mode*

Fig. 6 represents the previous homepage in dark mode.

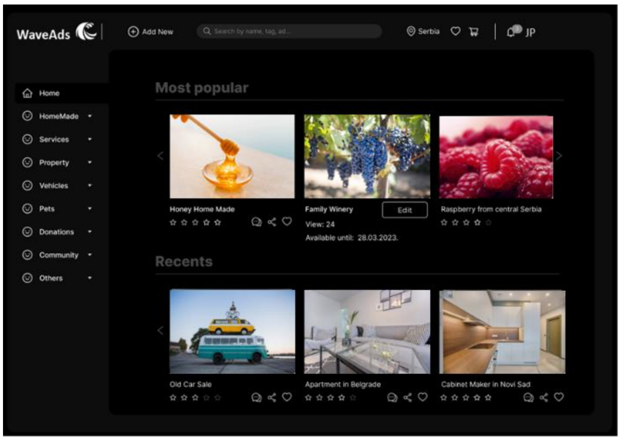

Figure 6. *Homepage – dark mode*

By clicking on one of the advertisements, a detailed view of that advertisement opens up, as shown in Fig. 7. Within this page, it is possible to see multiple images, the title, price, and comments, and the user also has the option to order the product by clicking on the "Order now" button.

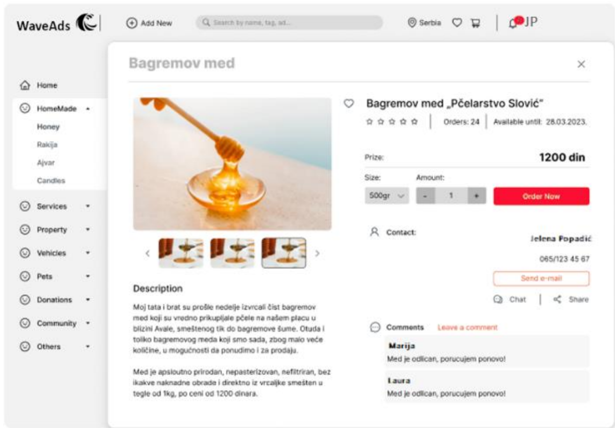

Figure 7. *Display of individual advertisement - light mode*

The previously shown page in Fig. 8 is presented in dark mode. Applications are increasingly equipped with the dark mode. It is noted that many computer enthusiasts have the impression that dark mode is somehow better than the traditional light mode [12].

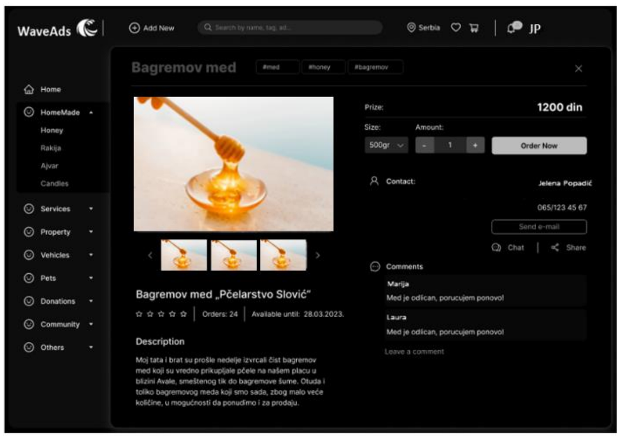

Figure 8. *Display of individual advertisement - dark mode*

5. CONCLUSION

"Keep it simple," "The less is more," or "Simplicity is the ultimate sophistication" are just some of the phrases that suggest a long-standing pursuit of minimalism and stylization in design.

Themes like minimalism and dark mode have emerged as significant trends in web design, offering clear benefits and improving the user experience. By combining the principles of minimalism and dark mode, web designers have the opportunity to create visually captivating web pages that are easy to navigate and pleasant to view.

However, it's important to remember not to blindly apply these design choices. Each website should be evaluated individually, taking into account factors such as brand identity, target audience, and overall goals of user experience. Like with any design trend, it's crucial to establish a balance between aesthetics and functionality.

Emphasizing minimalism shouldn't compromise the accessibility or usability of the website, and dark mode shouldn't hinder the readability or clarity of the content. It's essential to ensure that these design choices align with the purpose and goals of the website while providing users with a visually appealing experience.

In conclusion, themes like minimalism and dark mode in web design have brought about a change in the way websites are designed and experienced. By carefully embracing these trends, designers can create visually stunning web pages that cater to the preferences and needs of modern users.

ACKNOWLEDGEMENTS

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Improving Spa Tourism in Republic of Serbia Through Information and Communication Technologies: Development and Application of Tools for Data Visualization

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Abstract: *The paper presents an application that serves for the visualization and graphical interpretation of data on spas in the Republic of Serbia, which are located by region. The application is written in client languages Python, HTML and CSS. The aim of this work is to improve the visibility and attractiveness of spas in the Republic of Serbia by using information and communication technologies, especially through data visualization tools. Taking into account the fact that the main role of spas is the preservation and promotion of health, as well as the offer of various wellness contents, the use of this application can contribute to the increase in the number of visitors, that is, spa tourism, and therefore the economic development of the Republic of Serbia.*

Keywords: *Application; data visualization; programming languages; spas; Ubuntu*

1. INTRODUCTION

Tourism is a relatively new phenomenon in a historical context, although travel has existed for a long time, such as pilgrimages and visits to spas. Today's form of tourism began to develop with industrialization, segmentation of work, regulation of working hours and general economic development [1].

Tourism has experienced significant transformations in the last few decades, and the key driver of these changes is the expansion of information and communication technologies (ICT). These technological advances have reshaped the way we travel, providing new opportunities and creating an interactive environment for travelers around the world. With the introduction of the Internet as a central platform for communication and information exchange, tourism has taken on a completely new face.

The values of the number of Internet users worldwide are constantly changing due to the growth of Internet availability and digital inclusion. In 2021, Europe had an extremely high internet penetration rate of 89.2%, significantly higher than the world average of 67.9%. This wide availability of the Internet allows travelers to access the variety of information and resources they need to plan and personalize their trips. This indicates the widespread use of the Internet among the European population and a high level of Internet access, figure 1.

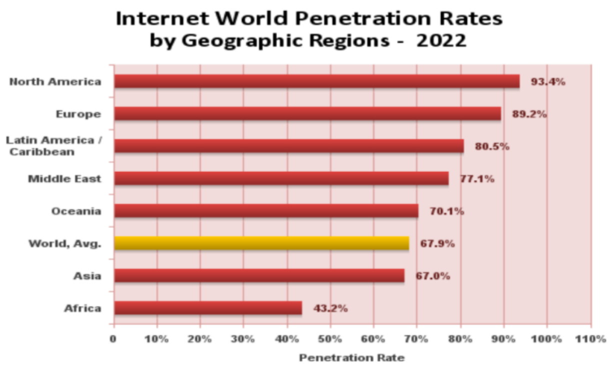

Figure 1. *Internet World penetration rates by geographic regions [2]*

Travelers can personalize their trip according to their wishes and needs. This change is crucial for the evolution of the tourism industry, as it allows greater flexibility and adaptation of the tourist offer to individual preferences. ICT and tourism are inextricably linked, creating a synergy that shapes both demand and supply in the tourism industry. As the use of ICT becomes more widespread, travelers have the ability to search the Internet and find a wealth of offers tailored to their individual preferences. This trend puts more emphasis on individual travel and dynamic packages, not only raising the quality of services and providing outstanding travel experiences, but also enabling tourism organizations to remain competitive in the modern development environment. In addition, the application of ICT in tourism contributes to cost reduction, improves operational efficiency, service quality and user experience, which further popularizes and makes the application of information technologies in tourism more and more flexible [3, 4].

By analyzing the available literature, it can be concluded that tourism has a direct and indirect impact on the country's economy, primarily on the gross domestic product (GDP) and national income of that country. The direct impact is reflected through the support of certain sectors of material production that serve the tourism industry, while the indirect impact implies the spillover of income from other countries into the domestic economy. Also, tourism can have a positive effect on the development of tourism activities, increase employment and raise the living standard of the population. The direct impacts of tourism include the impact on investment activities and the structure of investments, as well as on the accelerated development of less developed regions in the country [5].

Taking into account that spa tourism is considered one of the key elements of the tourist economy in tourism-developed countries, and that spas play a significant role in attracting tourists and promoting health and well-being, the focus of this paper is focused on presenting information about spa destinations on the territory of the Republic of Serbia without AP Kosovo and Metohija. However, one of the research problems of this work is insufficient availability and transparency of information about spas in the Republic of Serbia. Therefore, the goal of this study is the development of an application that will facilitate access to information and improve the promotion of spa tourism. This application is gaining importance because it can contribute to more visits to spas and overall economic development. Since spas represent an important part of the natural heritage of the Republic of Serbia, the aim of the work was to show the diversity and wealth of thermal mineral springs and wellness content that these destinations offer.

2. DATA VISUALIZATION IN SPA TOURISM USING OPEN SOURCE SOFTWARE TOOLS

Spa is an area that includes one or more natural healing factors, such as thermal and mineral water, air, gas and healing mud (peloid). These areas are arranged and equipped in accordance with legal regulations in order to enable their use for therapeutic purposes. The state assumes responsibility for the management of these areas as a natural asset of general interest, setting standards and regulations that ensure their preservation and proper use in accordance with scientifically proven therapeutic properties [6].

Spas of the Republic of Serbia represent a vital part of the country's tourist offer, attracting both domestic and foreign visitors. With over 300 thermal mineral springs, the Republic of Serbia can boast of a wealth of healing waters that attract tourists from all over the world. This long history of treatment and recovery, which goes back to the Bronze Age, makes the spas of the Republic of Serbia a unique place for rest, recreation, prevention and rehabilitation. Modernized spa complexes allow tourists to enjoy various activities throughout the year [7].

The potential of spa services is growing rapidly, and its importance is best illustrated by a study conducted by ESPA (European Spas Association). According to this study of 50,000 participants, patients who had to stop their spa treatments during the pandemic reported that their pain and symptoms worsened (63.5% vs. 13.4%) and that their ability to perform daily activities was significantly decreased, as well as the quality of life. In addition, patients who had to give up medical spa visits noted an increase in the number of consultations with health professionals (26.5% vs. 8.3%) as well as an increase in medication consumption (30.1% vs. 6.5%) [8].

In addition to numerous health problems that people face, there are also symptoms of long-term Covid. According to ESPA, mental health has become a central theme, with the introduction of programs for the long-term effects of Covid. More than 4 million citizens of the European Union (EU) should immediately receive a special program of spa therapy due to prolonged Covid. According to the European Spa Study, every patient with long-term Covid needs therapy in health spas at least 7 to 10 days a year. In order to help these patients achieve the maximum quality of life, European spas offer complex recovery programs using natural remedies, including the spas of the Republic of Serbia. Namely, according to ESPA, the Republic of Serbia is recognized in the Western Balkan region not only for its medical spa treatments, but also for its medicinal mud treatments and highly trained therapists [9].

The opportunity for the development of spa tourism considering only these data is extremely favorable. Here are some key points that confirm this:

Increased demand: With millions of patients struggling with the long-term effects of Covid-19, there is a huge demand for therapeutic treatments and recovery. Spa treatments are increasingly being recognized as useful in relieving symptoms and improving the quality of life of patients with long-term Covid.

Specialized treatments: The Republic of Serbia, with its rich sources of thermal mineral waters and tradition of spa treatment, can become the destination of choice for these patients.

Economic Development: The development of spa tourism can bring economic benefits, including job creation, attracting investment and increasing tourism revenue.

International cooperation: Cooperation with the EU and other countries can help the Republic of Serbia to use the potential of spa tourism.

One of the ways that can be used to promote spa tourism is the use of the open source software tool Leaflet.js [10].

Using Leaflet.js, interactive maps of spa locations can be created, display additional information about each spa, enable travel planning, and finally display geographic context around the spa locations. Through this kind of data visualization, visitors are provided with an interactive experience of exploring spa destinations, which enables easier access to information about spas and therefore increases interest in spa tourism.

3. DEVELOPMENT OF AN APPLICATION FOR VISUALIZING DATA ON SPAS IN THE REPUBLIC OF SERBIA

The application that was developed for the visualization of data about spas in the Republic of Serbia was created on the operating system Ubuntu [11], and for its development the programming language Python, HTML (Hypertext Markup Language) were used for the appearance of the application, as well as CSS (Cascading Style Sheets) which is in charge of the appearance of the application in order to better visualize the data [12]. This approach was chosen to ensure the flexibility and adaptability of the application, taking into account the widespread use of the Ubuntu operating system and the popularity of the Python programming language.

The Ubuntu operating system is installed on a virtual machine, that is, in a virtualized environment. The virtualized environment consists of the client and server parts of the Ubuntu operating system, which is part of the Linux family of operating systems and was originally intended for personal computers, although it is now also used for servers. The client part of the system in the Ubuntu operating system includes software and components that enable the user to interact with the computer, while the spa review application on the server part of the system is hosted on the Apache web server.

The authors developed an application for the visualization of open data about spas in the Republic of Serbia. With the help of collected data about spas, a JSON (JavaScript Object Notation) file was created using information obtained from different sources. To locate spas on maps, Google Maps [13] was used to get the exact coordinates. Also, other resources like [14], as well as many other sources were used to collect all relevant information about spas. This application allows users to explore data about spas in a simple and interactive way, providing detailed information about each spa based on available data. Figure 2 shows the created JSON file.

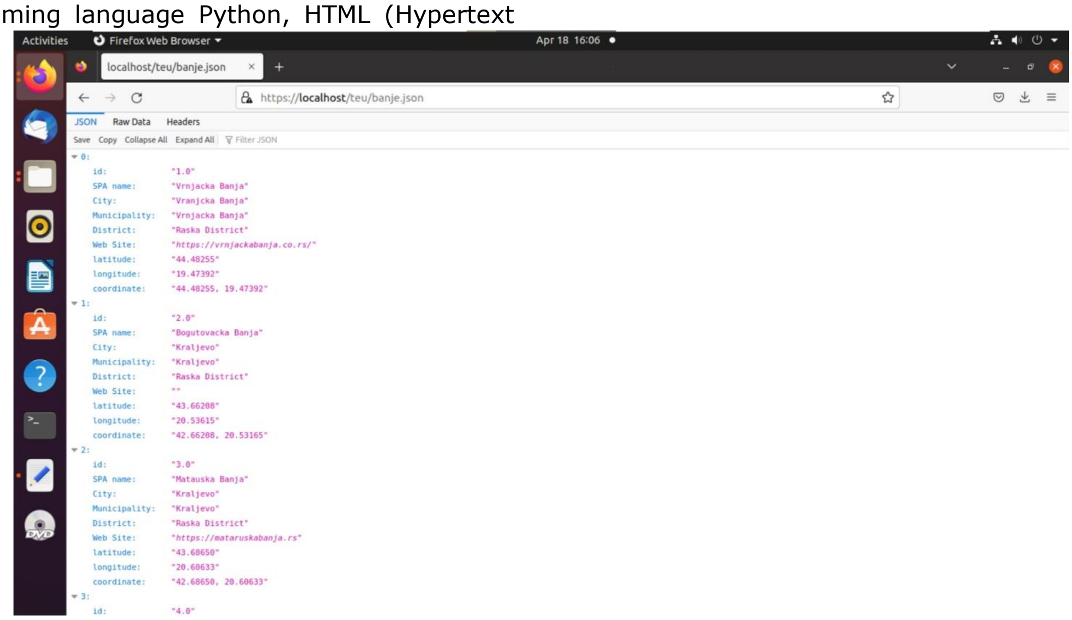

Figure 2. *View JSON file with spa information. [Source: Authors]*

Figure 2 contains part of the code used to load, filter and sort JSON data.

At the very beginning of coding the application, various libraries are included which are necessary for its successful functioning.

We especially highlight the use of the Leaflet.js library to create a map in the developed code.

Leaflet is the leading open source JavaScript library for interactive maps. It includes all the necessary functionalities for mapping, and stands out for its simplicity, performance and usability. It works efficiently on all desktop and mobile platforms, and can be easily extended through various plugins. Leaflet has an intuitive API (Application Programming Interface), well documented, which makes it easy to work with. In addition, it allows the creation of interactive maps, which means that users can interact with the map, zoom in, move around it and click on different parts. To mark locations on the map, Leaflet uses markers, and in addition supports other markers such as tiles, polygons, and circles [15].

In the part of the code shown in figure 3, a map is created (with the help of the Leaflet.js library) with initial coordinates showing a specific district with the name of the spa. The next step is to create a marker. These markers serve to mark the spas and show their exact location on the map.

In the continuation of the code, the retrieval of the JSON file is presented, specifying the location where the file is located in the system (ie the path to the file). After the file is successfully loaded, the next step is to search for each line individually within the JSON file.

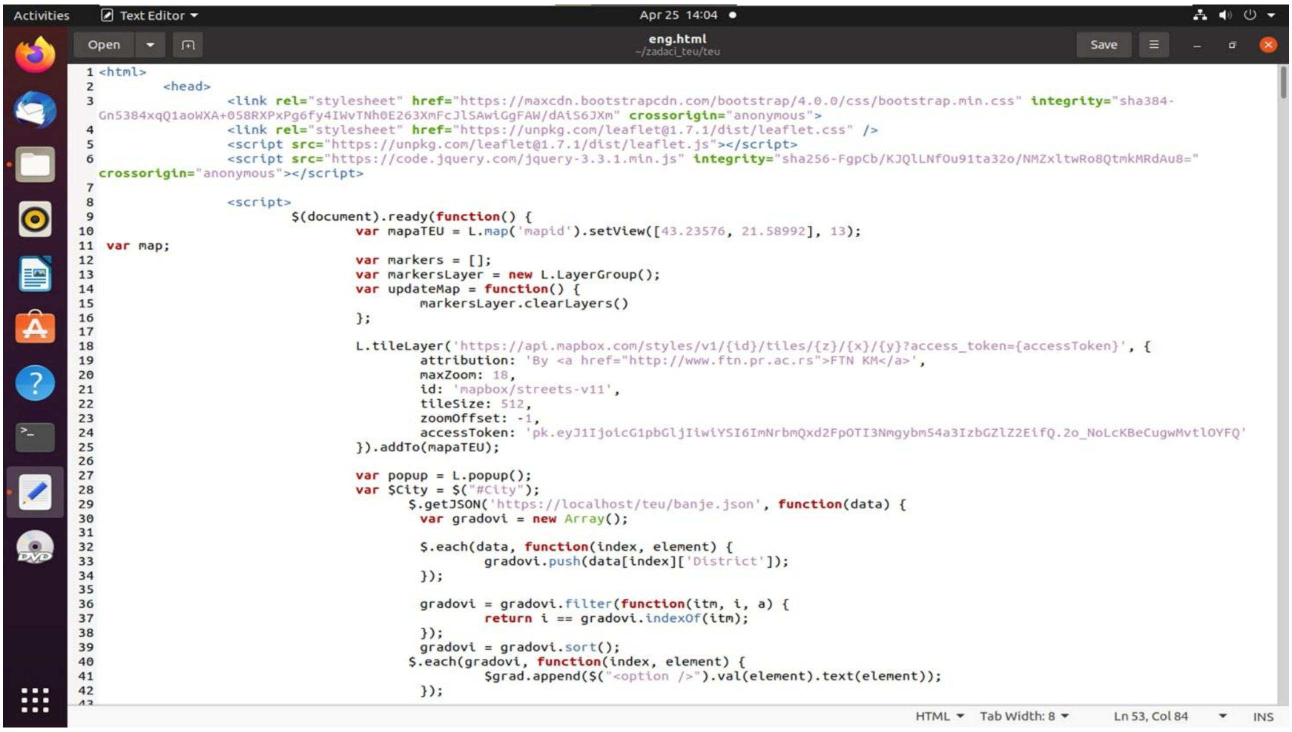

Figure 3. *Layout of part of the application code. [Source: Authors]*

During the search process, information about spas (spa name, city, municipality, district...) is extracted from the JSON file.

After spa data is extracted from the JSON file, there is a sorting process to organize or further process it in a certain way. These operations can include filtering cities according to specific criteria, as well as sorting cities alphabetically or by some other criterion relevant to the application. In creating the application, the authors sorted the spas by district.

In the continuation of the code, the already loaded JSON file is checked - whether the requested spa is located in the district. If the spa is present, a counter is introduced in the code, which is incremented every time the requested spa is found. This counter can be useful for further analysis or data manipulation. This can be useful, for example, to identify the popularity of spas in a district.

4. LAYOUT OF SPA SEARCH APPLICATIONS

When creating the application, the authors took care to make it available in two languages to ensure a broad user experience. This decision stems from the desire to allow users to access the application in the language most convenient to them, thereby improving accessibility and user satisfaction. This approach ensures that the application is available to a wider range of users.

Figure 4 shows the appearance of the home page of the application, where on the home page there is a panel with menu selection (Home, Maps, Contact) as well as language selection (English, Serbian). In addition, we notice the text "Explore spas in the Republic of Serbia" located on the home page, as well as the "View More" button located just below this text. By clicking the "View More" button, the view of the "Maps" page is opened, which is shown in figure 5.

This design allows users to easily navigate through the application and access various functions and contents.

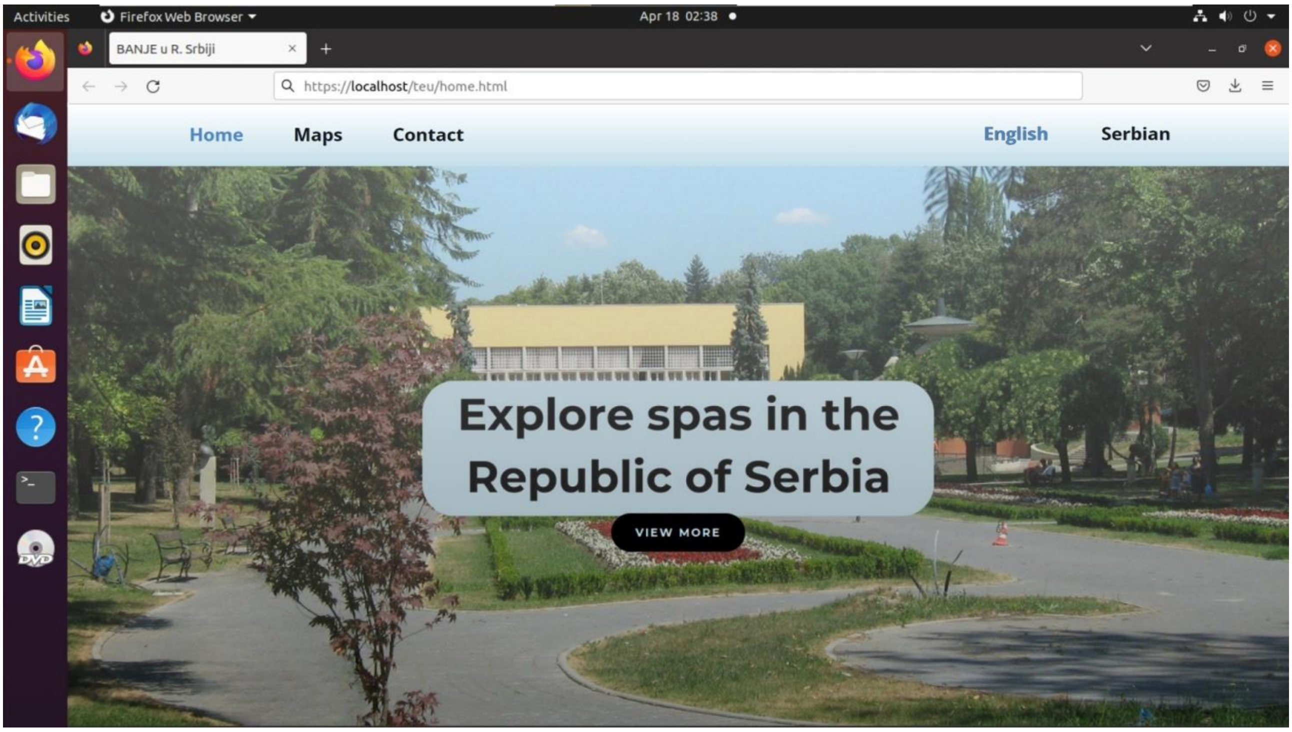

Figure 4. *Homepage layout. [Source: Authors]*

Figure 5 shows a page that has the ability to select the district option from the drop-down menu. A drop-down menu allows users to select their preferred district. This is useful because it allows information to be filtered based on geographic location, making it easier for users to find relevant data.

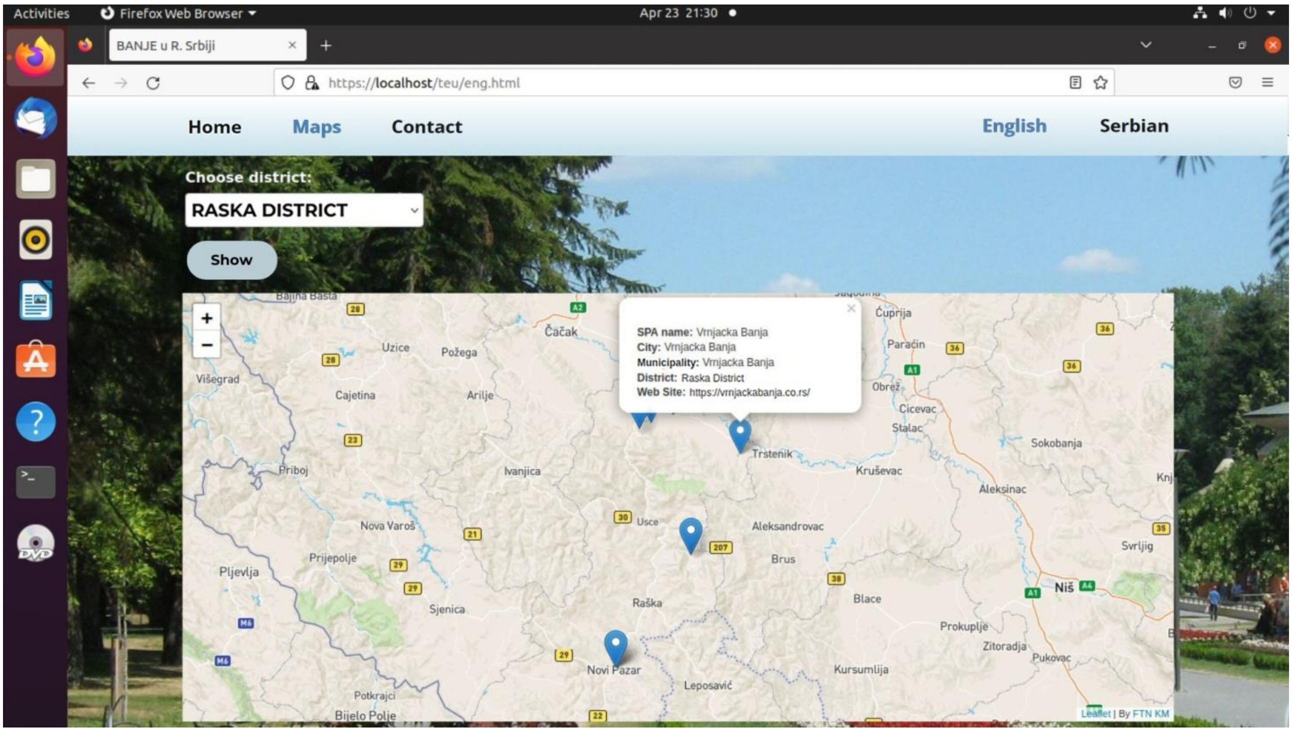

Figure 5. *Layout of the spa search page. [Source: Authors]*

After the user selects a district, by pressing the "Show" button, the page reacts by changing the focus of the map to the coordinates of the selected district. This interaction is crucial because it allows users to quickly and easily explore a desired location on the map. Additionally, markers are automatically displayed on the map to indicate spa locations within the selected district. This provides a visual representation of the layout of the spas on the map, which makes it easier for users to navigate and find the desired spa.

The most important functionality of this page is the ability to get detailed information about the spas by clicking on the markers on the map. When the user presses the marker, all necessary information about the spa is displayed, including the name of the spa, city, Web Site, etc.

This combination of functionality makes this page extremely useful and intuitive for users who want to visit a spa within a specific district. The integration of the cartographic view with the drop-down menu and the function of displaying information on the user's request enables efficient searching.

5. CONCLUSION

In this work, an application was developed for the visualization of data about spas in the Republic of Serbia, which uses ICT in order to improve accessibility and promote spa tourism. Through the use of technological tools, such as Python, HTML, CSS and Leaflet.js, an interactive platform was successfully created that allows users to research and access information about spa destinations in a simple way. The key findings indicate favorable conditions for the development of spa tourism in the Republic of Serbia, especially in the context of increased demand for therapeutic treatments due to the long-term consequences of the COVID-19 pandemic. The implications of this research include the possibility of economic development through attracting tourists, creating jobs and increasing income from tourism.

The role of tourism in economic development is also shown, both globally and at the level of individual countries such as the Republic of Serbia. Analyzing the development of tourism throughout history, it is clear that technological progress, especially in information and communication technologies, is the key factor that shaped modern tourism. E-tourism, as an integration of technology and the tourism industry, has enabled the personalization of travel and the creation of interactive experiences for travelers.

In addition, tourism has a significant direct and indirect impact on the economy, contributing to the gross national product, national income, employment and infrastructure development.

The use of JSON format for data storage and Google Maps for geolocation of spas further enriches the user experience, enabling precise location and viewing of information about each spa. The integration of multiple data sources contributes to the comprehensiveness and accuracy of information available to users.

This application is a step towards improving the tourist promotion of spa destinations in the Republic of Serbia, providing users with a wide range of information about available facilities, services and locations. Its development on the Ubuntu operating system further increases the accessibility and flexibility of the application, taking into account the popularity and widespread use of this operating system.

The multilingual presence of the application contributes to the wide availability and accessibility of users, while the drop-down menu allows users to effectively filter information based on geographic location. The interactivity of the map and the possibility of obtaining detailed information about spas further improve the user experience and make it easier for users to find the desired information.

Through this work, the power of technology in improving the user experience and promoting tourist resources is shown, highlighting the potential for further development of applications for the promotion of tourism in the Republic of Serbia.

For future analyses, it is proposed to deepen the research on the impact of spa tourism on economic development, to evaluate the effectiveness of applications in the promotion of tourism, and to investigate the possibility of international cooperation in the field of spa tourism.

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Detection of Broadcast Storms in Local Area Networks

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Abstract: *Broadcast storms represent events in the local area network (LAN) which is the result of excessive amounts of packet retransmissions by network switches which drastically reduce network performance and even overload network infrastructure which can result in that network becoming inoperational. Broadcast storms originate from broadcast and multicast packets which are targeted for all or groups of stations in LAN. Since these packets are addressed to multiple destinations, they are usually forwarded by network switches on multiple ports to reach all targeted destinations. This can become a serious problem in institutional LANs in which broadcast storms can create a temporary or permanent overload of the entire network infrastructure. This is most notably observed during the videoconferencing calls which could cause packet loss or connection interruptions. In this paper, we analyzed the influence of broadcast storms on network performance in institutional LAN and proposed a machine learning algorithm for the detection of broadcast storms based on the network traffic data collected by the Packet Capture (PCAP) Wireshark software.*

Keywords: *broadcast storm; network performance; network switch; PCAP; Wireshark*

1. INTRODUCTION

Computer networks are an important infrastructure component in every institution since computers are used in almost all segments of human activity. Computer networks connect computers to provide the following activities: communication, global access to information, resource sharing, remote access, etc. The physical organization and complexity of a computer network are usually invisible to the ordinary user, who expects a high speed of access, reliability and security of transmission and zero downtime deployment. Seamless operation of computer networks is the responsibility of the network administrator, who maintains and troubleshoots problems in computer networks.

Computer networks in institutions are organized in the form of local area networks, in which computers are connected in tree topology using networking components called switches. The primary role of network switches is to redirect packets sent from the source towards the destination. Switch analyzes the header of the received packet and based on the destination MAC address sends the packet via the appropriate port [1]. After the bootup, the switch starts to build its SAT (Source Address Table) based on the packet MAC (Medium Access Control) addresses of received packets. This table is used to associate to which port a certain network station is connected. To redirect the packet, the switch searches its SAT table to determine which port it should use for the redirection. If there is no such SAT entry, the packet is redirected to all other ports except the packet source port which ensures that the packet will reach an unknown station. When this unknown station replies to the received packet, the reply packet will come through one of the ports and the MAC address of the unknown station will be entered in the SAT table.

This concept of switching using SAT tables works well only if one station is connected to just one of the ports. Thus in local area networks the only accepted topology is tree topology, in which there is only one route between source and destination stations. Loops are not allowed because they could confuse the switching logic since one station can appear to be connected to two ports. This situation could cause that packet to be routed through an infinite loop. These redundant loops are detected by STP (Spanning Tree Protocol) which is used by switches to disable loop connections to establish tree topology.

Besides unicast traffic which is destined for specific network stations, multiple stations can be marked as packet destinations in case of multicast traffic, or all stations in the network can be marked in case of broadcast traffic. Broadcast is a special type of packet in which the destination address is set to all binary ones (or FF:FF:FF:FF:FF:FF in hexadecimal) and is intended to be received by all stations in the network. In the presence of loops in LAN topology these packets could cause a high inrush in network traffic a so-called broadcast storm [2]. These situations can temporarily or permanently interfere with regular LAN operation, which could cause a significant drop in network performance.

Broadcast storms can also occur in LAN without the loops where there is a source that generates frequent broadcast packets [3]. The source of such behavior can be multiple, improperly configured network services, malicious software and others. Troubleshooting of broadcast storms represents a challenge for every administrator, especially in large LAN networks. In this paper, we presented the algorithm that can be used to monitor network traffic and classify the presence of broadcast storms.

The most common networking technology based on the IEEE 802 standard uses Ethernet for wired networks and IEEE 802.11 for wireless networks. Each packet contains two address fields, destination MAC address and source MAC address. MAC addresses are uniquely assigned to every NIC (Network Interface Controller), and network switches use these MAC addresses to redirect packets from the source towards their destination. Switching operation is transparent to networked stations which are not aware of the presence of the switch. All network traffic that reaches certain network stations can be monitored with packet capture tools, such as Wireshark [4]. Wireshark is a software networking tool used to analyze network traffic via the network interface card. This tool uses NIC in promiscuous mode in which NIC allows all frames to pass, allowing the computer to read frames intended for other machines or network devices. Under regular operation (non-promiscuous mode) when the NIC receives a frame, it drops if it’s not addressed to the NIC's MAC address.

Packet capture is a networking tool that intercepts packets that are sent through the network. After these packets have been captured they are saved for further analysis by the network administrators. Analysis of these captured packets enables administrators to identify and solve networking problems that can influence regular daily operations. Packet capture can help in the analysis and identification of problems regarding network performance (packet loss, network congestion, etc), network security, intrusion detection, etc. In order to monitor traffic on certain links that are not redirected to packet capture NIC, administrators use managed switches to perform port mirroring. By using port mirroring all data traffic on certain ports can be mirrored to a port that is connected to packet capture NIC, where is been analyzed by packet capture software (Fig 1).

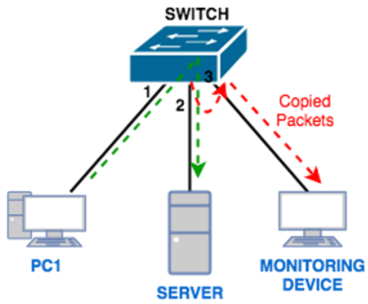

Figure 1. *Packet capture using port mirroring*

Broadcast storm needs to be separated from regular network protocols which rely on the broadcast packets. For example, DHCP (Dynamic Host Configuration Protocol) uses DHCP Discover and DHCP Request broadcast packets to find and request IP configuration from the DHCP server. Also, ARP (Address Resolution Protocol) sends a broadcast packet in order to find the MAC address of the unknown station.

Clues that could identify the source of the broadcast storm in LAN are:

- frequent broadcast packets
- broadcast packets with the same length
- broadcast packets which use the same protocol
- broadcast messages sent by a single network station
- broadcast messages sent by a group of closely addressed stations (similar IP or MAC addresses).

2. METHODOLOGY

In this paper, we proposed a clustering algorithm that enables to detect the presence of broadcast storms in captured packets and identify sources of such traffic. Since the number of packets in large networks can be exceptionally high it is difficult and impractical to classify them by hand. We employ machine learning algorithms to classify the data as regular traffic and broadcast storms.

Clustering is a key task in discovering useful patterns in large data sets that are not pre-labeled to belong to a certain class [5]. Clustering is a process in which objects, according to predefined properties, are arranged into groups, called clusters in such a way that objects in the same cluster are more similar to each other than to objects in other clusters. Thus by being able to separate objects into classes, clustering provides new knowledge about observed phenomena. Unlike supervised learning, clustering cannot be fully automated, since it doesn’t use label data to calculate exact model performance. Instead, clustering requires human judgment and domain knowledge in order to select appropriate data and iteratively adjust model parameters to achieve the desired result. The key criteria in clustering revolve around usefulness of generated clusters and did they discover new patterns in the data which haven't been known before clustering.

The first step in the clustering process is to define the expected number of clusters in the data. Sometimes if the number of expected clusters is not known in advance, the optimal number can be determined by iteratively increasing the number of clusters and finding the most satisfactory result. Figure 2 shows the process of clustering the unlabeled data shown on the left figure into six clusters marked with different colors shown in the right figure.

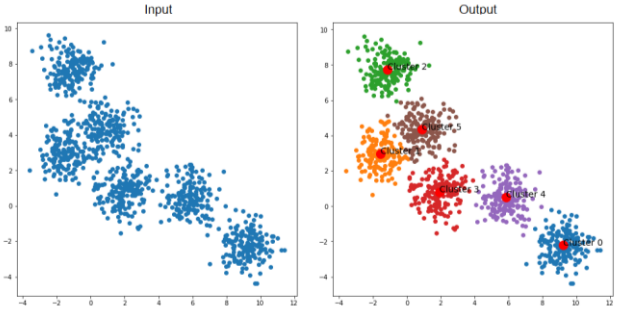

Figure 2. *Clustering of unlabeled data*

Clustering algorithms can be separated into following categories:

- Centroid-based Clustering,
- Density-based Clustering
- Connectivity-based Clustering
- Distribution-based Clustering

The choice of clustering algorithm depends mainly on the nature of the data. Data which tends to group around certain points can be cluttered with centroid-based algorithms, such as K-means. In case of data which is not clearly separable, density based clustering algorithms are used, such as DBScan. When data set has tendency to group in elongated shapes connectivity based clustering algorithms are used. The agglomerative hierarchical clustering is the most widely used type of connectivity-based clustering [6].

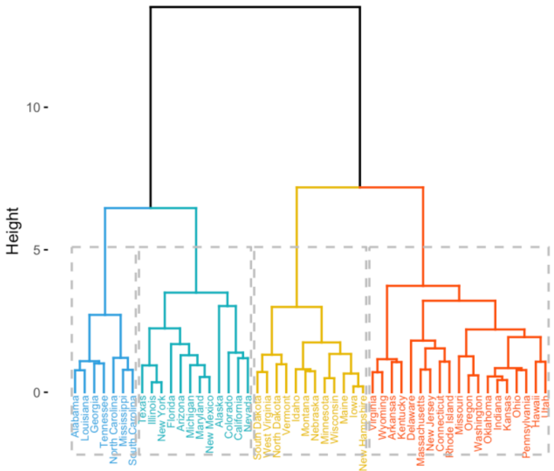

Figure 3. *Clustering dendogram*

First, the algorithm treats every data point as a separate cluster, after which it starts to merge most similar points into the cluster. The algorithm ends when all data points are connected into one big cluster, resulting in the formation of a tree-based representation, called a dendogram. Depending on how many clusters are required, the dendrogram is cut at a certain value, as shown in Fig 3, with four separate clusters.

3. RESULTS AND DISCUSSION

In this paper, we analyzed broadcast storms that originate from an improperly configured network service installed in one of the computing classrooms. Upon powering on, all student computers in this classroom start the service which sends broadcast packets in order to find the running server. This operation should end briefly as soon as the server responds, but when this server is not powered on host computers start to permanently send these broadcast packets. These broadcast packets created a broadcast storm in the entire faculty network reducing the available bandwidth and inducing unnecessary network traffic. Part of the broadcast traffic captured by Wireshark is presented in Fig 4.

No.	Time	Source	Destination	Protocol	Length
1	0.000000	10.1.4.64	255.255.255.255	UDP	106
2	0.000000	10.1.4.76	255.255.255.255	UDP	106
3	0.000000	10.1.4.96	255.255.255.255	UDP	106
4	0.000072	10.1.4.95	255.255.255.255	UDP	106
5	0.000153	10.1.4.70	255.255.255.255	UDP	106
6	0.000153	10.1.4.106	255.255.255.255	UDP	106
7	0.000153	10.1.4.60	255.255.255.255	UDP	106
8	0.000156	10.1.4.74	255.255.255.255	UDP	106
9	0.000398	10.1.4.89	255.255.255.255	UDP	106
10	0.000398	10.1.4.56	255.255.255.255	UDP	106

Figure 4. *Wireshark captured broadcast traffic*

By analyzing this traffic we can observe that multiple stations generate frequent UDP broadcast requests each having the same length. The entire packet capture file was recorded at two-minute interval, in which 2.6 million broadcast packets were sent, on average 20000 packets per second. This traffic generated cumulative load on entire LAN of around 16Mbps. which can cause significant drop of LAN performance, especially in networks segments which operate at 100Mbps. Ethernet statistics for the packet capture were exported in the form shown in Fig. 5.

Ethernet · 96 | IPv4 · 114 | IPv6 · 21 | TCP · 84 | UDP · 310

Address	Packets	Bytes	Tx Packets	Tx Bytes	Rx Packets
18:31:bf:24:0b:85	337	23k	337	23k	0
e0:d5:5e:0c:a4:7f	548	88k	320	57k	228
6c:3b:6b:fd:85:ef	1,122	94k	994	77k	128
20:1a:06:f6:af:d2	120,686	12M	120,686	12M	0
20:1a:06:f6:b6:2d	125,500	13M	125,500	13M	0
20:1a:06:85:d2:0f	129,461	13M	129,461	13M	0
20:1a:06:f6:aa:f3	129,736	13M	129,736	13M	0
20:1a:06:f6:a3:21	131,980	13M	131,980	13M	0

Figure 5. *Statistics of broadcast generation by MAC addresses*

Ethernet statistics was exported into MATLAB where we perform agglomerative hierarchical clustering analysis. First MAC addresses which are shown in hexadecimal format were converted into numerical data. Data used for clustering algorithm was MAC address, number of packets and amount of transferred data in bytes. We expected that selected data will be well grouped for nodes which are generating broadcast storm, than for nodes which generate regular network traffic. Clustering algorithm was set to find two clusters, one which will be marked as regular traffic and other marked as broadcast storm as shown in Fig 6.

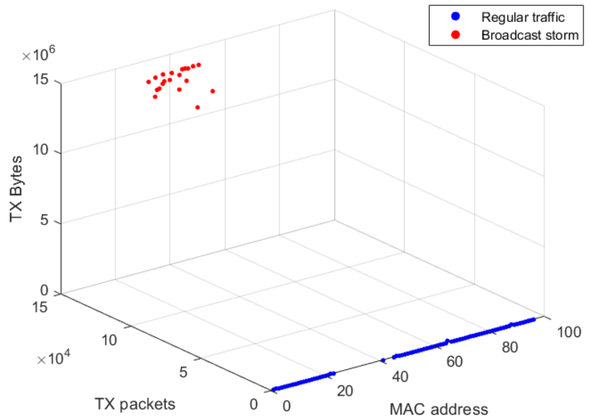

Figure 6. *Clustering broadcast storm traffic*

As a result, we were able to classify and identify 20 MAC addresses that are the source of broadcast storm as shown in Table 1.

Table 1. *Identified NIC's MAC addresses as source of broadcast storms*

No.	MAC address
1.	20:1a:06:85:d2:0f
2.	20:1a:06:f6:a2:f8
3.	20:1a:06:f6:a3:21
4.	20:1a:06:f6:a4:ee
5.	20:1a:06:f6:a7:b4
6.	20:1a:06:f6:a8:2e
7.	20:1a:06:f6:a8:c6
8.	20:1a:06:f6:a9:29
9.	20:1a:06:f6:aa:38
10.	20:1a:06:f6:aa:f3
11.	20:1a:06:f6:ad:8c
12.	20:1a:06:f6:af:d2
13.	20:1a:06:f6:b3:09
14.	20:1a:06:f6:b3:29
15.	20:1a:06:f6:b3:42
16.	20:1a:06:f6:b3:44
17.	20:1a:06:f6:b3:91
18.	20:1a:06:f6:b5:ff
19.	20:1a:06:f6:b6:2d
20.	20:89:84:30:6a:ca

4. CONCLUSION

In this paper, we analyzed the influence of broadcast storms in large institutional LANs. We proposed a clustering algorithm that can be used to classify and identify sources of broadcast storms from data obtained from packet capture software. As a result, we identified 20 MACs from which broadcast storms are transmitted and network service running on those computers will be configured to mitigate its influence on the institution's LAN. The proposed algorithm can be realized as a service implemented on the managed switch. Further work will be focused on the application of other clustering algorithms for the detection of broadcast storms.

ACKNOWLEDGEMENTS

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Exploring Geometrical Content with ICTs: A Case Study on Infinitesimal Bending of a Hyperbolic Paraboloid

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Abstract: *Information and Communication Technologies (ICTs) usage is of great importance in development of mathematics in general and geometry in particular. Software packages can, for instance, be helpful in differentiation and integration, as well as for solving complex numerical problems, which can be time-consuming if done without ICTs. Instruction of geometrical content at any level often requires usage of the content's graphic representation. For that purpose, software packages for geometrical content visualization are used. Here we present an example where the computer usage in geometrical content exploration is shown. Visualization is especially important in the infinitesimal bending theory. In the paper we examine infinitesimal bending of a curve on the hyperbolic paraboloid and determine the infinitesimal bending field that leaves the bent curves on it. Since two such fields are obtained, we use Mathematica software package for representation of the curve and observe the impact both fields have on it. We also determine the bending field that leaves the curve on the hyperbolic paraboloid with a given precision.*

Keywords: *infinitesimal bending; hyperbolic paraboloid; visualization; geometry education; Mathematica*

1. INTRODUCTION

The *Mathematica* supports symbolic programming which makes it suitable for creating interactive and dynamic content, and therefore useful in many areas of mathematics instructions. In this paper we will demonstrate its use in geometry, precisely the use in visualizing geometric contents. For more information on using this software package, we recommend the books [3], [7] and [13].

The geometric content that will be visualized in this paper is the infinitesimal curve bending. The infinitesimal bending is a deformation in which arc length is stationary with a given precision. Under bending, some geometric magnitudes remain unchanged, i.e. stationary, and the others have variations different from zero. In addition to the arc length, stationary variables are the coefficients of the first fundamental form, the Christoffel's symbols, the determinant of the first and second fundamental form, etc.

The theory of infinitesimal bending has found application in many fields of mathematics as well as in other scientific disciplines. For example, the paper [4] shows the application of infinitesimal bending in knot theory, papers [11] and [12] presents its application in biology and membrane theory and [10] application in architecture.

In [5] it has been shown that it is possible to determine the infinitesimal bending field for curves on ruled surfaces that leaves them on those surfaces. In particular, the paper gives a bending field for curves on a hyperbolic paraboloid with parameterization $\mathbf{r}(u,v)=(u,v,uv)$. In continuation of this research, we determine the field of infinitesimal bending of curves on the hyperbolic paraboloid with parameterization $\mathbf{r}(u,v)=(u,v,u^2-v^2)$, that leaves the curves on that surface. We will graphically present the obtained results using *Mathematica*.

In [6] authors determined infinitesimal bending field that leaves the bent curves on the ruled surfaces with a given precision. This research motivated us to determine the bending field for curves on the hyperbolic paraboloid with parameterization $\mathbf{r}(u,v)=(u,v,u^2-v^2)$, which leaves the bent curves on it with a given precision.

2. PRELIMINARIES

Here we will briefly outline the necessary theory for studying infinitesimal bending of curves, and for more details, see [1], [2], [8] and [9].

Let us consider a continuous regular curve $C\subset\mathbb{R}^3$

$$C\colon\ \mathbf{r}=\mathbf{r}(t),\quad t\in I\subseteq\mathbb{R}.$$

The family of curves C_ϵ

$$C_\epsilon\colon\ \mathbf{r}_\epsilon = \mathbf{r}(t) + \epsilon \mathbf{z}(t), \quad t \in I \subseteq \mathbb{R}, \qquad \epsilon \in [-1,1],$$

is an **infinitesimal bending of the curve** C if

$$ds_\epsilon^2 - ds^2 = o(\epsilon),$$

where the field $\mathbf{z} = \mathbf{z}(t)$, $\mathbf{z} \in C^1$, is an **infinitesimal bending field** of the curve C. For $\epsilon = 0$, we obtain curve C, i.e. $C = C_0$.

Theorem 1. ([2]) The necessary and sufficient condition for $\mathbf{z}(t)$ to be an infinitesimal bending field of a curve C is

$$d\mathbf{r} \cdot d\mathbf{z} = 0, \tag{1}$$

where $\cdot$ denotes the scalar product in $\mathbb{R}^3$.

The condition (1) can be written in the form $\dot{\mathbf{r}} \cdot \dot{\mathbf{z}} = 0$, where $\dot{\mathbf{r}}$ denotes a derivate of function $\mathbf{r}$ by parameter t.

Theorem 2. ([8]) Infinitesimal bending field for the curve C is

$$\mathbf{z}(t) = \int (p(t)\mathbf{n}(t) + q(t)\mathbf{b}(t))dt,$$

where $p(t)$ and $q(t)$ are arbitrary integrable functions and vectors $\mathbf{n}(t)$ and $\mathbf{b}(t)$ are unit principal normal and binormal vector fields of the curve C, respectively.

3. VISUALIZATION OF INFINITESIMAL BENDING OF CURVES ON THE HYPERBOLIC PARABOLOID

We will observe the hyperbolic paraboloid with parameterization

$$\mathcal{S}\colon\ \mathbf{r}(u,v) = (u, v, u^2 - v^2),\ (u,v) \in U \subseteq \mathbb{R}^2, \tag{2}$$

and continuous regular curve on it

$$C\colon\ \mathbf{r}(t) = \mathbf{r}\big(u(t), v(t)\big) = \big(u(t), v(t), u^2(t) - v^2(t)\big),$$

$t \in I \subseteq \mathbb{R}$.

Theorem 3. The equations

$$\mathbf{z}(t) = \bar{C} e^{-2\int \frac{(u-v)^{\cdot}(u^2-v^2)^{\cdot}}{(u+v)^{\cdot} + 2(u-v)(u^2-v^2)^{\cdot}}dt}(1,1,2(u-v)), \tag{3}$$

$(u+v)^{\cdot} + 2(u-v)(u^2-v^2)^{\cdot} \neq 0$ and

$$\mathbf{z}(t) = \bar{C} e^{2\int \frac{(u+v)^{\cdot}(u^2-v^2)^{\cdot}}{(v-u)^{\cdot} - 2(u+v)(u^2-v^2)^{\cdot}}dt}(-1,1,-2(u+v)), \tag{4}$$

$(v-u)^{\cdot} - 2(u+v)(u^2-v^2)^{\cdot} \neq 0$, where $u = u(t)$, $v = v(t)$, and $\bar{C} = const.$, determine the infinitesimal bending field $\mathbf{z}(t)$ for the curve C on hyperbolic paraboloid $\mathcal{S}$, which leaves the bent curves C_ϵ on it.

Proof: We can prove this theorem by using the same procedure as in the proof to the Theorem 9 in the paper [5]. Following the procedure of this proof, we get that the following system is valid for this parameterization

$$\begin{cases} 2u(t)z_1(t) - 2v(t)z_2(t) - z_3(t) = 0, \\ z_1^2(t) - z_2^2(t) = 0, \end{cases}$$

where $\mathbf{z}(t) = (z_1(t), z_2(t), z_3(t))$, and $z_1(t), z_2(t), z_3(t)$ are real continuous differentiable functions. By solving this system, we get the field

$$\mathbf{z}(t) = \big(\pm z_2(t), z_2(t), \pm 2z_2(t)(u(t) \mp v(t))\big).$$

From the conditions $\dot{\mathbf{r}} \cdot \dot{\mathbf{z}} = 0$ we obtain the expression for $z_2(t)$ and finally determine the field of infinitesimal bending (3) and (4). □

Since we have obtained two bending fields, our goal is to examine their effect on a given curve on a hyperbolic paraboloid $\mathcal{S}$, i.e. to check how these fields bend it. For this purpose, we provide the following examples.

Example 1. Let us observe the curve

$$C\colon\ \mathbf{r}(t) = (2t, t, 3t^2),\ t \in (t_1, t_2) \subseteq \mathbb{R}, \tag{5}$$

located on the hyperbolic paraboloid (2). Assuming that $\bar{C} = 1$, by the equation (3) we obtain the first bending field for the curve C

$$\mathbf{z}(t) = \left(\frac{1}{\sqrt{1+4t^2}}, \frac{1}{\sqrt{1+4t^2}}, \frac{2t}{\sqrt{1+4t^2}}\right). \tag{6}$$

Thus, the family of curves obtained by the effect of the bending field (6) is given by equation

$$C_\epsilon\colon\ \mathbf{r}_\epsilon(t) = \left(2t + \frac{\epsilon}{\sqrt{1+4t^2}}, t + \frac{\epsilon}{\sqrt{1+4t^2}}, 3t^2 + \frac{2\epsilon t}{\sqrt{1+4t^2}}\right).$$

We will visualize this family of curves, i.e. the infinitesimal bending of curves (5) using the *Mathematica*. At the same time, we will also graphically display the hyperbolic paraboloid, in order to visually ascertain that the bending fields given in Theorem 3, do indeed leave bent curves on that surface. This example shows us the great importance of the *Mathematica* software package in geometry instruction, as it gives us the opportunity to sense the problem and anticipate some conclusions visually.

The command used to draw the parametric $3D$ curve is

```
ParametricPlot3D[{x[t],y[t],z[t]}, {t,tmin,tmax}],
```

which also has additional options for determining the appearance of curve graphics. Here we used the `PlotStyle → Directive [Thickness [0.01], Red]` option to determine the style of the lines drawn, i.e. the thickness and color of the line.

The command used to draw a parametric surface is

ParametricPlot3D[{x[u,v],y[u,v],z[u,v]}, {u,umin,umax}, {v,vmin,vmax}].

As the additional options, we used Mesh → False, by which we omitted drawing the grid of coordinate lines on the surface in order to make the bent curves that we will present as clear as possible.

With the Show[g1,g2,...] command, which is used to display multiple graphical objects at the same time, we will show the bent curves on the hyperbolic paraboloid. This command offers an option to manipulate the appearance of the graphical environment. In this case, we used the additional PlotRange, Axes → False and Boxed → False options, which: defined the boundaries where the graph would be displayed, removed the coordinate axes and removed the graph box.

Finally, the bent curves for negative ϵ will be colored black, and the bent curves for positive ϵ will be colored blue. We used the values $\epsilon = \pm 0.25$, ± 0.5, ± 0.75, ± 1 to visualize this example (Fig. 1).

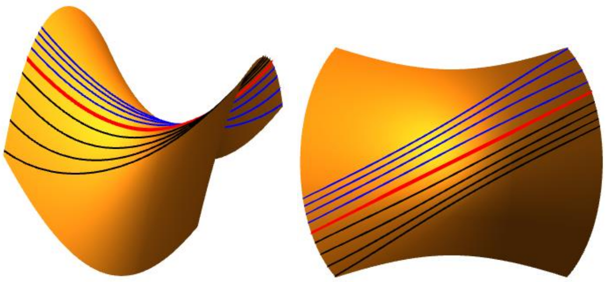

Figure 1. *Infinitesimal bending of the curve C on the hyperbolic paraboloid under field (3) (default and top view)*

Example 2. Let us consider again the same curve C from the previous example. Now, based on the equation (4) we get the second infinitesimal bending field for curve C

$$\mathbf{z}(t) = \left(-\frac{1}{\sqrt{1+36t^2}}, \frac{1}{\sqrt{1+36t^2}}, \frac{-6t}{\sqrt{1+36t^2}}\right)$$

and the family of curves C_ϵ

$$C_\epsilon\colon\ \mathbf{r}_\epsilon(t) = \left(2t - \frac{\epsilon}{\sqrt{1+36t^2}}, t + \frac{\epsilon}{\sqrt{1+36t^2}}, 3t^2 - \frac{6\epsilon t}{\sqrt{1+36t^2}}\right).$$

The infinitesimal bending of the C curve in this field is shown in Fig. 2, for $\epsilon = \pm 0.25$, ± 0.5, ± 0.75, ± 1.

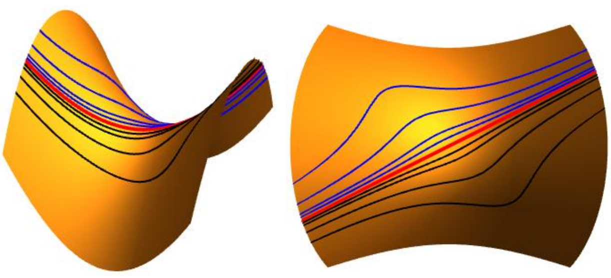

Figure 2. *Infinitesimal bending of the curve C on the hyperbolic paraboloid under field (4) (default and top view)*

⋄

By visualizing the resulting bending fields for curves on the hyperbolic paraboloid, we have obtained graphs to see the effect of these fields. Since in the visualization we used the same values for ϵ in both examples, from Figures 1 and 2 we can easily conclude that the field (4) has "stronger" effect on the C curve, i.e. with the effect of this field, the C curve "bends more" comparing to the bending of the C curve effected by field (3).

The implicit equation of hyperbolic paraboloid (2) is given by

$$\mathcal{S}\colon\ x^2 - y^2 - z = 0.$$

If the bent curves

$$C_\epsilon\colon\ \mathbf{r}_\epsilon = \mathbf{r}(t) + \epsilon \mathbf{z}(t) = (x_\epsilon(t), y_\epsilon(t), z_\epsilon(t))$$

satisfy condition

$$x_\epsilon^2(t) - y_\epsilon^2(t) - z_\epsilon(t) = o(\epsilon),$$

then they are approximately on the hyperbolic paraboloid $\mathcal{S}$, where $o(\epsilon)$ is an infinitesimal magnitude of at least second order with respect to ϵ. By using the same procedure as in [6], we can prove the following statement.

Theorem 4. The equation

$$\mathbf{z}(t) = (z_1(t), z_2(t), 2(u(t)z_1(t) - v(t)z_2(t))), \qquad (7)$$

where

$$z_2 = e^{2\int \frac{\varphi_1}{\varphi_2} dt}\left(\bar{C} - \int \frac{\varphi_3}{\varphi_2} e^{-2\int \frac{\varphi_1}{\varphi_2} dt} dt\right),$$

$\varphi_1 = \dot{v}(u^2 - v^2)^{\cdot}, \varphi_2 = \dot{v} - 2v(u^2 - v^2)^{\cdot} \neq 0, \varphi_3 = (\dot{u} + 2u(u^2 - v^2)^{\cdot})\dot{z}_1 + 2\dot{u}(u^2 - v^2)^{\cdot} z_1,\ u = u(t),\ v = v(t), \bar{C} = const.$ and $z_1(t)$ is an arbitrary function, determine the infinitesimal bending field $\mathbf{z}(t)$ for the curve C on hyperbolic paraboloid $\mathcal{S}$, which leaves the bent curves C_ϵ on it with a given precision.

Example 3. Let us consider the curve C given by (5) and determine its bending field according to the previous theorem. If we choose $z_1(t) = t^2$, then we obtain

$$z_2(t) = \frac{1}{\sqrt{1-12t^2}}\left(\bar{C} + \frac{2}{3}(1+3t^2)\sqrt{1-12t^2}\right),\ t \in \left(-\frac{\sqrt{3}}{6}, \frac{\sqrt{3}}{6}\right).$$

Assuming that $\bar{C} = 0$, from equation (7), we obtain the following bending field

$$\mathbf{z}(t) = \left(t^2, \frac{2}{3}(1+3t^2), -\frac{4t}{3}\right) \qquad (8)$$

and the family of bent curves C_ϵ

$$C_\epsilon\colon\ \mathbf{r}_\epsilon(t) = \left(2t + \epsilon t^2, t + \frac{2\epsilon}{3}(1+3t^2), 3t^2 - \frac{4\epsilon t}{3}\right). \qquad (9)$$

We can easily verify that $\dot{\mathbf{r}} \cdot \dot{\mathbf{z}} = 0$ holds for each t. Also, from equation (9), we have

$$(2t+\epsilon t^2)^2 - \left(t + \frac{2\epsilon}{3}(1+3t^2)\right)^2 - \left(3t^2 - \frac{4\epsilon t}{3}\right) = -\frac{1}{9}\epsilon^2(27t^4+24t^2+4) = o(\epsilon).$$

The infinitesimal bending of the C curve in the field (8) is shown in Fig. 3, for $\epsilon = \pm 0.05$, ± 0.1, ± 0.25, ± 0.5.

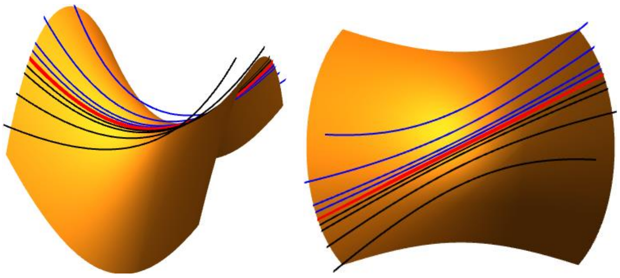

Figure 3. *Infinitesimal bending of the curve C, given by (5), on the hyperbolic paraboloid under field (8) (default and top view)*

Based on the previous figure, we can see that for both positive and negative values of ϵ, the bent curves C_ϵ are located "above" the hyperbolic paraboloid.

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Issues During Data Migration

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Abstract: *Virtualization represents one of the key technologies in modern computing, offering numerous advantages such as running multiple operating systems on a single computer, efficient resource utilization, process execution independence from specific hardware, and enhanced data security. This paper presents the process of virtual machine migration, including migration from one physical server to another without interrupting application operations. Additionally, it discusses some of the key benefits of virtual machines in various contexts, such as resource isolation, resource allocation flexibility, software testing, migration and backup, resource efficiency, and support for different operating systems. Through the analysis presented in this paper, the importance of virtualization as a fundamental technology in modern computing is highlighted, as well as the necessity of understanding the migration process and optimal use of virtual environments.*

Keywords: *virtualization, operating systems, resources, independence, security, virtual machine migration, efficiency, software testing, hardware resources.*

1. INTRODUCTION

Running multiple different operating systems on the same computer, more efficient resource utilization, independence of process execution from hardware, better protection and increased security, and the reduction of physical limitations are just some of the reasons why virtualization is becoming increasingly popular and indispensable in today's computing. Virtualization involves the abstract representation of computing resources (servers, memory, networks, applications, etc.) so that they can be used by different physical systems. Virtual machines are systems that contain their own operating system and applications, and they can run on different hosts, i.e., physical servers [1].

Virtual machine migration involves transferring it from one physical server to another without impacting its operation and the services it provides [2]. During the attempt to carry out this process, various issues and errors may occur, which can result in unsuccessful migration. Some of the most common ones are listed and briefly described below.

The research described in the paper examined how likely each error and problem was to happen when moving a machine from VMWare to Microsoft HyperV, two popular and widely used virtualization platforms nowadays. In addition to pinpoint the situations where errors could arise, the aim was to find solutions for them.

1.1. Cluster of two or more servers

Putting two or more servers into a cluster is the process of creating a highly available and redundant system. A cluster is a group of connected computers that work together as a single unit to ensure stability, increased availability, and fault tolerance [6].

Procedure for Creating a Cluster with Two Servers [6]:

- *Selection of Cluster Technology:* Choosing the appropriate cluster technology that is compatible with the needs and environment. For example, Windows Server offers clustering options, as do Linux systems with tools such as Pacemaker or Corosync.
- *Hardware and Software Preparation:* Provisioning appropriate hardware and network infrastructure. Servers in the cluster need to be connected via high-quality networking to facilitate fast communication between cluster members. Installing operating systems on each server and the required clustering software,

along with any additional tools specific to the clustering technology being used.

- *Network Configuration:* Setting up network settings so that servers in the cluster can communicate efficiently. This includes configuring static IP addresses, DNS settings, and, if necessary, additional network resources.
- *Configuration of Shared Resources:* Setting up shared resources that the cluster will use, such as shared storage that all cluster members can access.
- *Cluster Service Configuration:* Configure specific cluster services that are desired to be provided. This may include application services, web servers, databases, or other resources.
- *Testing and Optimization:* Testing the cluster to ensure it functions correctly. Conducting fault tolerance tests and simulating scenarios where one server becomes unavailable. Optimizing the cluster according to performance and availability requirements.
- *Maintenance and Management:* Regularly maintaining the cluster, upgrading software, and monitoring performance. Managing the cluster using available administration tools.

1.2. Advantages of virtual machines

Virtual machines offer a range of advantages in various contexts, including software development, testing, system maintenance, and efficient hardware resource utilization. [5]

Main advantages of virtual machines [5]:

- *Resource Isolation:* Virtual machines enable resource isolation, meaning each VM has its own separate workspace. This helps prevent conflicts between different applications and operating systems running on the same physical computer.
- *Resource Flexibility:* Virtual machines facilitate dynamic adjustment of resources for each VM according to needs. It's possible to increase or decrease allocated resources (CPU, RAM, storage) to a virtual machine without the need for physical hardware changes.
- *Software Testing and Development:* Development teams can use virtual machines to test software on different operating systems and configurations, facilitating issue identification and ensuring that the software functions correctly in diverse environments.
- *Migrations and Backups:* Virtual machines enable easy relocation and migration between different physical servers or data centers. Additionally, creating backups of virtual machines becomes easier and more efficient.
- *Resource Efficiency:* Through resource sharing, virtual machines enable more efficient utilization of physical hardware. Multiple virtual machines can operate on the same physical server, reducing the need to purchase additional physical machines.
- *Faster implementation:* Creating virtual machines is often faster than configuring physical computers. This means that new instances of operating systems can be deployed and put into use more quickly.
- *Security:* Virtual machines can provide an additional level of security through isolation. If one virtual machine experiences an issue or attack, other virtual machines on the same system can remain unaffected.
- Broad Support for Different Operating Systems: Virtual machines enable running various operating systems on the same physical hardware, which is useful in situations where supporting different platforms is necessary.

2. RESEARCH METHODOLOGY

2.1. Live migration of virtual machines

Live migration is the process of moving a virtual machine from one physical server to another without interrupting the operation of the virtual machine. This technique allows IT administrators to maintain the functionality of applications and services during the transfer process, ensuring that users do not notice the migration and that operations continue uninterrupted. Data transfer occurs over an Ethernet network using the TCP/IP protocol, connecting servers within a cluster. The live migration process involves copying the state of the virtual machine, including memory, CPU state, and network connections, from one physical server to another. This process requires careful management to ensure data consistency and minimize downtime. Various virtualization platforms such as VMware, Microsoft Hyper-V, or KVM/QEMU provide live migration as part of their functionality [5].

Benefits of live migration include [5]:

- *Minimal downtime:* End users do not notice the transfer, as applications and services on the virtual machine remain accessible throughout the entire process.
- *Resource Optimization:* Enables optimal use of resources by allowing virtual machines to dynamically adjust to changes in workload and resource demands.
- *Increased Availability:* Provides the ability to maintain physical servers or perform other administrative tasks without interrupting system and service operation.
- *Management Efficiency:* In addition to resource optimization, live migration facilitates the

administration and management of virtualized environments.

- *Load Balancing:* Enables dynamic load balancing between physical servers, improving overall system performance.

System load balancing, energy savings, resource allocation flexibility, and fault tolerance depend on live migration. From a process perspective, live migration has three different types (Figure 1) [7]:

1. Pre-copy,
2. Post-copy,
3. Hybridcopy.

Pre-copy live migration is a data migration strategy that involves preemptively copying data from the old to the new system before the final transfer. This strategy enables continuous synchronization of data between the old and new systems over a specified period, ensuring that data on the new system is up-to-date and ready for use. Once the data has been successfully pre-copied, the final transfer is executed quickly and without prolonged delays or interruptions in system operation. This method is often used to reduce downtime and minimize potential risks during system migration.

Post-copy live migration is a data migration strategy that involves copying data from the old system to the new system after the migration has already begun and when the new system is already live and operational. This strategy differs from pre-copy migration strategy, where data is copied to the new system before the migration begins. In post-copy live migration, the migration starts without fully completing the data copy. Instead, data copying continues after the migration has started, and data is transferred in real-time or in small batches to reduce system downtime. This strategy can be useful when reducing the time needed to complete migration or when it's impractical to stop the system for an extended period for full data copying before migration. However, there is a risk of data loss or data inconsistencies if the data copying process is not carefully managed.

Hybridcopy live migration refers to a data migration strategy that combines elements of multiple different migration approaches, including pre-copy and post-copy strategies, to optimize the migration process. This strategy may involve applying various data copying and synchronization techniques between the source and target systems, tailored to specific migration requirements and characteristics. For example, certain data or applications may be pre-copied to the target system before migration, while other data may be transferred live during or after migration. The goal of hybridcopy live migration is to minimize system downtime and reduce the risk of data loss, while providing flexibility and adaptability to the migration process according to specific organizational requirements and constraints. This strategy can be useful in situations where achieving a balance between migration speed, data integrity, and minimal disruptions to system operation is necessary.

2.2. Imaging

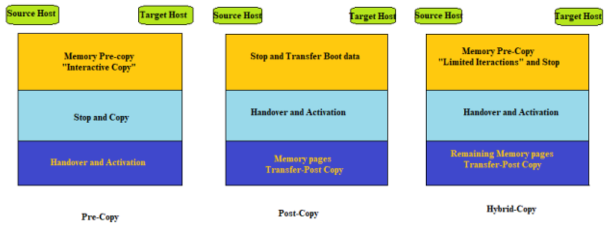

Figure 1. *Types of live migration*

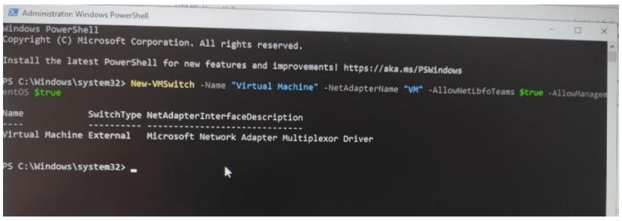

Figure 2. *Adding an External Virtual Switch through PowerShell*

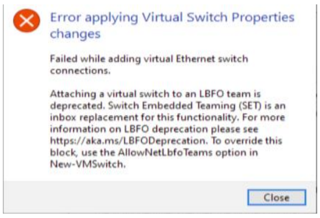

Figure 3. *Error when adding External Virtual Switch*

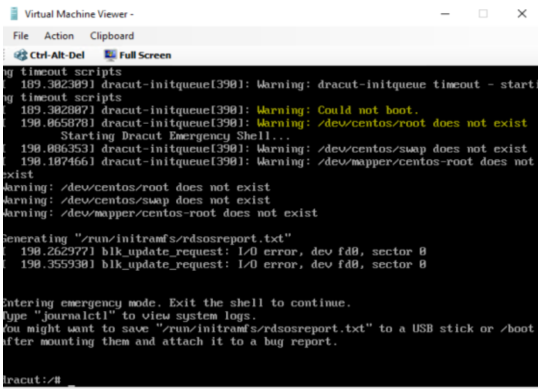

Figure 4. *Errors during the startup of the migrated virtual machine [9]*

3. RESULTS AND DISCUSSION

In the paper, a brief overview is provided on the concept of virtual machines, their migration, and the errors that may occur during this process. Additionally, measures are outlined that should be implemented before starting the migration to minimize the possibility of errors. The second part of the paper discusses the most common errors encountered in a specific example of migrating a virtual machine from VMWare to the HyperV virtualization system, along with possible solutions.

3.1. Lack of isolation of virtual machine from physical components

The inability to migrate a production virtual machine (VM) from one server to another may occur as an error, not because the VM is designated for a specific server, but due to the presence of an attached CD/DVD within the VM itself.

3.2. Incorrect configuration of the virtual switch

For proper communication of a virtual machine with other machines, it is necessary to configure different types of virtual switches. During this process, errors can also occur. One of them, which may occur when trying to add an External Virtual Switch through PowerShell on Windows Server 2022 Datacenter (Figure 2), is shown in Figure 3.

3.3. Unsupported hardware

Unsupported hardware during virtual machine migration can lead to various issues and challenges. Possible problems during virtual machine migration related to unsupported hardware include:

- *Incompatibility with virtualization:* If the hardware on the desired (target) host or server is not compatible with the virtualization used on the source host, the migration may fail. This can involve different versions or types of virtualization technologies.
- *Lack of appropriate drivers:* If the desired hardware lacks suitable drivers for virtual machines, the operating system within the virtual environment will not function correctly. This can lead to performance issues or even the inability to boot the virtual machine. This manifests when the Hypervisor has its own drivers for the operating system running on the virtual machine. However, during the migration of the virtual machine, since the Hypervisor encounters different hardware, it needs to add drivers that correspond to this new hardware, essentially requiring an upgrade.
- *Different hardware configurations:* If the source and target hardware have different configurations, issues with resources such as CPU, RAM, or storage space may arise. This can affect the performance of the virtual machine and may require specific adjustments during migration.
- *Network issues:* The network configuration of the source and target systems may differ, leading to connectivity problems for the virtual machine after migration.
- *Unsupported hardware features:* If a virtual machine relies on specific hardware features that are not available on the target hardware, it can lead to issues. For example, if a certain type of graphics card is used that is not present on the desired hardware, visualization within the virtual machine may be compromised.

To avoid the previously described issues, careful planning of virtual machine migration is recommended, including checking compatibility between the source and target hardware, updating drivers, adjusting configurations, and testing migration before going into production. Using migration management tools like VMware vMotion or Microsoft Hyper-V Live Migration can also facilitate the process and reduce the risk of hardware-related issues during migration.

3.4. Lack of resources

Lack of resources during virtual machine migration can lead to various issues, including reduced performance, loss of availability, or even failed migration. Insufficiency in different types of resources can pose different challenges that need to be overcome for the virtual machine migration to be successful. Some of these challenges include:

- *Insufficient CPU Resources:* If the desired or target host lacks sufficient processor cores or processor speed to support demanding tasks of a virtual machine, this can result in significant performance degradation or system failure.
- *Insufficient RAM:* It's possible that the host to which the migration is being performed does not have enough RAM to support the operation of the virtual machine being migrated, leading to similar issues as in the previous case, potentially causing application freezes as well. Virtual machines with high memory demands may also likely fail to start altogether on the desired host or server.
- *Insufficient Storage Space:* If the desired host lacks sufficient free storage space to accommodate virtual disks, migration will be prevented. This can lead to operational interruptions or data loss.
- *Insufficient Network Bandwidth:* The lack of sufficient bandwidth between the source and destination hosts can slow down or prevent efficient virtual machine migration. This is particularly critical for live migration scenarios where data is continuously transferred during the migration process.
- *Resource Conflicts:* The host to which a virtual machine is being migrated may already host other virtual machines that are using its resources. Additionally, the host may be running various tasks that also consume resources, leading to competition for resources that can affect the performance of the new virtual machine.

To reduce the risk of resource shortages during virtual machine migration, it is recommended to:

- Careful resource planning, which involves analyzing the requirements of each virtual machine and ensuring sufficient resources are allocated on the desired host.
- Continuous monitoring of resources, i.e., tracking resource usage on the desired host over time to ensure there will be enough resources available for new virtual machines.
- Resource management automation, i.e., using tools for automating resource management to dynamically adjust resources according to the needs of virtual machines.
- Testing before migration, i.e., conducting test migrations to identify and resolve resource issues before moving to production.

3.5. VM (Linux OS) – from VMWare to HyperV

Two of today's most popular virtualization programs, VMWare and HyperV, are compatible, allowing virtual machines created with one to be migrated and run on the other. Certain conditions need to be met for this to work. One of them is that the virtual machine must have appropriate drivers for the program it is running on.

When migrating a Linux virtual machine from VMware to Hyper-V, various issues may arise, including [8]:

- *Virtual drivers:* Linux distributions often come with drivers optimized for VMware environments. When migrating to Hyper-V, different drivers may be required to ensure proper functionality of the virtual machine.
- *Network configuration:* Network configuration on Hyper-V may require adjustment, especially if different types of virtual network adapters are used or if specific settings from the VMware environment are incompatible with Hyper-V.
- *Virtual hardware conflicts:* Virtual hardware conflicts can arise if a Linux VM is configured to use specific features of the VMware platform that are not supported or implemented differently in the Hyper-V environment.
- *Performance loss:* While both Hyper-V and VMware are powerful virtualization platforms, performance can vary between them. Certain optimized procedures that work well in one environment may not deliver the same performance in the other.
- *Setting up tool integration:* Integration tools for Linux (such as Integration Services for Hyper-V) may be necessary to ensure proper functionality and improved performance of the virtual machine on the Hyper-V platform.

To overcome these issues, it is recommended [8]:

- Using migration tools that support virtual machine migration between VMware and Hyper-V platforms.
- Updating drivers and configuring the virtual machine to adapt to the Hyper-V environment.
- Testing the virtual machine post-migration to identify and resolve any issues that arise.
- Following guides and resources provided by Microsoft and Linux distributions for migrating virtual machines between different virtualization platforms.

3.6. Disabled Hyper-V network driver

If a virtual machine is created using VMWare and is being attempted to run on HyperV, it must have appropriate drivers for HyperV in addition to VMWare drivers [3].

Some of the most common driver issues that lead to the inability to start a virtual machine after migration include disabled drivers, changed or incorrect NIC MAC addresses, etc [4]. Figure 4 shows the appearance of errors on the console that are received if there is one of the previously listed problems.

The following describes possible ways to solve the above problems using the example of migrating a VMWare Linux virtual machine to HyperV.

The most common cause of issues when connecting a migrated virtual machine to the network is faulty operation of the network driver. To determine if there is indeed an issue with the network driver, access to the serial console on the virtual machine is necessary. For the serial console to function correctly, the operating system must be configured to read and write console messages to the serial port. Most Linux distributions have the serial console enabled and configured based on default settings. However, if this is not the case, the serial console needs to be enabled for the Linux VM in the /etc/inittab file to initiate the ttyS0 terminal.

During the mentioned procedure, sometimes it is necessary to instantiate a new getty (terminal management program) service on ttyS0, which can be done using the command systemctl start serial-getty@ttys0.service.

When it is determined that the network driver is disabled, it needs to be re-enabled using the serial console. Access the serial console of the virtual machine and log in with correct credentials, then switch to either the root or a user account with administrative privileges. The next step is to navigate to the /etc/modprobe.d directory and find the lines that disable the hv_netvsc driver. Use the command grep -nr "hv_netvsc" /etc/modprobe.d/ in the console to identify the file and their line numbers. Once found, modify the file by commenting out or deleting entries that disable the driver, typically in the form of install hv_netvsc /bin/true or blacklist hv_netvsc.

Finally, it is necessary to regenerate the initial RAM disk image for the currently loaded kernel and then restart the virtual machine [9].

The previously described solution can be implemented if serial console access is enabled. In case of network issues, serial console may not be available, necessitating an alternative method without network access, known as offline. In such cases, Azure serial console can be used for login. To access the OS disk content of the virtual machine (the disk with the installed operating system when the virtual machine was created) experiencing the issue, az vm repair commands are used. The filesystem part containing the necessary content is isolated using chroot instructions. Once successful access is achieved, locating the file containing the lines that disable the hv_netvsc driver and modifying it to re-enable the driver is done in the same manner as in the previous case. After making the changes, exit the chroot environment and regenerate the initial RAM disk image. The final step involves automatically replacing the OS disk with the virtual machine and restarting the system using the command az vm repair restore [9].

3.7. Incorrect NIC MAC address

Another possible reason for network service malfunction after migration is a changed or incorrect NIC (Network Interface Card) MAC address in the configuration, which can occur if the NIC was deleted, added by an administrator, or modified in the background. If the network driver is enabled and issues persist, checking the OS NIC configuration is necessary. Repairing the NIC MAC address can be done, similar to addressing a disabled driver, using either the serial console or offline methods [9].

The initial steps in troubleshooting using the serial console are the same as for a disabled driver. Therefore, access the console, log in with correct credentials, and switch to either the root or a user account with administrative privileges. Next, navigate to the /etc/cloud/cloud.cfg.d directory using the appropriate command, and open and modify the following files, depending on the Linux distribution [9]:

- 91-azure_datasource.cfg for RHEL.
- 90_dpkg.cfg for Debian and Ubuntu.

The parameter apply_network_config should be set to true, ensuring that the new MAC address will be preserved in the network configuration after system restart. If no value is specified for this parameter, true is assumed. If the parameter is set to false, it should be changed to true before proceeding to the next step. If it is absolutely necessary for apply_network_config to remain false and the desired configuration cannot be achieved using cloud services, the solution involves deleting the /var/lib/cloud/instance/obj.pkl file with the command # rm /var/lib/cloud/instance/obj.pkl. After making changes to the NIC configuration, the system needs to be restarted to ensure proper functioning of the network services [9].

A similar scenario as with offline driver enabling repeats when troubleshooting issues with NIC MAC address, especially when serial console access is not possible. Azure serial console and az vm repair commands are again used to access the OS disk content. The procedure for making changes in the network configuration or deleting the obj.pkl file is the same as in the previous case. Finally, the az vm repair restore command is used to automatically replace the OS disk with the original virtual machine and restart the system [9].

3.8. Inappropriate drivers for Hyper-V

Besides the network driver, the culprit for issues that occur when starting a virtual machine migrated to Hyper-V can be an incorrect or disabled operation of another driver. In this case, serial console cannot be used, so the only solution is to use offline access to re-enable the driver. After accessing the content of the OS disk where the issue exists, similar to offline resolution of network issues, switch to a chroot environment, navigate to the /etc/modprobe.d directory, and identify all lines that disable hv_utils, hv_vmbus, hv_storvsc, and hv_netvsc drivers. To find the required file and the line numbers of problematic entries, use the command:

```
egrep -nr  "hv_utils|hv_vmbus|hv_storvsc|hv_
netvsc" /etc/modprobe.d/
```

Within the identified file, comment out or delete entries related to these drivers, typically in the form of blacklist driver_name or install driver_name /bin/false. After successfully making these changes, regenerate the initial RAM disk image for the currently loaded kernel and replace the OS disk used in the repair process with the original virtual machine using the command az vm repair restore. The final step, after making any configuration changes, is to restart the system, which is necessary in this case as well [4].

4. CONCLUSION

This paper examines a number of virtual machine migration topics, with an emphasis on the main benefits of virtualization and potential difficulties that could occur. Virtualization is an essential technological advancement in modern computing due to its many advantages, including hardware independence, data security, and effective resource utilization. It is possible to move from one physical server to another through the process of virtual machine migration, particularly live migration, which guarantees continuous availability by not disrupting application services.

Analyzed are common migration errors, such as resource shortages, unsupported hardware, network switch configuration, and resource isolation problems. For each of these errors, recommendations and potential fixes are given in order to reduce risks and guarantee a successful migration execution.

Lastly, it's critical to remember that the successful deployment of virtualization and virtual machine migration depends heavily on thorough planning, testing, and the use of the right migration management tools. Knowing these procedures improves the general security and dependability of information systems in addition to helping to use IT resources more effectively.

Based on the experiences gained during the research process, new opportunities for improving the work emerge, focusing on the analysis of the obtained results applied to other types of virtualization systems and determining migration methods that will minimize the occurrence of errors, regardless of the type of virtualization system.

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The New Role of the Teacher in Education 4.0

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Abstract: *Today's social, political and technological changes, known as the 4th Industrial Revolution, have merged the physical and digital worlds and are affecting expectations for student education. In addition to expectations for soft skills development, there is an emphasis on adaptability, sustainability and critical thinking. This requires a change in the role of the teacher, especially in the technical/technological area of teaching, which is dynamic but also offers numerous opportunities for the development of the desired skills. In this context, Education 4.0 emerges as a strategy that should provide today's students with a personalized learning experience, mobile learning, a flexible and tailored curriculum and the development of practical and applicable skills. The analysis shows that in such a context, the teacher should primarily play the role of a mentor, facilitator and helper in discovering the student's preferences, but also as an organizer of practical activities and a guide to the student's development path according to their preferences. Whether a teacher is willing to take on such a role depends on their knowledge and skills, but also on their attitude, beliefs and teaching practice, as well the willingness of educational authorities to lose complete control over the educational process.*

Keywords: *applicable skills; education 4.0; sustainability; technical and technological education; the role of the teacher*

1. INTRODUCTION

Today's way of working and producing, which undoubtedly affects the way society lives and functions, is in many ways determined by the synergy of modern technologies, also known as *Industry 4.0*. This is the digital transformation of the manufacturing industry, which focuses on the automation, networking and optimization of real-time processes using digital technologies [1]. Perhaps it is better to say that it is the result of the integration of combined "exponential technologies" [2]. These technologies include the Internet of Things (IoT), machine learning (ML), artificial intelligence (AI), cyber-physical systems (CPS), cloud computing, additive manufacturing (AM), digital twins, cybersecurity and other technologies, all of which serve the purpose of mutual communication and control [3]. It really is about digital, or rather computing technologies that are in synergy with the systems of the physical world and still "do" what is necessary. In this context, AI, ML, Big Data, Cloud computing and cybersecurity are fundamental computing technologies, while automation and robotics, IoT, CPS and AM form the physical part of Industry 4.0 [1]. The concept of *Industry 4.0* itself describes the increasing digitalization of the entire value chain and the resulting networking of people, objects and systems through real-time data exchange [4]. Today, all of this together enables flexible production, production on demand, rapid customization of production and high product quality and efficiency. Nevertheless, such a development also raises fears of the loss of numerous jobs, economic imbalance and greater inequality in society [1], [5]. The challenges of *Industry 4.0*, which is still present and has yet to be realized in many countries, can be reduced to an increase in unemployment, the loss of manufacturing skills and wage inequality [1]. The need for human intelligence is often ignored, as are the undesirable effects of digital technologies on the environment and society. In other words, excessive automation and optimization in many areas of industry and production has neglected the human factor as the driver of development and the reason for the existence of modern technology and production, thereby bringing the environment and human society into imbalance and to the brink of sustainability.

Due to this pervasive dehumanization, *Industry 5.0* is already being seriously considered as a vision of industries that think beyond increasing productivity and efficiency and contribute to society by placing workers at the center of the production process, with a focus on research and innovation that is sustainable, human-centric and resilient [6]. Therefore, it is predicted that *Industry 5.0* will include two missing key elements: human inclusion and sustainable development [1]. This also requires upgrading existing technologies to those that enable collaboration between the digital world and people's ability to think critically and creatively, i.e., the integration of physical and cyberspace [7], [8] for the future *Society 5.0*. In this way, the industry would continue to offer flexibility and agility to respond quickly to changing market conditions and customer preferences. Due to such a "minimal" superstructure on existing technologies, some authors state that *Industry 5.0* would only be an incremental evolution of *Industry 4.0* technologies and practices [9], so such a development might be better labelled as "Industry 4.0S" or "Sustainable Industry 4.0" [1].

However, it is less important what such a change is called. Much more important is how the young generation is trained and prepared for the current industry, but also for challenges and problems that do not yet exist [10]. For this reason, *Education 4.0* is now emerging as a desired learning strategy that coincides with the fourth industrial revolution [11]. In this sense, education is reimagined as an inclusive, lifelong experience where the responsibility for building skills lies with the students, with teachers and mentors acting as facilitators and helpers [12]. It emphasizes the unique development of each student, a personalized learning environment [13, 14, 15] as well as hands-on activities and applicable skills [16], where each student should be able to choose their own learning path and develop according to their preferences [17, 18]. Problem-solving skills, co-operation and adaptability [19, 20], but also sustainability skills [21] and critical thinking [22] stand out as critical skills that play a central role in the students' personal curriculum. It is clear from these intentions of *Education 4.0* that it is in line with the future *Industry 5.0* and *Society 5.0*. In the future, such transformation of education should be supported by the application of cutting-edge technology and automation, including robotics, artificial intelligence and "smart" technology [23], which are part of today's *Industry 4.0*. Research therefore suggests that school enrolment in early childhood and primary school can have a major positive effect on critical cognitive development and skill building, which is then multiplied by learning later in life [24]. In this sense, engineering, technology and the so-called STEM fields are particularly exposed, but also offer numerous opportunities. As teachers are the main drivers of educational quality [25, 26, 27], their readiness for *Education 4.0* (or 5.0) depends on their knowledge, attitudes, beliefs and the practice of their own teaching. Therefore, research today focuses on teachers' beliefs about their own competences in empowering students for the challenges of the modern world [28], on the way they integrate technology into their own teaching process [29, 30, 31], on the way they implement sustainable development issues in the classroom [10, 21] and on approaches that teachers should adopt when teaching engineering and technology [32]. In other words, the question arises as to what role the teacher should have in *Education 4.0*.

Before we try to answer this question, we should know the competences that *Industry 4.0* requires from employees today and that should serve as a reference point for teachers in terms of teaching activities and expectations for students.

2. EMPLOYEE COMPETENCES AS A MILESTONE FOR *EDUCATION 4.0*

It is certain that with the increasing automation and optimization of production and other processes, the demand for some professions is decreasing, for others it is disappearing, while new disciplines and requirements for new jobs and skills are emerging every day. The education system must therefore inevitably deal with such changes, which is a major challenge, especially in technical (engineering) and technology education. This often requires a shift in focus from technical activities, which are no less important, to advising companies, globalization, rapid technological change and the development of technical specializations, the critical relationship with society and environmental issues [19, 33, 34]. Such rapid changes in the "real world" once again highlight the gap between the competences developed during education and those required for work in the field of engineering and technology. Despite this, the education process often insists on theory and analysis at the expense of creativity, problem solving, innovation, design, ethics, thinking, the study of complex systems and the needs of practice [19]. Furthermore, research often points to deficits in the development of communication, interpersonal and leadership skills [35], in the development of emotional intelligence [36], to employers' dissatisfaction with the practical application of theory and entrepreneurial skills [20] and to a lack of basic and technical (engineering) knowledge [37]. All this happens despite the long-known fact that mental resourcefulness, entrepreneurship and interpersonal skills are correlated with effectiveness at work [38].

From all of the above, it can be concluded that today's competencies in the field of engineering and technology (and beyond) should include technical and non-technical competencies. Such competencies include communication, teamwork skills, development of professional attitudes, entrepreneurial skills, problem solving skills, self-learning management, critical thinking, creativity (inventiveness) and practical technical (engineering) skills [19, 34]. This does not diminish the importance of crucial theories, but emphasizes the need for their integration into meaningful concepts that students can apply and actually understand [34].

However, modern changes are too fast and dynamic, and the labor market is constantly changing and requires a higher level of skills and better digital literacy [39]. As it is very important to give everyone the opportunity for professional development and the acquisition of new skills, but also to enable the transformation of traditional professions according to the demands of the labor market, it is extremely important that teachers also understand which competences students need more and which less, at an early stage of education and especially during vocational training. For example, current research on the requirements of *Industry 4.0* shows that certain competences an individual "must have", some "should have" and some are desirable but not necessary [39]. The competences that individuals "must have" include: IT knowledge and skills, the ability to use modern equipment, an understanding of organizational and process issues, and the processing and analysis of data and information; [39]. Competencies that today's employees "should have" or would be good to have include: Information on IT security and data protection, interdisciplinary, exceptional knowledge of production activities and processes, and knowledge management [39]. The same authors note that competences related to exceptional knowledge of information technology, programming skills, knowledge of ergonomics and understanding of legal issues are desirable but not essential. From this analysis of the competences required by *Industry 4.0*, it is clear that the mandatory competences in the education system can only be taught through quality engineering and technology education, i.e., by teachers from this field of education who integrate technology appropriately into the teaching process.

The next level of student competences that align with the requirements of *Industry 4.0* and *Society 5.0* relates to the development of critical thinking and related competences for sustainability and sustainable development. Critical thinking can be understood as a person's ability to process and synthesize information in such a way that it can be meaningfully applied to tasks in order to make informed decisions and solve problems effectively [22, 40]. In the context of the Sustainable Development Goals (SDGs), this means not only knowing these goals, but gaining a "deep insight" into the needs, resources, technologies, consequences and perspectives for the future [10]. At the same time, technical and technological education is very well suited to operationalizing critical thinking skills in the context of the Sustainable Development Goals [22].

From the presented competences that are required of an individual (employee) today, a broad spectrum of professional knowledge and skills can be identified that a modern technology teacher should have in order to be able to develop such competences in students.

3. TEACHER COMPETENCES FOR *EDUCATION 4.0*

The expectations of students, i.e., the desired competences that today's "world of work" demands of them, are only a guideline for teachers to follow when designing teaching content that is suitable for *Education 4.0* (or *Society 5.0*). The competences are also a point of reference for education systems and curriculum creators, who should take these competences into account. However, teaching is an interactive process with people, so this knowledge is not sufficient for the successful development of students' competences. In this context, the learning and teaching of engineering and technology is very delicate because, on the one hand, it is necessary to cope with the "world of work", which is relentless, dynamic and very demanding, and on the other hand, it is necessary to develop a positive attitude in students and to encourage and develop students' interest in engineering and technology [32], which is one of the main objectives of this education [41].

For this reason, the knowledge that a teacher of engineering and technology should have can be categorized into three areas:

- Subject Matter Knowledge (SMK),
- Pedagogical Content Knowledge (PCK) and
- Teacher Attitudes as part of the general construct of teacher knowledge [42].

Subject Matter Knowledge (SMK) refers to the understanding of the subject and is related to the understanding of the expected student competences mentioned in the previous chapter, but also to the teacher's concept of technology. A correct and comprehensive technology concept of the teacher is very important to shape the students' attitude [43].

Pedagogical Content Knowledge (PCK) is the knowledge of how to organize, present and adapt specific topics, problems or questions to meet the diverse interests and abilities of students [32, 41, 44, 45, 46]. This includes knowledge of students' concepts and misconceptions about technology, knowledge of pedagogical approaches and teaching strategies specific to this course, and knowledge of the nature and purpose of technology education [42].

All this is also part of the **TPACK** (Technological, Pedagogical and Content Knowledge) framework for teachers' knowledge [47, 48], according to which the teacher's expertise consists of content knowledge, but also pedagogical and technological knowledge, as well as connections and combinations between them [49].

The teacher's attitudes (and beliefs) include their attitude towards technology and their confidence in their own ability to teach in the classroom, which may ultimately be critical to the development of students' competences. However, even if the above-mentioned framework for teacher knowledge is universal and widely recognized, it certainly needs to be constantly updated and "brought up to date' to equip the teacher for the new challenges of *Education 4.0* and/or *Society 5.0.*

The improvement of teachers' knowledge and competences is considered here only from the point of view of the competences that a person "must have" and which are listed in the previous chapter. When it comes to students' competences related to the ability to handle modern equipment, but also to understand organizational and procedural issues, it is repeatedly confirmed that direct and meaningful practical activities of students are without alternative in this respect [50, 51]. This also means that the teacher of engineering and technology must constantly improve their skills and knowledge in the use of new devices and technologies in order to provide students with activities that reflects "real world" processes and "equip" the student with practical and applicable skills. Even if the school and the education system cannot keep up with all the technological changes in the industry and do not have all the devices that are used there, the use of the technical means and devices that the school has will develop in the students the cognitive mechanisms necessary for a faster adaptation to the devices that they will use tomorrow in the "real world".

Regarding the development of competences for the use of digital media as a way to acquire IT knowledge and skills as well as competences for data and information processing and analysis, research on the application of pedagogical techniques guided by the Interactive Constructive Active and Passive (ICAP) framework perhaps provides the best answer [30, 52, 53, 54]. This framework distinguishes between learning activities in terms of visible activities (students' level of activation) and basic learning processes, i.e. students' cognitive engagement [31], and distinguishes four levels of cognitive activation: passive, active, constructive and interactive [29]. Research shows that an increase in the level of activity has a positive effect on learning success [29] and thus on pupils' competences. Digital media should be used to support cognitive learning processes [29, 55], i.e. to facilitate certain cognitive processes and increase the level of cognitive activation. In other words, a meaningful and well-organized active, interactive and constructive use of digital media can improve students' learning and competences, as opposed to the passive use that is unfortunately commonly used in the classroom. Therefore, teachers need new pedagogical skills to promote sophisticated learning activities with digital media to encourage students to engage in learning activities at all levels, depending on the desired goal of teaching and learning [56]. Such an approach to the use of digital media in the classroom can more easily provide a personalized learning experience tailored to students' individual characteristics and preferences [17, 18, 32].

With regard to the development of competences for sustainability and sustainable development that today's society and industry are striving for, it is clear that in order to reflect critically and constructively on sustainability and develop sustainable solutions for the future, it is necessary to understand everything that can disrupt but also ensure sustainability. For this reason, knowledge about the goals of sustainable development, but also about needs, resources, technologies, consequences and existing solutions should be the basis of any education of the future [10]. For this reason, every teacher, especially a technology teacher, should acquire the knowledge and skills to integrate the Sustainable Development Goals into students' activities in order to stimulate their critical reflection on sustainability issues and encourage their creative and transformative action.

Furthermore, *Industry 4.0*, which aims at *Industry 5.0*, puts people back at the center. Therefore, education should respect students' interests and preferences and support their personal development path. Certain research findings indicate that students' understanding of the purpose of learning and classroom activities, the implementation of activities that they consider useful and important, and the promotion of students' self-realization are related to students' interest and attitude towards teaching [32]. This confirms the importance of well structuring learning objectives and outcomes as part of the teacher's general pedagogical knowledge [27]. This does not only refer to the cognitive component, on which the teacher often focuses, but also to the development of students' personal qualities and to social and democratic objectives [57]. This also points to the importance of identifying needs as an element closely linked to the pedagogical (educational) needs of students, as well as the importance of teachers' situational skills and the need to constantly measure the quality of teaching [32]. In other words, the pedagogical component of a teacher's competence requires the development of their analytical skills, which are necessary to examine students' needs and interests, recognize their preferences, adapt the teaching activity to the student and develop the ability to accompany students on their own development path.

Ultimately, today's *Industry 4.0* and especially the future *Industry 5.0* and *Society 5.0* are certainly moving towards an increasing fusion of the physical and virtual worlds, which can put the teacher in a very unfavorable position, but also represents a challenge that the teacher must be aware of. Therefore, the teacher should accept that today's generations are deeply immersed in the virtual world, and all the technologies they already use, such as mobile technologies, should be accepted and aligned with the students' developmental needs [58]. Similarly, in their pedagogical work with students, the teacher should continue to emphasize and support the importance of the physical world and human characteristics in order to reduce the undesirable consequences of technological development, maintain the importance of humans interacting with technology, and preserve the humanity that *Industry 5.0* and *Society 5.0* strive for.

4. CONCLUSION

Today's *Industry 4.0* is characterized by a high degree of integration of technology into all aspects of human life and work. This also brings new challenges for *Education 4.0*, which should respond to the needs of the "world of work" while enabling the sustainability of society and the economy and maintaining humanity in the future *Industry 5.0* and *Society 5.0*. The most important skills that today's industry requires of a person are those related to IT knowledge and skills, the ability to use modern equipment, understanding of organizational and process issues, processing and analysis of data and information, but also critical thinking and understanding of sustainability and sustainable development. All this requires certain changes in the education system, i.e. in the knowledge and competences of teachers.

The analysis shows that the most important changes in teachers' knowledge and competences concern the following points: (a) improving skills in the use of modern devices to enable students to engage in activities with technology and to understand organizational and procedural issues; (b) training for the active, interactive and constructive use of digital media in the classroom; (c) integrating sustainability issues and problems into such activities to enable the development of students' critical thinking; (d) the development of analytical and mentoring skills to identify students' interests and preferences and personalize teaching; and (e) the ability to integrate the technologies used by students into their own teaching in order to tailor teaching to students' educational needs, but also to maintain the "supremacy" of a human approach over technology. The changes mentioned above are not so much changing the framework of teacher knowledge, but rather the emphasis on certain competences within this framework and, above all, the role of teachers in the classroom of today and tomorrow. All this puts the teacher in the role of a researcher (of the environment and of the students' interests and preferences), an action researcher of his own teaching, an organizer of student activities, a facilitator and mediator of these activities and a mentor and adviser for the personal development and promotion of the students. In this context, high technology should primarily be a means of contextualizing teaching content and enabling the automation of teachers' administrative tasks so that they have more time to work directly with students.

Accordingly, the main contribution of this research is to highlight the direction in which the teaching profession should evolve, especially in the field of technology and engineering, i.e., to emphasize the competences, skills and role that the modern teacher should have in *Education 4.0*. The arguments presented should influence initial teacher education and induction into the profession, but also determine the direction and content of teachers' professional development.

The envisaged changes in the competencies and role of teachers still require adequate institutional support, i.e., support from the school and education authorities. This support relates primarily to appropriate professional training that not only improves the teacher's professional skills but also shapes their attitudes and beliefs so that they are more confident in their own abilities. The support also refers to more flexible curricula that give the teacher more autonomy to personalize the student's development path.

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Advancing the Teaching Method in the Era of Widespread Artificial Intelligence Application: An Explorative Study

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Abstract: *This paper explores the application of artificial intelligence (AI) in education to improve teaching processes. Through the analysis of relevant literature, various aspects of the application of AI technologies in the educational sector are explored. It has been found that AI can provide a personalized academic experience and more efficient information retrieval; however, AI answers are perceived as often lacking in accuracy and correctness and should not be unquestioningly trusted. The research instrument was an online survey given to 105 university students with several types of questions to discover whether our students were familiar with the concept of AI tools. Through the analysis of the available literature and the student's response, it is concluded that a viable option to improve the learning and teaching process is a balance between traditional teaching methods and the application of AI technologies, where AI could support teachers through dynamic and interactive lessons and provide additional resources tailored to individual student needs. At the same time, the need for careful development and use of AI technologies concerning ethical principles and continuous expert supervision is strongly emphasized, underlining the crucial role of educators, researchers, and policymakers in ensuring responsible AI use in education.*

Keywords: *education improvement; teaching; artificial intelligence; motivating students*

1. NAVIGATING THE CHANGING LANDSCAPE OF TECHNOLOGY EDUCATION AND EMPLOYMENT

In an era marked by rapid technological advancement and evolving job markets, the assumptions guiding education must adapt to society's shifting needs. While universities continue to teach competencies that align with past industry demands, a looming discrepancy exists between these skills and the future employment landscape.

A prime example of this dissonance is the prevalent focus on programming languages in technology education. Despite emphasizing programming skills, forecasts suggest that many programming-related jobs may succumb to automation and artificial intelligence (AI) in the coming years. Consequently, technical companies are already experiencing layoffs, signaling a broader trend poised to escalate.

In this evolving scenario, the survival and success of students in the technology sector hinge on a combination of motivation, talent, and adaptability. Only the "best of the best"—those who possess a keen understanding of emerging technologies, maintain unwavering motivation, and demonstrate exceptional talent—will likely thrive in this competitive landscape. However, the question remains: What is the place and role of other students in technology?

While the future may indeed favor the technologically adept, it would be remiss to overlook the diverse skill sets and contributions of students beyond the elite cohort. In a field as multifaceted as technology, a spectrum of roles and opportunities extends beyond programming alone. Students with strengths in design, user experience, project management, and entrepreneurship will continue to play pivotal roles in driving innovation and progress.

Furthermore, the advent of AI and automation does not negate the need for human ingenuity, creativity, and empathy – qualities that machines cannot replicate. As such, students who possess a blend of technical and soft skills, such as critical thinking, communication, and collaboration, will remain indispensable in navigating the complexities of the digital age.

In essence, while the technological landscape may undergo profound transformations, the role of students in technology extends far beyond mere proficiency in programming languages. As educators and policymakers grapple with preparing the next generation for an uncertain future, it becomes increasingly crucial to cultivate a diverse range of skills, perspectives, and talents – ensuring that all students are equipped to contribute meaningfully to the ever-evolving world of technology. Incorporating technology into teaching is a powerful strategy in the digital age. It provides access to a wealth of information and resources, making learning more engaging and relevant. Technology can be used for interactive lessons, online research, virtual simulations, and multimedia presentations, enhancing students' understanding and expanding their horizons. It also prepares them for the technology-driven world they will encounter outside school [1].

An illustrative example of AI technology integration in the classroom is its use in addressing code-related tasks during hands-on lectures. Students frequently seek assistance from AI tools when faced with complex programming challenges, regardless of the language used. These tools generate a general response, providing a basic code structure to be incorporated into existing projects. However, despite AI's considerable help, a solid understanding of programming principles and logic is vital for effectively using AI-generated solutions within the task context. Students who do not possess fundamental programming skills and syntax knowledge often struggle to implement AI-generated code within their projects. AI aids by offering conceptual guidance and a preliminary solution, but expertise in the subject matter is essential for completing the task and producing functional code.

Another concrete application of AI in educational settings is its ability to generate descriptions for machine learning (ML) datasets. When encountering ML datasets for the first time, tasks such as data analysis, understanding, and separating predictors from outcomes can be daunting, especially if the dataset was not initially intended for ML applications. Students leverage AI-generated insights to enhance their project work, using AI for dataset analysis and explanatory purposes. However, relying on AI solutions without critically assessing their validity can result in illogical and insignificant outcomes. This highlights the importance of foundational knowledge for effectively merging AI-generated solutions with ongoing work. While AI assistance can significantly improve the effectiveness of classroom tasks, human expertise and critical thinking are indispensable for ensuring their completion and accuracy. In this study, we explore student perceptions of using AI tools in education, including students beyond the elite cohort who often lack motivation and knowledge for a more classical and rigorous technical study but still have specific interests and talents that would greatly benefit from personalized academic experience and study gamification in line with Gen Z preferences.

AI has the potential to transform education, and many researchers aim to understand students' perspectives on AI in educational settings by analyzing survey responses from diverse academic backgrounds [2]. [3], [4]. In addition, students' opinions on the use of AI in specific tasks were analysed, such as in essay writing [5].

The goal of this study is to explore the application of AI in education to improve teaching processes. This study aims to understand how AI can be utilized to create a personalized academic experience, enhance information retrieval, and support dynamic and interactive lessons. The purpose of the study is to analyze various aspects of AI application in education, determine students' familiarity with AI tools, and evaluate their perceptions and attitudes towards AI in educational settings. This study seeks to find balance between traditional teaching methods and AI technologies while emphasizing the need for ethical AI development and continuous expert supervision. Additionally, the goal is to gain insight into responsible AI use in education, providing additional resources tailored to individual student needs and preparing them for the technology-driven world [6].

2. METHODOLOGY

Our study employed a mixed research design, integrating qualitative and quantitative approaches to analyze the research questions comprehensively. The survey group included 105 Faculty of Technical Sciences Čačak students, comprising 80 first-year and 25 third-year primary academic Information Technology (IT) students. The gender distribution included 29 females and 76 males, offering a diverse demographic representation.

The questionnaire used in this study was meticulously developed by combining an adapted attitude scale with a set of original questions designed by the researchers. The adapted attitude scale was tailored to capture students' perceptions and attitudes towards integrating AI in educational settings [7]. The original questions were explicitly crafted to explore various dimensions of AI application in teaching, such as the types of tasks where AI was utilized, the effectiveness of AI in assisting with these tasks, and the students' overall experience with AI tools in their coursework. This comprehensive instrument ensured that the data collected would provide detailed insights into this research's specific areas of interest, as illustrated in Table 1.

Data was collected through a structured survey administered to the students during April 2024. The survey was designed to be both accessible and engaging, encouraging maximum participation from the students. To ensure the reliability and validity of the responses, the survey was administered under supervised conditions, with clear instructions provided to the participants. The questions were framed to elicit honest and reflective responses, focusing on their studies' practical aspects of AI application.

Table 1. *To thirteen survey questions, students could answer with: 1 = I strongly disagree, 2 = I do not agree, 3 = I neither agree nor disagree (neutral), 4 = I agree, 5 = I strongly agree. Results are later normalized to range -2 to 2, zero being neutral, making it easier to appreciate positive or negative attitudes towards AI.*

1.	Artificial intelligence is part of my everyday life.	1	2	3	4	5
2.	Artificial intelligence is part of my academic life.	1	2	3	4	5
3.	I am familiar with intelligent systems capable of answering my questions (ChatBot).	1	2	3	4	5
4.	I use intelligent systems during learning (e.g. ChatGPT, Gemini, Copilot, etc.)	1	2	3	4	5
5.	Intelligent systems are very reliable and always give correct answers.	1	2	3	4	5
6.	Artificial intelligence is sufficiently developed for use in teaching.	1	2	3	4	5
7.	Artificial intelligence can help improve education.	1	2	3	4	5
8.	Lectures in studies should also include the study of the use of intelligent learning systems.	1	2	3	4	5
9.	I would quickly get used to a form of teaching that uses intelligent teaching systems.	1	2	3	4	5
10	Teachers would provide better education to students with the use of intelligent systems.	1	2	3	4	5
11.	Realization of pre-exam and exam obligations with the use of intelligent systems would reflect my real knowledge.	1	2	3	4	5
12.	There are problems with studying that could be partially or completely solved by using artificial intelligence.	1	2	3	4	5
13.	In my daily life and work, I no longer need my own knowledge, because I can supplement it by using artificial intelligence tools.	1	2	3	4	5

The data collection process involved several steps:

1. Pre-Survey Preparation: Before administering the survey, an introductory session was held to explain the purpose of the study, the importance of their participation, and how their responses would contribute to the research. This session aimed to build trust and ensure informed consent from all participants.
2. Survey Administration: The survey was distributed during regular class sessions to ensure a high response rate. Participants were given sufficient time to complete the questionnaire, and researchers were available to clarify any questions.
3. Data Entry and Cleaning: Upon collection, the survey responses were carefully entered into a digital database. A data cleaning process was performed to identify any inconsistencies or errors in the responses, ensuring the integrity of the dataset.

The analysis phase involved both statistical techniques and qualitative response analysis. Descriptive statistics were used to summarize the demographic characteristics of the sample and the overall responses to the questionnaire items. Inferential statistics were employed to examine differences between groups (e.g., first-year vs. third-year students, males vs. females) and to Identify significant patterns and correlations within the data. Additionally, qualitative responses from open-ended questions were analyzed using thematic analysis. This approach allowed the researchers to identify common themes and insights related to the students' experiences and attitudes towards AI in their education. Integrating quantitative and qualitative findings provided a rich, nuanced understanding of the research questions.

3. RESULTS AND DISCUSSION

3.1 Pool results

Students answered 13 questions (q1-q13) and indicated the following opinions [8]:

- Majority of students do not rely much on AI systems in daily life or studies (q1-q2)
- Students are aware of AI systems (q3) and use them occasionally (q4), with male students being one point more positive than female students.
- Students doubt whether AI is sufficiently developed and believe that AI-provided answers are not always correct (q5-q6).
- Students believe that AI could eventually help them and would like to see some AI aspects in education. They believe that education could benefit from it and that they would get used to it quickly (q7-q10, q12).
- Students are generally aware that using AI tools during exams would reflect insufficiently their actual knowledge (q11).

- While believing that some knowledge augmentation is possible, students generally think that AI could not replace the lack of their knowledge sufficiently and that doing exams using AI systems would represent their actual knowledge. Female students are even more conservative on this than males (q13).
- The answers given by 1st and 3rd year students are pretty similar. Notable exceptions are that 3rd-year students show more awareness that AI currently often provides wrong answers (q5), but are still a bit more positive in wanting to learn how to use AI (q8).

The figure 1 shows box plots of student responses to 13 questions, with zero indicating indifference, positive values showing preference for AI, and negative values indicating skepticism, and compares responses of 1st and 3rd-year students. The results reveal minimal overall differences. However, 3rd-year students demonstrate greater awareness of AI's current inaccuracies (q5), are more positive about including AI training in the curriculum (q8), and believe more strongly that using AI during exams would not reflect their true knowledge (q11).

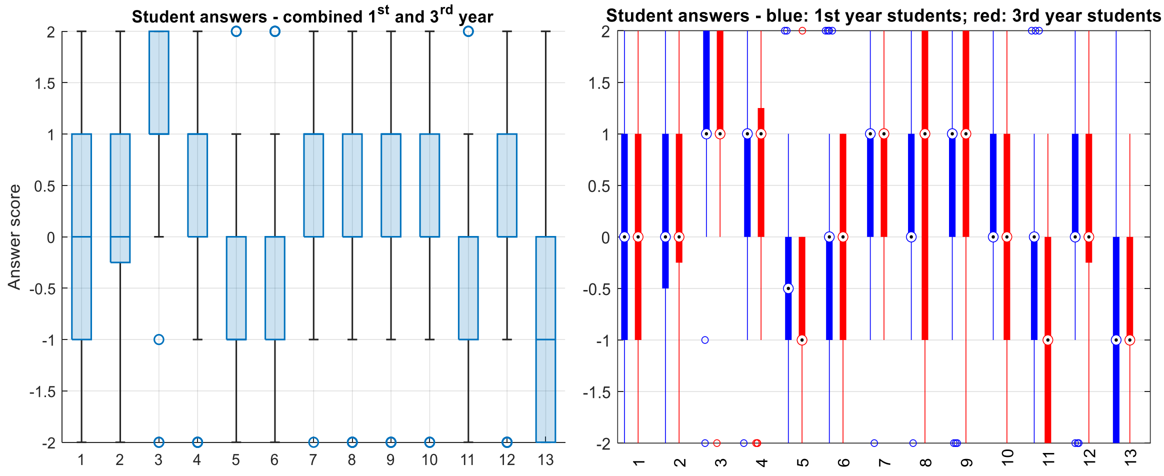

Figure 1. *Box plot analysis of student responses by academic year. (left) Combined analysis of responses for 1st and 3rd year students. (right) Comparative analysis of responses for 1st and 3rd year students.*

3.2. Student Comments

The following subsection presents the students' views and opinions provided as part of the survey, answering two additional open-ended questions:

1) If you think that you don't need more of your knowledge in your daily life and work but can supplement it by using AI tools, state how and in which cases intelligent systems can compensate for your lack of knowledge.

2) If you have problems while studying that could be partially or entirely solved using AI, state what those problems are and how AI-based tools would help you.

The excerpts of the student answers are as follows:

Coding help: AI can significantly increase the efficiency of the software development process, speed up projects and facilitate problem orientation and identification:

- Learning support: AI systems can provide coding support and advice, even for beginners, to facilitate learning and skill development.
- Real-time code analysis: AI tools can analyze code as you write it and alert you to potential errors or problems.
- Suggestions for corrections: AI can detect errors and offer suggestions for correcting them, speeding up the debugging process.
- Automated testing: AI can generate and run tests for your code, uncovering bugs that might otherwise go unnoticed.
- Real-time error prediction and resolution: AI can be programmed to monitor code execution in real-time and convert any errors that occur.
- Automatic code check: AI can analyze code and identify potential errors or non-compliance with coding standards. This helps in early detection and correction of mistakes before problems become significant.
- Learning from historical data: Based on previously discovered bugs and fixes, AI can learn how to better identify and predict potential problems in code.
- Static code analysis: AI static analysis tools can inspect code without executing it and identify structural and logical errors.
- Code optimization recommendations: AI can analyze existing code and recommend optimizing and implementing coding best practices.
- Analysis and prediction of problematic parts of the code: AI can analyze large code banks and predict possible problem areas or points of non-conformance. This helps teams focus their efforts where they are most needed.

- Automatic code generation: Some AI systems can automatically generate code based on criteria and requirements, significantly speeding up the software development process.

Work verification: AI-assisted verification can significantly improve student work accuracy and quality, allowing them to make faster learning progress. One could compare one's answers to AI's, and AI can find and correct mistakes in the following ways:

- Comparison of answers: The ability to compare your answers with those provided by the AI allows you to spot differences and potential errors quickly.
- Error identification: AI can analyze your work and point out the errors you have made, be they logical, syntactic or conceptual. It can assist in finding and remembering information that is easily forgotten or overlooked, contributing to the accuracy and quality of your work.
- Suggestions for corrections: In addition to detecting errors, AI can offer specific suggestions for correcting them, helping you improve your solution.
- Analysis and explanation: AI can provide detailed analysis and explanation of why something is wrong and how to correct it, contributing to a deeper understanding of the matter.
- Continuous learning: Using AI for verification, you learn from your mistakes and constantly improve your knowledge and skills.

Information searching and sharing: Using AI to search and share information greatly improves the efficiency of obtaining information compared to traditional search methods such as Google.

- AI enables faster finding and sharing of information from any domain. Instead of using Google to browse and search over many pages manually, we could get instant answers, saving time and effort.
- Processing large amounts of data: AI can quickly analyze and synthesize information from many sources, allowing for more comprehensive and accurate answers.
- Natural language processing: AI systems use technologies like natural language processing (NLP) to understand complex queries and provide answers tailored to your needs.
- Personalization: AI can tailor search results to your interests and past queries, providing the most relevant information.
- Interactive search: Through interactive conversations, AI can clarify your queries and provide more detailed answers based on your additional questions or clarifications.
- Integration of different sources: AI can combine information from various sources, including academic databases, newspaper articles, and technical documents, to give you the most comprehensive answers possible.

Learning and problem-solving: AI can enhance our ability to find answers to things we don't know or understand, thereby improving the efficiency and quality of the learning and problem-solving process:

- AI could help with searching for answers to things we do not know or understand, providing ideas on how to understand and solve problems better, and obtaining a complete answer, even for things otherwise difficult to find
- Compare solutions: AI tools can search for previous solutions to a problem and identify the best approaches for specific issues or tasks.
- Additional explanations and information: AI can supplement the material with explanations, examples, and additional information where a more profound understanding is needed. This provides students with additional learning resources and enriches their knowledge of the topic.
- AI could aid us by providing different perspectives and approaches to (algorithm) problems we are solving, which could significantly enrich our understanding and prepare us for future challenges.
- Condensing text: AI can create (short) summaries of longer pieces of text/theory, discerning the most critical aspects, concepts, and information, particularly mathematical and theoretical "stuff." This would make it easy for students to quickly review and absorb essential details [6].
- If teachers fail to explain specific lessons or examples sufficiently, we could get additional information and explanations through AI.
- AI can specifically focus on mathematical and theoretical parts of the text, which is especially useful in scientific fields. This helps students better understand and assimilate complex concepts and formulas.

Enriching classes: AI could make classes and lessons more interesting, engaging, and effective:

- Personalization of learning: AI can analyze students' needs, interests, and performances and suggest personalized materials and activities that match their learning styles. This will improve student engagement and result in more efficient knowledge acquisition.
- Interactive content: Interactive AI applications and content can engage students in new ways, allowing them to participate actively in their learning.

Generating assignments and tests: AI can automatically create assignments and tests tailored to students' levels of understanding and aligned with instructional objectives.

- Virtual Assistants: AI can be used to develop virtual assistants that can answer students' questions, explain concepts, and provide additional resources.
- AI can be used to find information easily forgotten or overlooked, like factual information or even grammar errors
- Integration of games and simulations: learning through games and simulations can effectively stimulate learning and achieve set goals.
- Adapting pace and learning styles: AI can analyze student progress and automatically adjust the pace and style of teaching to maximize understanding and learning.
- AI can allow students to make up for missed lectures more efficiently and receive the necessary explanations, thereby increasing the accessibility and efficiency of education.
- AI can replace attendance in classes and help us catch up and get an explanation of missed lectures. It could even replace consulting teachers since needed information could be obtained for most of the questions.
- AI can find additional information for deeper exploring and research into specific topics
- AI can help write seminar and term papers, with general-purpose and boring writing, to significantly save time and energy, making the research and writing process more manageable.

Limitations and concerns: AI can make mistakes and provide wrong answers despite progress. More knowledge and control on the human side are welcome, and students should avoid unquestioningly adopting AI-provided answers.

- There is no problem AI can solve that students cannot solve. We must be careful, as AI responses can often be wrong and do not provide complete solutions. Too big reliance on AI can detriment our learning process and skills
- The inclusion of AI in the educational process can be helpful, but it must be used with an awareness of its limits and possible errors
- Lack of knowledge cannot be substituted in case of mathematical calculation as results and formulas provided by AI could be erroneous, and AI cannot completely replace the human mind in this field
- In the IT sector, one's study, knowledge, and understanding are most important, always better, and irreplaceable, and should be maintained. AI can help to find patterns, find errors, fill in the knowledge, and do "easier stuff," but it cannot replace humans or provide complete solutions
- Self-learning, knowledge, and understanding are crucial to success in the IT sector. While AI can bring many benefits, it is essential to remember that people still play a vital role in developing and applying these technologies.
- Learning to use AI in classes shouldn't be a large part of the class but just a little help.

AI tools have profoundly reshaped university teaching and learning globally, with reported benefits in improving student learning and accessibility. The findings of this study align with similar research, demonstrating a moslty positive sttitude towards AI tools in education while also acknowledging concerns and limitations [2]. Previous studies have shown that AI technologies enhance learning and accessibility, with students appreciating benefits such as grammar checks and plagiarism detection, although they also express concerns about the impact on creativity and critical thinking. A study that analyzed a survey responses from students of diverse academic backgrounds and educational levels revealed generally positive perceptions of AI's benefits but also concerns about its drawbacks, necessitating measures to mitigate negative impacts while leveraging AI's advantages [13]. The study which explored students' perceptions of AI in academic essay writing among undergraduates, found that while AI tools were positively received for their benefits in grammar checks, plagiarism detection, and more, there were concerns about impacts on creativity and critical thinking, highlighting the need for a balanced integration of AI to support academic writing while preserving human ingenuity [5]. Another study highlights positive attitudes towards the use of AI in education while emphasizing the need for digital literacy to ensure its effective integration without compromising educational quality [3]. These studies highlight the necessity for a balanced integration of AI to support educational quality and foster human ingenuity. However, the current scarcity of research on student perspectives limits comprehensive insights into their practical engagement. This study aims to fill this gap by elucidating how AI tools affect students throughout their university education. As found in a study from 2023, the majority of students exhibited low familiarity, limited experience, and confidence with AI tools, emphasizing the need for tailored education and redesigned assessments to mitigate academic integrity risks [4]. Our research contributes to this body of work by emphasizing that students' positive opinions on AI are often idealistic, revealing a gap between their expectations and the current capabilities of AI. Matching positive opinions over AI with predominantly neutral to skeptic results from the questionnaire and seeing the current AI limitations brings an understanding that provided student comments are actually a list of wishes rather than a reality of what AI can offer at the current stage of development. Although most students are aware of issues with the incorrectness and lack of accuracy of answers that AI can provide, there is still a tendency to mix the current AI performance with their apparent needs. This also shows that student needs, interests and capabilities have changed and that the classical education system cannot provide satisfactory solutions [9].

This study provides a unique perspective by identifying that while students recognize the inaccuracies and limitations of AI, they still see potential in its application for personalized academic experiences, real-time feedback, and efficient information retrieval. Unlike previous research, our study underscores the inevitability of advancing teaching methods to incorporate AI, suggesting that while AI should not replace traditional education, it can enhance the learning experience [8]. This highlights the need for further exploration and careful implementation of AI technologies, ensuring ethical considerations and continuous expert supervision.

4. CONCLUSIONS

In this paper, we have performed an exploratory study on the application of AI in education to improve the teaching process. Many students had the opportunity to actively use AI tools in their classes or for home study, providing extraordinary insight into the potential of this technology. Through the analysis of the relevant literature and the results of the conducted research, numerous potential benefits of AI technologies in the education sector have been identified [10], including coding help, work verification, improved information search and problem-solving, enriching classes, etc. These findings point to the significant role that AI could play in transforming the educational experience and improving student success.

This study has identified a need to support a personalized academic experience with improved learning and problem-solving that enables faster error detection and more efficient information retrieval. Personalization should enable adapting content and resources to each student's needs and learning styles. Rapid error detection and learning support would allow students to receive real-time feedback, contributing to faster progress and improved learning outcomes . Instead of waiting for grades or teacher feedback, students could receive instant information about their work, allowing them to identify and correct deficiencies quickly. Also, obtaining information more efficiently would enable students to access relevant material more quickly, supporting the learning process.

It is our observation that advancing teaching methods is becoming inevitable. In particular, the role of AI in supporting teachers in organizing dynamic and interactive lessons and providing additional resources adapted to the needs of each student was highlighted. However, using AI tools should not substitute classical education but enhance it and get students interested in studying. In student's view, learning to use AI tools should be a small part of the lesson. This conclusion highlights the need for further research and implementation of AI technologies to achieve an optimal balance between traditional and modern approaches in education. In addition, the importance of carefully developing AI technologies concerning ethical principles and continuous expert supervision was emphasized.

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The Practice of Integrating Digital Tools into the Research of Natural Phenomena in Kindergarten Children

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Abstract: *Numerous studies are focused on examining the integration of digital tools into the educational process. However, only a small number of studies deal with examining the technological pedagogical knowledge (TPK) of pre-school teachers within the field of integration of digital tools in the research of natural phenomena with children. The goal of the research is to see how educators use digital tools in the research of natural phenomena during the development of a topic/project in kindergarten. Content analysis was used, and 35 stories were analyzed about topics/projects of master's degree students of the Pre-school Teacher Training and Business Informatics College of Applied Studies–Sirmium. The reasons for starting the analyzed topics/projects were children's interest in exploring the world around them, nature, natural phenomena and processes. The content analysis was performed on the basis of indicators of pre-school teachers' TPK. In the pre-school teachers' work, based on stories about topics/projects, the majority of indicators of TPK are present on a small scale. The implications of the research indicate the need to strengthen the pre-school teachers' TPK and the need to connect this knowledge with content knowledge in order to improve the practice of integrating digital tools into research of natural phenomena with children.*

Keywords: *digital tools; natural phenomena; pre-school teachers' TPK*

1. INTRODUCTION

One of the tasks of pre-school upbringing and education, not isolated from others, is to prepare children for life in a society where digitization is developing rapidly. "Many researchers worldwide have begun to articulate that, because of the immersed role of technology in young children's everyday life and the rapid changes in technology, there is an urgent need to take into account teachers' technology knowledge as a precursor to understanding how they can engage young children's cognitive engagement, for example, scientific thinking" [1]. The authors have shown how internal factors such as interest in technology, teachers' technological skills and extrinsic factors such as support from administrators and technical maintenance play key roles in shaping teachers' practices [2]. Educators, in general, have a positive view of the use of digital tools [3] but, at the same time, they want to develop their competences for creating technology-based activities that can contribute to children's learning [4]. In contrast, it has also been shown that some educators are not interested in digital tools and the opportunities they provide [5].

1.1. Previous research

Science and technology are seen as closely related fields, but are rarely combined in pre-school settings [6].

The international study in Australia and Finland of pre-school teachers' beliefs and pedagogical practices in the integration of technology to engage young children in learning science revealed that pre-school teachers occasionally used iPads and some apps within their intentionally constructed science investigations, both for teacher-initiated research and for communicating with parents via children's journals; teachers were not adverse to, but rather accepting of embedding technology as a pedagogical affordance and keen on planning for multimodal science-based experiences [1].

The results of another study on the possibilities and obstacles for the integration of digital tools in the research of natural phenomena in pre-school institutions indicated that the majority of educators have a positive attitude regarding the use of digital tools, but they also expressed the need for training on how to use the tools themselves; they see digital tools as a good complement to other tools when researching natural phenomena and when researching information about natural phenomena; digital use can encourage children's critical thinking, it is used to document activities and create a stimulating learning environment [7].

Despite the affordances offered by technology in science instruction, little is known about pre-school teachers' pedagogical practices in using technology.

This paper represents an attempt to investigate the technological and pedagogical knowledge of educators in the domain of researching natural phenomena with children in the kindergarten.

1.2. Theoretical research framework

Expanding Shulman's (1986) concept of Pedagogical Content Knowledge (PCK) Mishra and Koehler [8] added an additional domain of technological knowledge (TK) into PCK and created the Technological pedagogical content knowledge (TPACK) framework in order to teach effectively [1]. Below we present the definitions of the basic terms [7], [8].

Pedagogical knowledge (PK) is deep knowledge about the processes and practices or methods of - among other things, overall educational purposes, values, and aims. This is a generic form of knowledge that is involved in all issues of student learning, classroom management, lesson plan development and implementation, and student evaluation.

TK refers to teachers' knowledge of technological devices (hardware) and their uses, as well as sets of software. This relates to the practical handling of digital tools.

Technological Content Knowledge (TCK) concerns teachers' knowledge of the relation between technology (in this case, all kinds of digital tools) and subject content. Hence, how different digital tools can most appropriately embody and support understanding of specific concepts or processes.

TPK refers to teachers' knowledge of how teaching and learning change when particular technologies are used. Affordances – or obstacles – arise with different digital tools and their relation to teaching practice.

TPACK includes teachers' knowledge of the interaction between technology (digital tools), pedagogy, and subject, and of the strategic application of technology in the teaching situation. This knowledge is dynamic and adaptable to the needs of different students (in our case, children). This research examines pre-school teachers' TPK as part of TPACK, which enables them to integrate technology as a useful pedagogical tool to promote children's exploration of natural phenomena.

2. METHODOLOGY

The goal of the research is to see how educators use digital tools in the research of natural phenomena during the development of a topic/project in the kindergarten. The content analysis was used, and 35 stories were analyzed about topics/projects of master's degree students of the Pre-school Teacher Training and Business Informatics College of Applied Studies – Sirmium, who are employed in kindergartens. The reasons for starting the analyzed topics/projects were children's interest in exploring the world around them, nature, natural phenomena and processes. The content analysis was performed on the basis of indicators of pre-school teachers' TPK [1]. The protocol for the analysis of pedagogical documentation contains the basic characteristics of the pre-school teachers' TPK and indicators of the research of natural phenomena with the support of technology, adapted for the needs of research. Six essential characteristics of planning and integration of technology in the research of scientific phenomena with children in the kindergarten were singled out: planning, children's prior knowledge, building children's research skills, interactions: pre-school teacher-child, peers-peers; involving children in the research of scientific phenomena; pre-school teachers' assessment (monitoring and evaluation through documentation).

3. RESEARCH RESULTS WITH DISCUSSION

In Table 1. we present the number of stories about topics/projects in which the given indicators are represented.

Digital tools, which are used in pre-school institutions, can be divided into two groups: devices (tablets, phones, digital cameras, projectors, robots and digital microscopes) and applications and browsers [7]. The idea is not to make everything digital in pre-school, but to combine digital tools with analog tools and create an environment where children can choose and use tools for research. When pre-school teachers use a specific technology as a tool for teaching and learning, it can change the way students/children practice and understand concepts in a certain area, which implies knowing the pedagogical possibilities and limitations of different digital tools.

To the extent that they used digital tools in the planning, the educators made a good choice of tools that were in line with the learning objective (e.g., While in the yard, the children caught a praying mantis. When we entered the room, we searched the Internet to find out more about it.), while science concepts are integrated through meaningful activities (e.g., Searching the Internet, finding photos of clouds and printing them; children use those photos to explore and identify clouds outside.).

Table 1. *Representation of indicators in topic/project stories*

TPK for developing children's scientific engagement	Indicator	Representation in topics/ projects (N)
Planning PK	Well planned selection of digital tool that aligns with the learning objective	12
	Meaningful activities that integrate science concepts	11
Children's prior knowledge PK	Scientific concepts linked to children's previous experience	6
	Pre-school teachers make specific connections with children's previous experience in using technology	3
Building children's inquiry skills TK	Using the appropriate technological tool, a variety of questions asked that promote children's inquiry skills	6
	Pre-school teachers promote creative thinking skills by asking scientific oriented questions	3
	Choosing a digital tool helps with visualization abstract scientific concepts and making creative models	10
Pre-school teacher-child/children and peer-peer interactions PK	Using a digital tool opens up opportunities for pre-school teacher/child and child-to-child interaction and discussion about scientific concepts	8
	Digital tools provide a lot of opportunities for children to clarify key science concepts	10
	Pre-school teachers' questions, arising from the use of digital tools, encourage children's creative thinking in the domain of science	0
Children's involvement in the research of scientific phenomena TPK	Pre-school teachers' selection of a digital tool stimulates children's thinking in the domain of science	5
	Children explore science-oriented questions using digital tool(s) together with the pre-school teacher	5
	While using a digital tool, children generate hypotheses in the field of scientific concept research	0
	Children engage in problem solving and come up with new ideas/innovative solutions	0
	Children produce an artefact as a result of an exploratory activity using technology	0
Monitoring and evaluation through documentation PK	Using technology to document children's research	22

Appreciation of children's prior knowledge of scientific concepts is rarely present. We give an example of relying on the children's previous experiences about the natural concept being investigated (While they were playing in the sand, S. found a dead snake. The children gathered and asked: Is it real? Is it alive? Is it poisonous? O. said that a snake is an insect, U said that a snake is an invertebrate, while N. said: "It's a reptile." By searching the Internet, we got answers to the children's questions.), and an example of connecting with the children's previous experiences in the use of technology (The children transferred the photos to the laptop, together with the pre-school teacher, they selected and printed the photos that showed what they were up to, and then we added our panel about insects.).

In the domain of building children's research skills, it was noted that digital tools were not widely used to encourage children to ask questions which further guided the development of their research skills. One of the good examples of the use of digital tools for the mentioned purposes was the use of the Google Lens tool to research the names of plants and insects, while the use of digital tools almost did not encourage educators to ask science-oriented questions. The educators used digital tools to help visualize abstract natural concepts (e.g., We expand experiences about insects through presentations and video clips; introduce the children to the secrets of Risovača Cave using a YouTube video.) and build creative models (e.g., Using the Story Jumper tool to making a digital book about wood). In the literature, we find examples of the use of digital tools in the function of illustrating various natural phenomena to children - such as air [9] or dinosaurs [10], but the importance of combining digital tools with physical objects [7] is also highlighted. For example, in addition to concrete research on the aggregate states of water, children expand their experiences of water through images and sound by watching a film about different aggregate states. Therefore, different encounters with specific content in different modes, such as physical, visual (images) and auditory, strengthened children's experiences.

The use of digital tools has initiated interactions in the field of scientific phenomena research. The interactions were carried out in the domain of clarifying natural concepts (e.g., Via e-mail we invite the Camping Society as guests in order to train us about camping; On the website jigsawplanet.com we find the puzzle Water cycle in nature and solve it together with the children). A good example of using digital tools to clarify scientific concepts through interaction is the use of tablets [11], children made photos and slow-motion videos showing different states of water.

Digital tools have opened up opportunities for interaction and discussion between teachers and children and among children about scientific concepts (e.g., Through Viber calls we realized a discussion about healthy food with teachers and children from another kindergarten since they were also researching a similar topic; we notice that girl I. shows a great interest in cotton. She draws, writes and makes her own journal about cotton. In order to support her, we gave her the opportunity to share her knowledge about cotton with the other children via video beam.). Pre-school teachers' questions arising from the use of digital tools which encourage creative thinking in the field of science are not represented.

The involvement of children in the research of natural phenomena with the support of technology is visible, to a small extent, through the choice of a technological tool by the educator that stimulates children's thinking in the domain of science and through the investigation of scientifically oriented questions using technology together with the pre-school teacher (e.g., Internet search, searching for experiments that help us solve problems and understand the process of changing the aggregate state of water; together with the children, we browsed information about Tara Mountain on the Internet in order to prepare well for our stay in nature). In the literature [7], we noticed that some pre-school teachers were in no hurry to "Google" the answer. They consider it important to "stay involved" with children and analyze with them. This provided an opportunity for them to think and imagine for themselves. They argue that many reflective encounters are lost immediately after the digital search for answers. Instead, children should be given the opportunity and time to think about how to find the answer (on their own).

It is not represented that children generate hypotheses or predictions in the field of research of scientific concepts, engage in problem solving and come up with new imaginary ideas/innovative solutions and produce an artifact as a result of the research activity using digital tools.

Pre-school teachers, children and parents, according to our findings, use digital tools to the greatest extent for monitoring and evaluating research through documentation (e.g., We created a table that monitors the process of growth and development of plants, in which children recorded the regularity of watering and the growth process. In addition to recording changes that occur on the plants, we photographed the observed changes; Based on the children's questions about where and in what conditions the insect lives, we decided to take a walk in the park, take a magnifying glass and a digital camera, investigate and document the research process; the Viber group with parents and posting home videos with experiments and watching them together in the kindergarten; V. and his dad sent us a video of the experiment they performed at home and we showed it to other friends). From the stories about the topics/projects, it is not clear how it is documented to support the research of natural phenomena. The literature [7] emphasizes the importance of continuous use of digital tools in order to capture children's experiences and ideas; by using documentation supported by digital tools, such as video recordings of children's conversations, pre-school teachers become aware of how children understand scientific concepts and what previous experiences they have about them. In addition, through reflections on the basis of documentation with digital tools, pre-school teachers create guidelines for further work with children.

The results of the research show that the practice of integration of digital technologies in the research of natural phenomena with children is mainly based on pre-school teacher's PK and TK. TPK is rarely applied in this field. PK is mostly seen in the field of planning, following, and evaluating children's investigation, then in the field of establishing interactions (teacher-child/children and between peers), and is the least present in the field of validation of the children's previous experiences, especially in the field of digital tools usage. TK has been observed from the viewpoint of the measure in which the use of digital tools for support of children's research skills during the research of natural phenomena is present. TK is used by pre-school teachers most often to help children visualize abstract scientific concepts and build creative models, as an incentive to pose questions in order to develop children's research skills, and to the smallest extent to incentivize creative thinking skills. Pre-school teachers' TPK has been observed from the viewpoint of children's engagement in the research of natural phenomena by using digital tools. It is also displayed through the choice of digital tool which stimulates the child's thinking in the field of science and through research of natural phenomena by using digital tools with the teacher. Pre-school teachers' TPK in the fields of using digital tools with the function of generating hypotheses by children in the field of research of natural phenomena, the function of problem-solving realizing new ideas/innovative solutions and the function of artifact creation as the result of research activity has not been observed.

4. CONCLUSION

TPK is considered the basis for starting the research of natural phenomena with the integration of digital tools with kindergarten children.

The implications of the research indicate the need to strengthen the pre-school teachers' TPK (e.g. knowledge of digital tools and their application in the research of natural phenomena, how to connect children's previous experiences of natural phenomena and digital technologies with work in the kindergarten, how to combine analog and digital tools, how to develop children's scientific research skills with and without digital tools, how to encourage children to use digital tools as an incentive for setting hypotheses, monitoring learning, creating products, etc.) and the need to connect this knowledge with content knowledge in order to improve the practice of integrating digital technologies into the research of natural phenomena with kindergarten children.

Previous research has shown that TPACK can be a useful framework for researching the practice of pre-school teachers in the integration of digital technologies into the investigation of natural phenomena [1], [7] and this was confirmed by our research. It is recommended that further research should be based on the proposed framework, and to consider the possibility of it to be a framework for creating the professional development of pre-school teachers in the field of integrating digital tools into the research of natural phenomena.

The limitations of our research can be seen in the indirect examination of the practice of integration of digital tools in the research of natural phenomena with kindergarten children, through stories about project/topics, and therefore the use of research methods and instruments that would support the direct and more comprehensive examination of the problem should be considered in further research.

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How the Development of Technology Changes Teaching Practices

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Abstract: Every day we witness the introduction of technological innovations into our daily lives, which are changing significantly under their influence. In the past, roots were drawn by hand with paper and pencil, then calculators appeared. Today, nobody tries to draw the root by hand anymore. People used to look for important information in encyclopedias and various archives and libraries, but today they turn to Google for every little thing... Using an example from the field of applied mathematics, we want to show how technology is changing the approach to solving relatively complex technical problems. The example presented in this paper is solving complex mathematical problems such as optimization using a method that has only recently become available through the development of technology. Advanced methods for solving optimization problems such as the Brents method or the Limited memory Broyden–Fletcher–Goldfarb–Shanno method with boundaries are now partially replaced by the Brute Force method, which is much easier to handle. This example shows that we are constantly adapting to new circumstances and that each generation uses the latest knowledge available, changing the approach to daily practice. Adapting to new circumstances and technologies and abandoning and neglecting old methods (i.e. optimizing the necessary acquired knowledge) leads to the false claim that the new generation does not know and does not want to learn the basic methods.

Keywords: *Technology, teaching, computer, optimization*

1. INTRODUCTION

Every day we witness the introduction of technological innovations into our daily lives, which change considerably under their influence. This introduction of technological innovations is becoming a constant flow that is constantly changing every single aspect of our lives. One of these aspects is learning and/or teaching and solving practical learning problems. Not so long ago, students looked for important information in encyclopedias and various archives and libraries to learn more about topics that interested them. Today, they turn to Google for every little thing and find so much information that it is sometimes impossible to tell the good from the bad. The modern generations have adapted well to the new circumstances and technologies, abandoning and neglecting the old methods (i.e. optimizing the knowledge they need to acquire). This leads to the false assertion that the new generation does not know the basic methods and does not want to learn them. But is it necessary to learn basic methods?

The next example shows how modern technology changes the aspect of solving complex optimization equations. In the second chapter, the problem is outlined and the target Equation is presented. The basic solution (the old method still used in schools and universities) is presented in the third chapter. The development of computers enabled the creation of computer programs that allowed faster solutions but required additional and often more complex (and more difficult) solutions, which are presented in Chapters 4 and 5. The methods available at that time were not favored by students because they were complicated and required extensive mathematical knowledge and programming skills. Recent advances in computer technology have made it possible to use a very simple solution (the simplest method). This solution is already being used in practice and is likely to become more widespread over time. A detailed description of this solution with its advantages and possible implications for teaching practice can be found in Chapter 6.

Chapter 7 analyzes the main disadvantages of this method and makes predictions about future developments based on the analysis of the advancements in the recent progress.

2. THE PROBLEM

The optimization of the total maintenance and spare parts costs (C_{Tot}) which are shown in Equations 1, 2 and 3, can be carried out using various methods and techniques. These costs are the sum of the maintenance costs (C_M) and the spare parts costs (C_S) and are shown in Equation 1:

$$C_{Tot} = C_M + C_S\,. \tag{1}$$

The maintenance costs are further expanded as shown in Equation 2:

$$C_M = \frac{N_U \cdot (C_{mh} \cdot W \cdot h_p + C_{Sto} \cdot h_p \cdot P_{sto} + C_{cmP})}{T} + \left[\begin{array}{l} C_{mh} \cdot W \cdot h_c + \\ (C_{Sto} \cdot h_c + C_{Fai} + C_{Dam}) + \\ + C_{cmC} + C_{XEC} \end{array}\right] \cdot \frac{N_U \cdot \int_0^T u(t)\,dt}{T} \tag{2}$$

where:

N_U–number of units,
C_{mh}–work force hourly costs,
W–number of persons performing the task,
h_p–number of hours needed for a preventive task,
C_{Sto}–stoppage costs,
P_{sto}–probability of the stoppage,
C_{cmP}–preventive task consumption materials costs,
T–maintenance interval,
H_c–number of hours needed for a corrective task,
C_{Fai}–failure costs,
C_{Dam}–costs of damage to other devices,
C_{cmC}–corrective task consumption materials costs
C_{XEC}–external costs for one corrective task,
$u(t)$–function intensity.

Extended spare parts costs as shown in Equation 3:

$$C_S = \frac{\left[N_p + N_c \cdot \int_0^T u(t)\,dt\right] \cdot C_{Spa}}{T \cdot N_e} + \left[\left(\frac{N_e}{2} + S_s\right) \cdot C_{Hol}\right] + \left[\frac{C_{Han}}{T} \cdot \left(N_p + N_c \cdot \int_0^T u(t)\,dt\right) + C_{cus}\right] \tag{3}$$

where:

N_P– number of parts for preventive maintenance,
N_c– number of parts for corrective maintenance,
C_{Spa}– costs of unit size of spare parts,
N_e–order quantity,
S_s–safety spare parts quantity,
C_{Hol}–holding costs,
C_{Han}–handling costs,
C_{cus}–customs, agency and other costs.

The optimization in this case is to find the overhaul time T^* and the spare parts order quantity N^* that minimize the total maintenance and spare parts costs, taking into account that the spare parts order quantity is the sum of the spare parts needed for preventive maintenance (N_P) and the spare parts needed for corrective maintenance (N_C):

$$N = N_P + N_C \tag{4}$$

3. BASIC SOLUTION

The basic solution to this problem is to approach the Equation using mathematics, which means that the person who wants to solve the problem must take partial derivatives of the objective function as follows:

$$\frac{\partial C_{Tot}}{\partial T} = \frac{\partial C_M}{\partial T} + \frac{\partial C_M}{\partial T} = 0\,. \tag{5}$$

and

$$\frac{\partial C_{Tot}}{\partial N} = \frac{\partial C_M}{\partial N} + \frac{\partial C_M}{\partial N} = 0\,. \tag{6}$$

results obtained can be considered as the minimum of the function when the value of the second derivative of the function is greater than 0.

As will be shown, in order to obtain optimization results, one needs to know how to perform derivatives, i.e. one needs relatively advanced knowledge of mathematics (not too complex, but above the level of a normal person). This approach means that students have to learn derivative mathematics, which is quite challenging for some of them (in the authors' experience). Therefore, with the advancement of computers, the new generations have rushed to develop computerized programs that will help in solving the problem and simplify the process of solving the Equation.

4. THE FIRST ADVANCED SOLUTION

The first advanced solution is to create a program that solves the Equation without too much effort for the user. The creation of the computer program was a solution that could replace the simple solution.

One of the best-known computer-based methods used for optimization problems is Brent's method [1, 2]. It is a hybrid root-finding algorithm that combines the bisection method, the secant method, and inverse quadratic interpolation [3]. The method is named after Richard Peirce Brent, an Australian mathematician and computer scientist who improved an earlier algorithm by Theodorus Jozef Dekker. Dekker created the first known correct solution to the problem of mutual exclusion in concurrent programming, where processes only communicate via a shared memory. Brent introduced a modification to Dekker's method by adding an additional test that must be satisfied before the result of the secant method is accepted as the next iteration step. The Brent's method has the reliability of the bisection, but can be as fast as some of the less reliable methods. Due to its relative simplicity, it is often used as a method for solving mainly one-dimensional optimization problems.

The Brent's method has many advantages and disadvantages compared to other optimization methods. The advantages include that the function does not need to be differentiable, that the method guarantees convergence to a root (if one exists), that it can easily find multiple roots, that it can easily handle function discontinuities and that it has the best properties of the root finding algorithms [4]. In addition to a number of advantages, this method also has disadvantages, such as that the method can be computationally intensive and slower than other methods for larger problems, and that it may require extensions and/or adaptations to solve more complex problems [4].

From the description of the method, it can be seen that to successfully solve the Equation using the Brent method, one needs to know the principles of the bisection method, the principles of the secant method and how to perform inverse quadratic interpolation. In addition, the method requires knowledge of the iteration process or methods. Just the beginning of the encoding in FORTRAN 77 shows the need for programing language knowledge as well as knowledge of the method principle:

FUNCTION zbrent(func,x1,x2,tol)

(find the root of a function which lies x1 and x, the root has to be defined with accuracy tol).

Finally, the computer programs used for this method were originally written in the programming languages C and PASCAL or TURBOPASCAL [5, 6]. They were created for internal use and are not freely available for further use. Even today, with all the knowledge available online, creating the Brent method from scratch (in any programming language) is a major challenge for any student. For the reasons mentioned above, the use of this method is not very widespread in student circles.

5. THE SECOND ADVANCED SOLUTION

Similar problems exist with other computerised methods and their early deployment. The second method analysed is Limited memory Broyden–Fletcher–Goldfarb–Shanno method with boundaries (L-BFGS-B) [7, 8, 9].

This method is an iterative optimization algorithm from the family of quasi-Newton methods, which is widely used in computer graphics and general scientific computing [8, 9]. This method has some serious advantages, such as the code is easy to use and verify, the user can determine the memory size and thus the computational speed, the method is not computationally intensive when N is large and is therefore well suited for large problems, the method usually does not require extensions and/or modifications to adapt it to different problems, and it is extremely fast and accurate and can be installed on multiple computers and run in parallel [7, 8, 9]. The method also has some drawbacks, such as problems with the parallel implementation of L-BFGS-B on GPUs (Graphics Processing Units) and that difficult problems may require a large number of function evaluations to converge [7, 8, 9].

From the description of the method, it is clear that to successfully solve the Equation using the L-BFGS-B method, one needs to know the iteration process or methods as well as the process for solving the Hessian matrix which is shown in code snippet.

Compute scalars ys and yy:

ys = y^t \cdot s = 1 / \rho.

yy = y^t \cdot y.

Similar to the early coding of the Brent's method, the solutions of this method were coded in FORTRAN for internal use [9, 10].

Similar to the Brent's method, it is not surprising that there are not many students who attempt to solve the target Equation using this method.

6. THE RECENT SOLUTION

Recently, the Brute Force Method (BFM) (Fig. 1) is used more and more for solving advanced mathematical problems with computerised programs written in Python. The BFM is the simplest method for solving mathematical problems which can be described as a method in which the problem is solved by exhaustion, i.e. the method searches for all possible solutions and finally selects the most favorable solution if it exists.

This method requires considerable computing power and was not applicable until recently due to insufficient computing capacity [11, 12]. With the development of better and more powerful computers, the application of this method became possible, and recently studies have appeared in scientific journals using this method for simpler examples with a smaller number of optimization parameters and with limited range [13, 14, 15, 16].

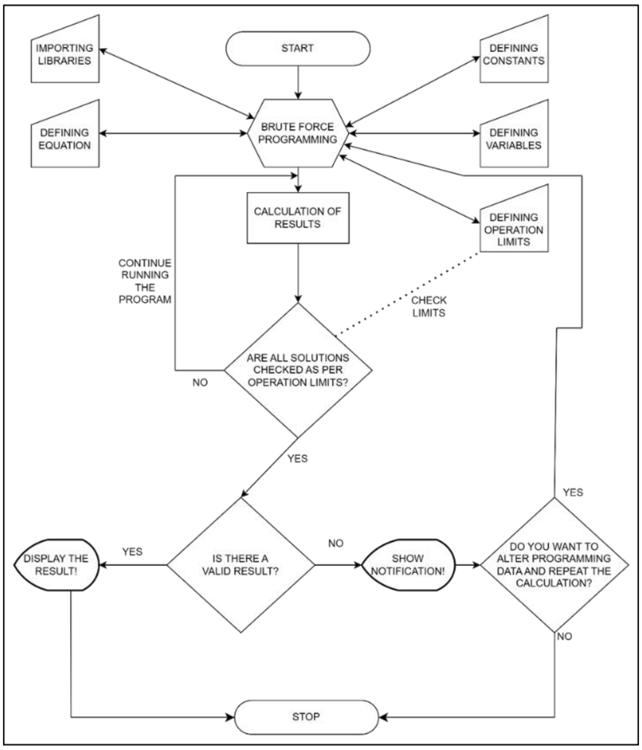

Figure 1. *BFM flow diagram*

Python, which is used to write the code, is a programming language that is relatively easy to learn and very popular in the programming community. It is freely usable and distributable, even for commercial purposes [17, 18, 19]. The most important feature Python has to offer is SciPy [20]. SciPy is an open-source Python library that stores a large selection of freely available code. This library makes creating and modifying code extremely easy [21]. Combining the Python programming language with BFM and SciPy leads to a relatively simple and painless solution to the target Equation problem. In this case, students need beginner knowledge of the Python programming language and can copy and easily modify the BFM code from SciPy. Apart from that, nothing else is required. The remaining problem is the time needed to perform the action, i.e. how long the calculation will take.

7. COMPUTER SPEED

To illustrate the problem, a simple test is carried out. The test is performed in a mode in that the same Python program coding BFM is executed on two different computers with the specifications shown in Table 1.

Table 1. *Computer specifications*

	Processor	DATA	Year
Computer 1	Intel(R) Core i3-4030U	1.90 GHz, 4 GB, 1600 MHz	2014
Computer 2	Intel(R) Core i5-1135G7	2.40 GHz, 24 GB, 3200 MHz	2021

The calculation times are measured and shown in Table 2. From the data in the Table 2, it can be seen that the computing time needed to calculate the solution of the target Equation has been reduced by almost 50%.

Table 2. *Comparison of computational times*

	[ms]
Computer 1	40459.7410
Computer 2	20934.4581

Data from the Table 2 does not meet Moore's Law conditions [22] that the speed and performance of computers doubles every two years although it can be stated that there are quite significant advances in calculation time. If the data from Table 2 is further analyzed and if a prediction of computational speed is created based on that data, a curve presented in Fig. 3 is created.

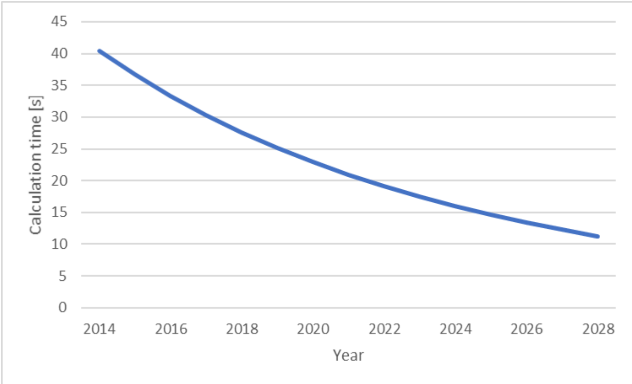

Figure 3. *A projection of calculating speed*

According to presented data, it can be concluded that the computation time of the brute force method for this example will fall below 10 seconds in this decade, but the overall speed will still be much slower than any other computerized method.

This predicted improvement in brute force computation speed will certainly lead to much wider use of the method.

8. CONCLUSION

The approach to solving the problems presented has changed over time. The first solution presented, which is a basic principle, requires knowledge of derivatives, which is not very attractive for many students. Computers brought a different approach to problem solving, namely the creation of computer programs that helped with the solution, but required knowledge of the method and how it worked, as well as knowledge of the programming language. The advent of BFM, Python and SciPy allowed for a different approach where the person solving the target Equation does not need to know the derivations, how the method works or learn how to program the method into the computer.

Students no longer need to know how to solve the problem, the computer solves the problems for them. The combination of Python and SciPy makes it possible to solve a mathematical problem such as an integration with just two lines:

"from scipy import integrate"

"=integrate quad (a, 0, t)"

and it is executed immediately. In addition, Python and SciPy allow students to copy and use the code for the Brent's method and the L-BFGS-B method without knowing anything about these methods and their principles. This changes the students' approach to problem solving and shows that they are more and more dependent on computers.

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The Impact of Digital Literacy and the Application of Educational Software on the Quality of Teaching

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Abstract: *In this paper, the possibilities of applying educational software and the influence of digital literacy in the function of electronic teaching are investigated. For the purposes of the work, the latest relevant literature in the country and abroad in this current field was researched. The subject of research of this paper will be a comparative analysis of educational software that is applied in our environment with a special emphasis on educational institutions in the area of Kosovo and Metohija and the Toplic district. Based on the conducted research, the paper will present an overview of the most popular software that is used today in the teaching process. The goal of the research is to determine teachers' attitudes about the application of educational software in teaching, to investigate the effects and possibilities of improving teaching, highlighting the positive effects that can be achieved by their application in primary, secondary and high schools. The results of the research show that the use in subject teaching resulted in an increase in the quantity and quality of students' knowledge compared to the traditional form of teaching, as well as that students generally have a positive attitude towards the use of educational software in teaching. Standard methods of statistical processing will be used for data processing.*

Keywords: *Educational software; Digital literacy; Electronic education.*

1. INTRODUCTION

Digital literacy includes skills and knowledge from the process of identification, processing and analysis of information, communication in a digital environment, creation and editing of content, consideration of security aspects and use, to the meaningful use of information and communication technologies. Digital literacy and educational software are interconnected in function of the quality of the teaching process. How and in what way to apply ICT in the teaching process is a special question that is posed to teachers. In the relevant literature, it is emphasized that the teaching staff should be qualified to implement educational projects in the field of application of information technologies in educational work, to diagnose and evaluate knowledge using information technologies, to encourage independent learning, to continue independent improvement [1]. However, research in practice indicates that some educators face problems and barriers when using modern educational technologies in teaching. It is important to emphasize that with digital skills we are not only talking about the ability to use technology, but also about the aspects of responsible use and data security, so it is important that the educational system recognizes the role of teachers in this area as well. One of the main reasons for the inefficient application of educational technologies in the teaching process is insufficient IT or digital literacy of teachers. In this sense, the literature emphasizes that the success of the application of information technologies in educational work depends to a large extent on the knowledge, skills and abilities of teachers and professional competences, which include the use of computers and computer systems in data evaluation and manipulation, communication, cooperation and problem solving [1]. However, in this context, a very important question that arises is what are the competences of knowledge and skills necessary for effective teaching. Since new technologies enable quick access to knowledge, it is logical to focus the field of education on the field of digital literacy. In this sense, the conclusion emerges that an important aspect of today's learning is digital or information literacy. Thus, the common European principles for the competences and qualifications of teachers state the key competences that pedagogues must master in order to teach with modern technologies: working with technology, access, analysis and evaluation, thinking and transferring knowledge through technology, knowledge of technologies, integration of new technology into teaching. In this direction, some authors in the literature emphasize that future teachers should be trained [2]:

- For the implementation of educational projects in the field of ICT application in learning and teaching,

For diagnostics and evaluation using ICT,

- To shape the environment and learning appropriate to the developmental age of children (by competent use of ICT in teaching),

- To encourage independent learning,

- To evaluate and select educational program support for different areas of knowledge,

- To continue self-improvement

Teachers who use modern technologies in their teaching develop one of the key skills in their students, the competence of lifelong learning, which we call digital literacy.

One of the modern forms of learning that has found its place especially in the time of the Covid-19 pandemic is electronic learning, which requires teachers to have a good knowledge of IT. Many authors explore how changes in approach and practice affect teachers and how they cope with them. The literature emphasizes that E-learning, as a complex system, includes distance learning, teaching materials in various forms, group and individual learning processes, as well as interactive and tutoring work. In order to increase the effectiveness of the e-learning system, it is necessary to first of all consider the characteristics of the students and their learning styles. [3].

In this direction, some authors emphasize that Online teaching supported by information technologies implies at least three basic components [4]:

1. Computer Assisted Learning (Computer Assisted Learning - CAL),

2. Computer Assisted Research (Computer Assisted Research),

3. Distance Learning (DL).

By applying the distance learning system, there are no more departments, but the whole world is one flexible department. No more forty-five minute classes in the morning or afternoon shift, you can study as much as you want, whenever you want, at any time of the day [5]. In the literature, an approach is often used that emphasizes that the introduction of distance learning systems (UND) into the teaching process can be achieved in several ways [6]:

1. Traditional model - retains all the elements of classical teaching: fixed place and time, classroom without computers, and the Internet is an additional resource that pupils/students can use in the computer room during certain periods or in their free time.

2. Transitional model - retains the traditional elements of a fixed place and time, but the place can include regularly planned visits to a computer cabinet or a computerized classroom.

3. Distance learning model - exceeds the limits of traditional teaching online by hosting all teaching materials, exercises and resources. Students do not have to come to school for classical lessons; instead they exchange ideas and information entirely over the Internet.

4. Software for preparing computer-based lessons. If teachers mastered the appropriate software, then they would be able to relatively easily transform their existing teaching material into multimedia material, organize discussions and prepare electronic exercises for their students.

The results of representative surveys indicate that today's youth are in most cases ready to accept digital technologies, but at the same time they do not fully understand the impact of these technologies on their lives. For this reason, it is crucial that parents guide their children and limit their use [7].

Numerous studies of the application of educational technologies in teaching point to the advantages provided by ICT through numerous web tools and applications that teachers can use for interactivity during learning" [8]. In this sense, the author emphasizes that modern information technologies, primarily computer ones, have made it possible to [8]:

- take an active role in the information process and not be just a simple recipient of information sent to him by someone else;

-quickly exchanges information with other people;

-controls information flows, which is not possible in the mass media;

-sends messages when it suits him best (asynchronously, delayed communication);

-establishes a connection with remote individuals and databases, which eliminates the unfavorable influence of spatial distance and achieves maximum economy;

-record the selected content on one of the information carriers (video tape, CD, DVD disc) and deal with them when it suits him best;

- learns independently, independently of peers from the group or class and progresses according to his potential;

- study in any place.

2. EDUCATIONAL TECHNOLOGIES IN TEACHING

The application of modern technologies in education creates numerous opportunities for significantly improving the quality of the educational process. ICT application in teaching process could have enormous possibilities for simulation, presentation and visualization of learning materials [9].

New technologies make it possible to integrate visual, audio and written materials in order to convey information to children in the most efficient way. Educational software, multimedia presentations, computer process simulations, educational games, computer programs and many websites promote mathematics, bring it closer to children and facilitate the acquisition of mathematical concepts and the formation of mathematical thinking. Educational software (OS) is widely used in developed educational systems. Instead of closed computer elastic and open modules, which are embedded in digital educational content, or are designed individually. Modern education and modern educational technology enable the effective application of these contents. The need to create educational software and research its efficiency and effectiveness is an imperative for improving education in the Republic of Serbia.

Existing systems for LMS can be divided into two categories [10]:

1. Open source: Atutor, Claroline, Dokeos, Moodle,
2. Commercial software: Blackboard, eCollege.

The introduction of distance education can also be seen as the evolutionary development of a new way of education. Distance learning is both a challenge and a tool for improving and advancing educational processes in our country and is one of the foundations for new and better ways of managing knowledge. The intensive introduction of information technologies into educational processes has become a priority of modern higher education institutions around the world.

Digital technology offers young people many opportunities, such as virtual classrooms, expanding social circles and easier problem solving, as well as increasing creativity, improving technical skills and self-image [7].

On the other hand, we have an excessive use of digital technologies, which carries certain risks, such as loss of privacy, health problems and changes in social norms [11]. There are other potential dangers, such as cyberbullying, addiction and other psychological effects [11]. In addition to the above, there is a large number of educational software that is used in teaching, one of the software used in teaching is Kahoot, which is a free interactive software that enables a more dynamic and interesting test of students' knowledge compared to traditional testing methods. Kahoot is a popular platform for educational quizzes and interactive games that are often used in the classroom. Teachers around the world use Kahoot to engage students and enhance learning through play. Below are the results of the conducted research on the application of educational technologies in teaching.

2.1. The results of the conducted research on the application of educational technologies in teaching

For the purposes of the work, two independent studies were conducted in educational institutions in Kosovo and Metohija (Jovan Cvijić Elementary School - Zubin Potok, Branko Radičević Elementary School - Kosovska Mitrovica, Vuk Karadžić Elementary School - Zvečan) as well as research in secondary schools and gymnasiums in the Toplic district. The following Figure 1 presents the results of the research at the Jovan Cvijić, Branko Radičević and Vuk Karadžić schools.

In order to answer the research question "How is the experience in online teaching and what are the barriers in the application of educational technologies in teaching as well as the frequency of application within the framework of empirical work, two sets of research were conducted, namely the first for the analysis of application and the relationship to use of modern educational technologies and the way they are used in teaching, and others for the specific application of educational software Kahoot

The purpose of the research therefore aims at the following goals: to investigate the relationship of digital literacy to the use of technology and the use of technology in educational institutions in the area of Kosovo and Metohija and Toplicka district. Based on the results, conclusions and suggestions for further research will be presented.

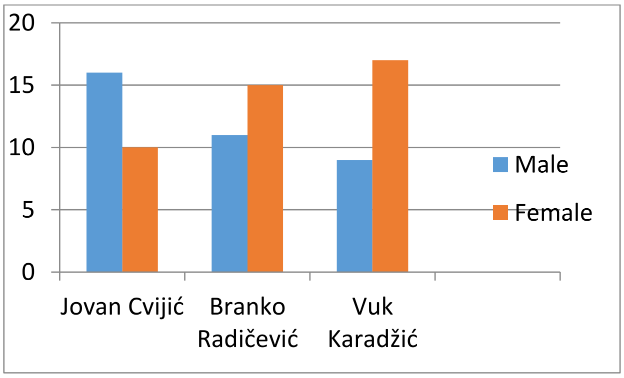

Figure 1. *The number of respondents in educational institutions in the of Kosovo and Metohija*

According to the gender structure in Elementary School Jovan Cvijić - Zubin Potok, the majority of respondents are male (16 - 62%) compared to female (10 - 38%). There were 15 (58%) female teachers and 11 (42%) male teachers in Branko

Radičević Elementary School - Kosovska Mitrovica. In Elementary School Vuk Karadžić - Zvečan, there were 12 (46%) male teachers, while 14 (54%) female teachers. We will show the gender structure of respondents by school graphically. In the following Table 1, the schools of the Toplički district are presented.

Table 1. *Schools in which research is conducted on the territory of Toplica district*

No.	Name of secondary school	Place	District
1.	Secondary school Blace	Blace	Toplički
2.	Secondary school	Žitorađa	Toplički
3.	Gymnasium	Kuršumlija	Toplički
4.	Economic - technical school	Kuršumlija	Toplički
5.	Medical School „Dr. Aleksa Savić"	Prokuplje	Toplički
6.	Agricultural High School „R.Jovanović Selja"	Prokuplje	Toplički
7.	Gymnasium	Prokuplje	Toplički
8.	Technical school „15. maj"	Prokuplje	Toplički

The following Figure 2 presents the results in elementary schools in the of Kosovo and Metohija

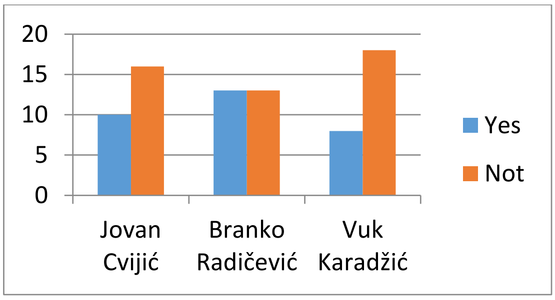

Figure 2. *Experience in online teaching*

As presented in the previous Figure 2. teachers in elementary schools Branko Radičević declared with the highest percentage that they have experience in online teaching and that it is equal. While the results in the remaining two institutions showed that a higher percentage of teachers did not have the necessary experience in online teaching.The following Figure 3 presents the results of barriers in the implementation of online teaching in elementary schools in the of Kosovo and Metohija.

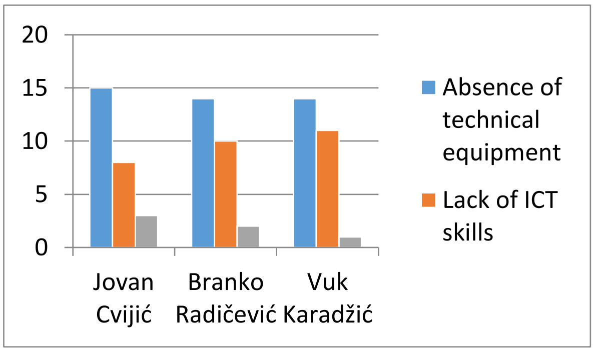

Figure 3. *Barriers in the application of online teaching*

The following Figure 4 presents the results of the frequency of using Kahoot in secondary schools and gymnasiums in the Toplički district.

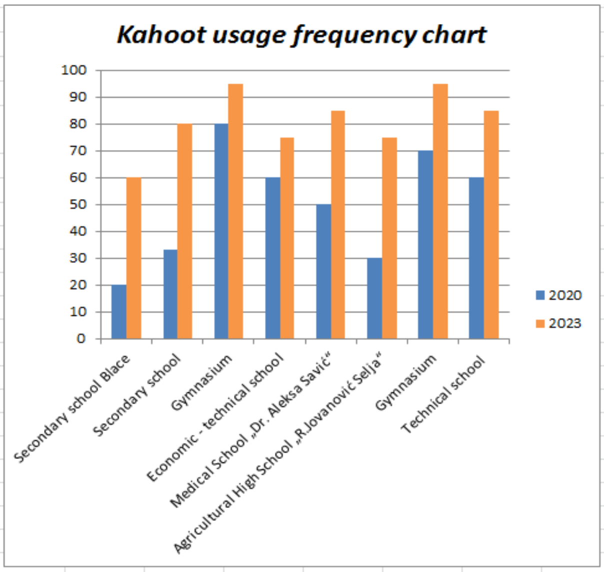

Figure 4. *Kahoot usage frequency chart*

2.4. Discussion of results

Based on the results of the research, we can conclude that teachers on average achieve digital competence at a medium level, and if there are significant differences and deviations in their answers, given that most teachers had no experience in online teaching before starting work. pandemic caused by the COVID-19 virus. The results of the research show that electronic learning in classes additionally motivates students, provides a larger amount of information and easier renewal of the processed material, and therefore makes classes more interesting, dynamic and successful. However, research shows that teachers cite lack of technical equipment and lack of ICT skills as the reason for insufficient use of IT in teaching. In addition, the reason lies in the complexity of the field, in which it is difficult to change habits and attitudes, or in the lack of support from the institutions that regulate the field - in the form of demonstration and testing of good practices that show positive results and ways of using educational technology in teaching.

The research results confirmed that the practice of developing digital literacy in teaching is not sufficiently established, although there is a practice of using digital technologies in teaching processes and for learning purposes. The results confirmed that teachers use some forms of electronic teaching, that they are satisfied with its use, but that they are not sufficiently trained in its use. A positive step in that direction is certainly the fact that more and more teachers are attending online courses, i.e. professional development programs prescribed by the Institute for the Advancement of Education of the Republic of Serbia, and thus mastering IT skills.

All this means that schools must turn more to educational technologies and prepare teachers for their use. Just as curricula and programs with mostly optional content in the field of digital competences direct teachers to use digital skills, which I classify as a more basic group of skills, the analysis shows a similar picture in practice.

The results of the research on the application of the educational software Kahoot in secondary schools and gymnasiums of the Toplički district show that the frequency of use was higher than the original expectations, especially during the period of intensive preparation for teaching material consolidation. This unexpected tendency points to the need for additional research to understand the specific factors that influence the dynamics of using Kahoot quizzes in a teaching context.

3. CONCLUSION

The introduction of information and communication technologies into educational processes has become a priority of modern educational institutions around the world. The computer makes it possible to pay special attention to children and their internal factors that will motivate them to actively and creatively participate in the teaching process. In the digital age, the importance of improving digital competences for the successful digital transformation of society, economy, individuals, public administration, and especially education is increasingly highlighted. The biggest challenge of every society today is how to make education possible for every individual as a main part of everyday life. However, in Prague we also encounter negative connotations of application where digital technology and the Internet negatively affect memory, as individuals, instead of reading books and delving into the content, search the Internet where information is presented superficially.

In order to make essential changes in education, it is necessary to use information and communication technologies in the teaching process. Only through their effective application can we improve the teaching process and more dynamic development of educational institutions. Education, as an integral part of society, must respond to the changes taking place in society.

By implementing modern information technologies, conditions are created for the use of new teaching aids and the use of educational computer software. The application of information and communication technologies (ICT) and e-learning in the educational system could serve as a potential improvement of the teaching and learning process. It is necessary to introduce ICT into the teaching process as soon as possible due to the rapid development of information systems and technologies. Information and communication technology is the most pervasive technology today. It finds applications in every branch of the economy and in all areas of education and is the basis for the successful operation of all social and state structures. Research conducted on a sample of high school and vocational school students in the Toplička district confirmed that the use of mobile technologies in teaching resulted in an increase in the quantity and quality of students' knowledge compared to the traditional form of teaching, as well as that students generally have a positive attitude towards multimedia teaching.

From all of this, we conclude that the most important goal of this work is research into the possibility of improvement, that is, more efficient and effective work of teachers by encouraging the motivation of teachers and students, increasing the efficiency of the educational process and the durability of learned content, in addition to interactive and multimedia help through educational software.

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LocalStack: A Practical Approach to Teaching Cloud Computing

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Abstract: *Cloud computing has become the core of modern software development and deployment. LocalStack provides an efficient, cost-effective platform for developers and students to simulate complex cloud architectures. In this paper, LocalStack has been explored as a cloud service emulator as it offers local deployment of cloud-based services that would typically require Amazon Web Services (AWS) and accounts. The research has focused on the deployment of LocalStack, its capability of emulating AWS cloud services, the educational benefits for students learning cloud technologies and Infrastructure-as-Code practices using Terraform and LocalStack with the goal of demonstrating how it reduces barriers to cloud education with local development, debugging and testing.*

Keywords: *cloud computing, localstack, simulation, hands-on approach*

1. INTRODUCTION

Cloud computing has become an omnipresent technology, running applications of all kinds, especially with the rapid development of artificial intelligence, data science, and the Internet of Things. The Association for Computing Machinery (ACM) reserved an important place for cloud computing in their curriculum recommendations [1] and there are even complete master programs, with majors in this very field.

While for many other computer-related disciplines the traditional computer lab equipment or even students' laptops can be sufficient, cloud computing requires specific resources, responding to the essential features of the cloud computing model: on-demand access, available pool of resources, rapid provision [2].

The precise definition of resources required for the cloud computing course depends on the course objectives. On the other hand, there is also the other way around: as the subject is heavily reliant on expensive technology, the learning objectives are influenced by the institution's capacity to support various features requiring high computing power. Establishing a realistic testbed is a serious challenge and educators have taken various approaches regarding this matter. The most popular way is to use a well-known provider, such as AWS, Google Cloud, IBM Cloud, etc. These providers offer free tier subscriptions, allowing the implementation of less demanding cloud scenarios. Some also have education programs, such as AWS Academy (former AWSEducate) [3], providing both access to real cloud (with $100 credit) and learning resources. Inclining towards one particular provider is a two-sided medal: it provides specific knowledge and hands-on experience, but (a) the resources need to be used very carefully not to surpass the limit and (b) sticking to one provider leads to vendor lock-in, which arguably may not be a good pedagogy practice. The challenges teachers may face, including the provider choice, are described in [4]. To provide students with a universal way of interacting with cloud resources (e.g. virtual machines), researchers and practitioners came up with solutions running aggregating multi-cloud access. Such examples are CloudMesh [5] and EasyCloud [6].

Alternatives to using commercial providers are considered in [7], and include OpenStackc [8] and Chameleon. OpenStack enables composing its own cloud. Chameleon provides free access to cloud resources distributed by the University of Chicago and Texas Advanced Computing Center and runs on OpenStack.

Composing fully private hardware infrastructure providing features needed for teaching cloud computing and executing demanding parallel processing is also an option, advocated in [9]. Although the authors' calculation of expenses is in favor of the private, physical cluster scenario, there are certain circumstances, that might come up as very problematic and contribute to the increased total cost – such as administration of such cluster, additional expenses (space, cooling systems, etc.).

Lastly, there are cloud simulation software, such as CloudSim [10]. This simulator framework provides rich possibilities for simulating and testing cloud scalability, energy efficiency, load-balancing algorithms, and much more. However, it requires knowledge of Application Programming Interfaces (API) and the learning curve can be tedious to follow. Other simulators are mostly based on CloudSim. A comprehensive preview is given in [11].

In this paper, we discussed LocalStack, a local cloud emulator, and its prospects for use in teaching cloud computing.

2. LOCALSTACK ARCHITECTURE

LocalStack relies on Docker to provide isolated and reproducible environments for its execution. Each AWS service is typically run as a separate process within a Docker container, allowing LocalStack to emulate several services simultaneously. The architecture can be seen in Figure 1.

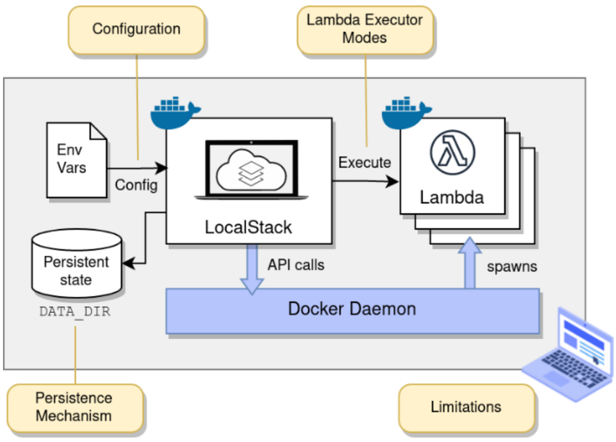

Figure 1. *LocalStack Architecture [12]*

LocalStack has several key components [12, 13]:

- Edge service – this serves as the main entry point for all requests to LocalStack. It listens to the default port (4566) and routes requests to appropriate services. It ensures request handling, routing, and forwarding to backend services.
- Service Emulators – these components are used to emulate specific AWS services with each service emulator mimicking the behavior corresponding to that AWS service, providing the same APIs and responses. There are plenty of emulated services, but the most common ones are covered with some less commonly available as well.
- Persistent storage – there is support for persistent storage for certain services that require it, meaning that data can be retained after restarts. Local directories are used to act as volumes to store data for services such as S3, DynamoDB, etc.
- Configuration and extensions – it is highly configurable, allowing certain services to be enabled and disabled, adjusting ports, various runtime options, etc. It also supports extensions and plugins allowing adding of new features.

Upon startup, LocalStack initializes the Docker environment and sets up the containers for AWS services. This may require downloading additional docker images if they are needed. The Edge service routes the incoming requests to these services which are being emulated based on the targeted service and API. Each service listens to its port and responds to API requests. These emulators use a combination of:

- Mock implementations – mock objects replicate the behavior of AWS services, for example, the local filesystem is used to emulate S3 buckets and objects.
- Local databases – some services use local databases to store and respond to queries (SQLite for example)
- In-memory data structures – for services that don't require persistent storage, an in-memory data structure is used to maintain the state.

When a restart occurs LocalStack will pull its configuration and data from local directories or Docker volumes. This is very useful for students, who often shut down and start their computers.

LocalStack is designed to use extensions so it can be used to add plugins, custom scripts (configuration or data population scripts), and various configuration options and settings with environment variables and configuration files.

To interact with LocalStack there are several options:

- AWS Software Development Kit (SDK) – perfect for development purposes and easy debugging apps.
- AWS Command Line Interface (CLI) – the standard approach for accessing AWS through the command line tools.
- Third-party tools – for example, Terraform, as a popular Infrastructure as Code (IaC) solution

All of this allows developers to easily do local development and testing without the need to deploy or access AWS directly, which also allows complex integration testing between multiple services in a reproducible environment and significant cost reduction that would normally be involved when developing and testing on AWS.

3. USING LOCALSTACK

LocalStack offers an application called LocalStack Desktop. This application supports Windows, Mac, and Linux and its main purpose is to provide an effortless way to view logs, interact with the containers, and use a resource browser from within the application. The main page with the running containers is shown in Figure 2.

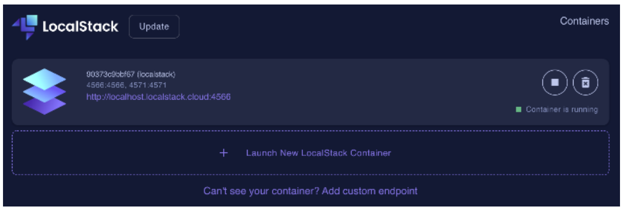

Figure 2. *LocalStack Desktop container management*

Logs can be seen on a container basis as shown in Figure 3.

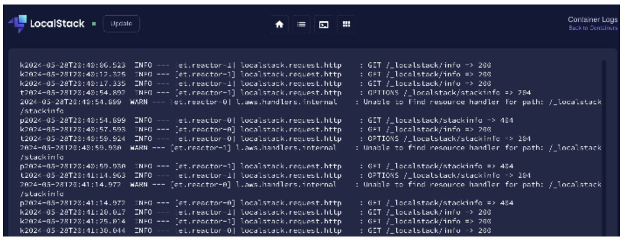

Figure 3. *LocalStack Desktop container log inspection*

Also, the Resource browser (Figure 4.) provides an overview of available resources, where it can be seen that some of them are free, while others require a pro plan. It can be used to view, manage, and deploy AWS services locally.

It is worth noting that the LocalStack in a paid version is available for individual developers, teams, and multiple teams, and the first two options are billed annually. The pro version offers support and advanced options. There is also a 14-day free trial available for the pro version before purchase. However, the community version is licensed under the Apache 2.0 open-source version, which enables smooth commercial use.

The resource browser is meant to provide an interface that is similar to the AWS Management Console. It is not meant to replace it, but rather as an interface to replicate some of its features.

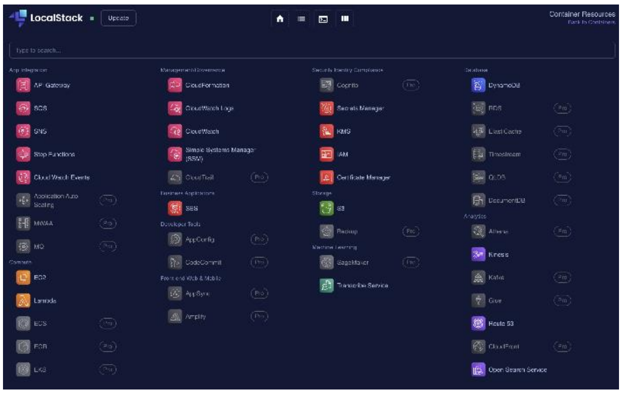

Figure 4. *Resource Browser*

Executing CLI commands requires modifications to the AWS CLI, those include setting up the Access Key ID and Secret Access Key, configuring the region to us-east-1, and overriding the default AWS endpoint to the LocalStack deployment on the local machine. After the configuration is completed standard AWS CLI commands can be used with LocalStack's deployment.

When integrating with the AWS SDK the same rules apply. The configuration remains the same, the only difference is the endpoint that the code is connecting to. Two examples in Figure 5. and Figure 6. can be seen for Java and Python.

```java
// Configure the S3 client to use LocalStack
S3Client s3Client = S3Client.builder()
        .region(Region.US_EAST_1)
        .credentialsProvider(StaticCredentialsProvider.create(
                AwsBasicCredentials.create("test", "test")))
        .endpointOverride(URI.create("http://localhost:4566"))
        .build();
```

Figure 5. *Java SDK endpoint override*

```python
# Configure the S3 client to use LocalStack
s3_client = boto3.client(
    's3',
    region_name='us-east-1',
    aws_access_key_id='test',
    aws_secret_access_key='test',
    endpoint_url='http://localhost:4566'
)
```

Figure 6. *Python SDK endpoint override*

This opens up for easy use with IaC tools such as Terraform. Terraform is an open-source IaC tool developed by Hashicorp that allows users to define, provision, and manage cloud infrastructure using declarative configuration language which is referred to as HashiCorp Configuration Language or HCL for short. This approach to writing IaC allows the use of version control, peer review, automation, etc. Terraform uses provider plugins which allow it to work with various providers and switch environments easier. To use Terraform with LocalStack it needs to be configured in a similar way as the AWS CLI and AWS SDK. However, for Terraform, the endpoint override needs to be done on a provider level. This means that all of the endpoints that are going to be used need to be configured in the provider and the credentials should be configured there as well. This configuration can be seen in Figure 7.

After the configuration is completed, the resources can be created and commands such as terraform init, plan and apply can be freely used with LocalStack.

```
provider "aws" {
  access_key                  = "test"
  secret_access_key           = "test"
  region                      = "us-east-1"
  s3_force_path_style         = true
  skip_credentials_validation = true
  skip_requesting_account_id  = true
  endpoints {
    apigateway     = "http://localhost:4566"
    cloudformation = "http://localhost:4566"
    cloudwatch     = "http://localhost:4566"
    dynamodb       = "http://localhost:4566"
    es             = "http://localhost:4566"
    firehose       = "http://localhost:4566"
    iam            = "http://localhost:4566"
    kinesis        = "http://localhost:4566"
    lambda         = "http://localhost:4566"
    route53        = "http://localhost:4566"
    redshift       = "http://localhost:4566"
    s3             = "http://localhost:4566"
    secretsmanager = "http://localhost:4566"
    ses            = "http://localhost:4566"
    sns            = "http://localhost:4566"
    sqs            = "http://localhost:4566"
    ssm            = "http://localhost:4566"
    stepfunctions  = "http://localhost:4566"
    sts            = "http://localhost:4566"
  }
}
```

Figure 7. *Terraform provider configuration for LocalStack*

4. LOCALSTACK IN EDUCATION

Implementing LocalStack in cloud computing classes offers significant benefits that can enhance student's learning experiences. Some of the major benefits include:

- Cost efficiency – there are no AWS charges and costs associated with service usage, as well as no budget limitations as those in AWS Cloud Academy. There is also the benefit of unlimited usage as the whole stack runs locally allowing unlimited experimentation and learning without worries of quotas and charges.
- Real-world skills in a safe environment – students gain hands-on experience that can be used in real-world cloud environments (AWS SDK, CLI, IaC) all while remaining in a safe sandbox environment.
- Feedback – a faster feedback loop for infrastructure changes would allow for a more rapid learning cycle in which students can quickly test their code and configurations. This would also allow students to do local debugging of cloud applications, potentially making it easier to identify and resolve problems.
- Flexibility – cloud applications can be developed and tested entirely on local machines and offline. Due to LocalStacks containerized nature, there are benefits of it working on various operating systems. LocalStack can also be included in Continuous Integration/Continuous Deployment (CI/CD) pipelines for teaching DevOps practices along with a Git-based approach for versioning IaC.
- Enhanced learning – professors and teaching assistants can assign more creative assignments and are not limited to the predefined scenarios in AWS Academy, allowing for more engaging learning as well as projects more tailored to the curriculum.

When implementing LocalStack into the curriculum it would be recommended to have a few starter projects to have students lean into it in an easy-going manner, with more challenging tasks planned as the course progresses. Having documentation and tutorials available for all tooling involved is a must – LocalStack, AWS SDK, AWS CLI, and Terraform (IaC). There are also plenty of community resources on various GitHub repositories, forum posts, etc. With this approach, a peer-reviewed feedback loop can be implemented which would foster collaboration and collective learning, as well as simulating working in a team, within a project in a company.

5. CONCLUSION

LocalStack is a very powerful, flexible, and convenient way to emulate AWS services in a local environment. The Docker-based architecture, service emulation, and extensibility make it a very desirable tool for developers and testers working with AWS infrastructure and applications.

Implementing LocalStack in a cloud computing curriculum could provide students with a cost-effective, low-risk, and practical learning environment. A setup like this would prepare students for real-world roles by offering hands-on experience using industry-standard tools and best practices, which in turn would equip them for their future careers.

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GeoGebra Interactive Simulations in Analytical Chemistry Education: Example of Lambert-Beer Law

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Abstract: *This paper presents combined experiences and efforts in Chemistry and Mathematics education based on STEM approach and using computer technologies in teaching. Analytical chemistry, particularly colorimetry and spectrophotometry, demands a strong instructional method for students to gain real insight and understanding of these concepts and methods. The main idea of this paper was to use diverse representations, such as animations and simulations, to improve students` proficiency in applying their knowledge. Dynamic mathematical software GeoGebra and principles of STEM education were applied to create interactive simulations and animations of the Lambert-Beer law. The implementation of GeoGebra interactive materials into the teaching and learning process and activities is described, and the impact of the digital learning environment and STEM education principles is discussed.*

Keywords: *Analytical Chemistry; GeoGebra; Interactive simulations; Lambert-Beer law*

1. INTRODUCTION

The main goal of modern education is to prepare students with the necessary skills and knowledge to succeed in an increasingly complex and technology-driven world. STEM (Science, Technology, Engineering, and Mathematics) education offers an interdisciplinary approach to teaching and learning that integrates concepts and principles from science, technology, engineering, and mathematics. Its benefits on the teaching and learning process are multiple confirmed [1].

Conversely, digital technologies enhance STEM education by providing interactive, personalized, and collaborative learning experiences and facilitating access to resources and real-world applications.

Chemistry education represents an extremely broad field for applying STEM education principles and digital technologies in the teaching and learning process [2].

Analytical chemistry computational tasks are integral to chemistry education. They offer a gateway to interdisciplinary learning through the STEAM approach. They also foster a deeper understanding of chemistry concepts while nurturing creativity, problem-solving skills, and innovation.

This paper will demonstrate the application of digital technologies and a STEM approach to teaching and learning analytical chemistry, specifically colorimetry, spectrophotometry, and Lambert—Beer's law.

One problem from this field will be solved in two ways: by the classical method, using digital technologies, and using a STEM approach. GeoGebra software is used as digital support for visualization in solving problems in colorimetry and spectrophotometry.

2. TEACHING CHEMISTRY IN DIGITAL ENVIRONMENT

Teaching chemistry in a digital environment offers numerous opportunities to enhance learning experiences, engage students, and facilitate a deeper understanding of complex concepts.

Interactive simulations allow students to explore chemical reactions and molecular structures and provide immersive experiences that simulate chemical phenomena [3].

Many software and applications can be used to create a digital environment for teaching and learning chemistry. In this paper, we will present the software GeoGebra and its application for creating digital dynamic materials.

2.1. GeoGebra Software

GeoGebra is dynamic mathematical software known for its robust visualization capabilities and versatility in handling various representations. It empowers educators to customize teaching content and methods.

The possibility of handling multiple representations (algebraic, numerical, graphical) makes GeoGebra ideal for use in STEM education. It can create the mathematical–graphical bond between concepts and processes, which is of great importance in teaching and learning chemistry [4].

With its interactive features, GeoGebra offers endless creative avenues for modern teaching strategies. It also serves as a cognitive tool streamlining procedural tasks, granting students more time to grasp concepts deeply.

Through interactive learning experiences facilitated by GeoGebra, students actively engage with dynamic representations, promoting a hands-on approach to learning while also serving as a catalyst for discussions, creative exploration, and critical thinking, nurturing a comprehensive learning environment.

Initially designed for student use, GeoGebra has the potential to revolutionize traditional teaching methods, shifting towards student-centered approaches. Its functionalities encourage experimentation, interactive exploration, and discovery-based learning, ultimately facilitating an environment conducive to active learning and empowering educators to inspire curiosity and foster deeper understanding among students.

GeoGebra offers great possibilities for creating simulations, which can be a powerful tool for teaching chemistry. Simulations allow students to visualize complex concepts and explore them interactively [5].

Some of the features of GeoGebra are:

1) Interactivity - Interactive simulations allow students to manipulate key parameters to enhance their conceptual understanding.
2) Dynamic Feedback - Each interaction with the simulation provides immediate feedback, such as changes in visual and algebraic representations. This dynamic feedback empowers students to ask and answer their own questions as they explore different features and phenomena.
3) Multiple Representations - Interactive simulations enable students to explore and establish connections across various representations. They can coordinate visual and symbolic representations, fostering a deeper understanding of the concept.
4) Pedagogically Useful Actions - Simulations offer the opportunity to perform challenging or impossible actions in the real world. For instance, students can modify the parameters and observe their impact. These unique actions provide valuable insights that are otherwise difficult to achieve.
5) An Intuitive Interface - Simulations feature an intuitive interface designed to minimize barriers to use and emphasize learning through interaction.
6) Real-World Connections - Whenever possible, simulations are designed to establish connections between science concepts and students' everyday lives. This approach helps students relate abstract chemistry concepts to their own experiences, enhancing their engagement and comprehension.
7) Implicit Scaffolding - Simulations provide students with implicit guidance, subtly directing their exploration without feeling explicitly guided.

We used GeoGebra's features to create dynamic material which illustrate problems in colorimetry and spectrophotometry.
The material is available for download on the official GeoGebra website [6].

3. ABSORPTION SPECTROPHOTOMETRIC METHODS

This paper presents an example of a problem in colorimetry and spectrophotometry that will be solved by absorption spectrophotometric methods. These methods are widely employed in various fields, such as chemistry, biochemistry, environmental science, pharmaceuticals, and materials science, for qualitative and quantitative analysis of substances.

Absorption spectrophotometric methods are analytical techniques based on measuring the decrease in the intensity of electromagnetic radiation due to absorption while passing through the test substance.

The amount of absorbed light, ΔI, is defined as the difference in light intensity before and after passing through the absorbing medium.

It is possible to determine the concentration of the absorber by measuring the change in light intensity due to absorption under given experimental conditions.

The absorption law, obtained by combining Lambert's and Beer's laws, known as the Lambert-Beer law, can be written in the form:

$$\frac{I_t}{I_0} = 10^{-\varepsilon bc} \quad (1)$$

where I_t-the intensity of transmitted light, I_0-the intensity of initial light, ε-molar absorption coefficient, b-optical path length (cuvette length-thickness) c-molar concentration of the analyzed substance.

Taking the logarithm of the equation (1):

$$log\frac{I_t}{I_0} = -\varepsilon bc = -logT \qquad (2)$$

where ε-the molar absorption coefficient or molar absorptivity, T-the transmittance, defined as I/I_0. Instead of transmittance, a new quantity, absorbance A, is introduced.

This law (2) is universal and applies to gases, liquids, solutions, and transparent solids.

4. EXAMPLES

The chosen example is typical for colorimetry and spectrophotometry, where the graphical method is employed for the solution.

The example will be solved in two ways: the classical method and the dynamical GeoGebra worksheet.

Both the classical graphical method and the GeoGebra worksheet will be presented and explained in detail.

4.1. Application of the Classical Graphical Method

Molar absorptivity is determined using experimental data on the absorbance of solutions with varying concentrations.

A plot of absorbance against concentration is generated, depicting a line whose slope corresponds to the molar absorptivity.

The slope of the plotted line (the tangent of the angle formed by the line with the x-axis) is determined by directly measuring the lengths of the catheti of the selected right triangle.

Subsequently, the molar absorptivity (ε) is calculated as the ratio of the obtained slope to the length of the cuvette (b).

Example task: The transmittance of a solution of bromine in carbon tetrachloride at $436\,nm$ in a cuvette of thickness $1.9\,cm$ for solutions of various concentrations is given in the table, Table 1:

Table 1. *The transmittance for solutions of various concentrations*

C [mol/dm3x103]	5,46	3,50	2,10	1,25	0,66
T	0,010	0,050	0,160	0,343	0,570

Calculate the molar absorptivity, as well as the absorbance of the solution of bromine in carbon tetrachloride with a concentration of $1.55 \cdot 10^{-3}$ if the measurement is performed in a cuvette with a thickness of $2\,cm$.

The molar absorptivity is calculated from the slope of the line $A = f(c)$, Table 2.

Table 2. *Dependency of absorptivity to solution concentration*

C [mol/dm3x103]	5,46	3,50	2,10	1,25	0,66
$A = -log\,T$	2,00	1,301	0,796	0,456	0,244

The line $A = f(c)$ and its slope are illustrated on Fig. 1.

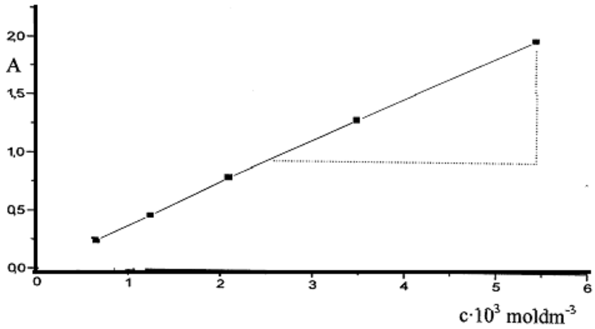


Figure 1. *The line A=f(c) and its slope*

$$\varepsilon = tg\alpha = 1/(5{,}46 - 2{,}73)\,x\,10^{-3} = 366{,}3 \qquad (3)$$

From (3), the slope of the line is 366.3, so, based on that, considering that the cell thickness is $1.9\,cm$, the molar absorptivity is calculated as follows:

$$\varepsilon = 366{,}3/1{,}9 = 193\,dm^3mol^{-1}\,cm^{-1}$$

$$A = 193\,dm^3mol^{-1}\,cm^{-1}\,x\,2\,cm\,x\,1{,}55\,x\,10^{-3}mol\,dm^{-3} = 0{,}5983$$

$$T = 10^{-A} = 10^{-0{,}5983} = 25{,}2\%.$$

4.2. The GeoGebra worksheet

The GeoGebra worksheet, which consists of two parts (Fig. 2), was created to solve the example task from section 4.1.

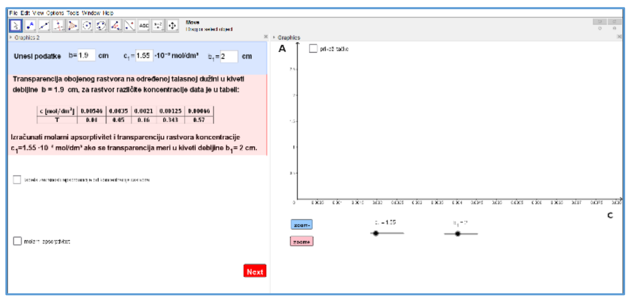


Figure 2. *GeoGebra worksheet*

In the left window of the GeoGebra worksheet are input boxes for variables b (length of cuvette, as given for the molar absorptivity calculation), c_1 (solution concentration) and b_1 (cuvette thickness).

Also, there are checkboxes for users to choose whether they want to see the table of dependency of absorptivity to solution concentration (Fig.3.) or the molar absorptivity (ε), Fig.4.

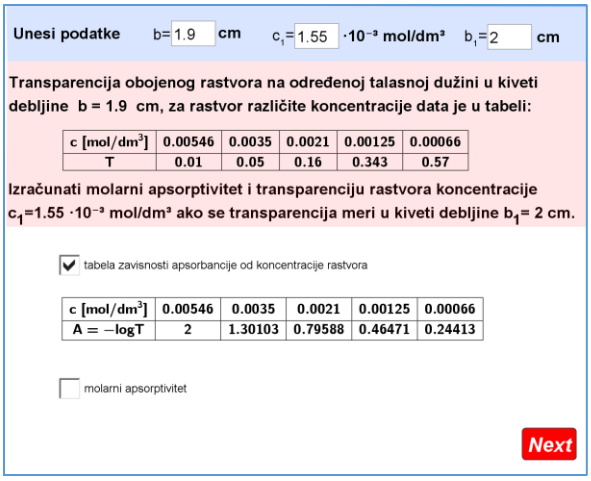


Figure 3. *Display of the table of dependency of absorptivity to solution concentration*

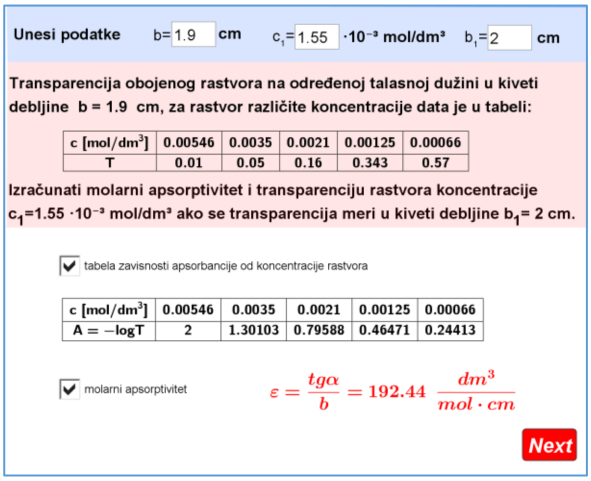
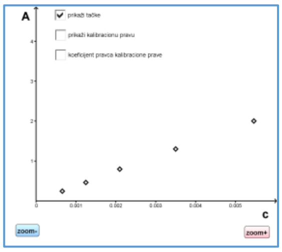
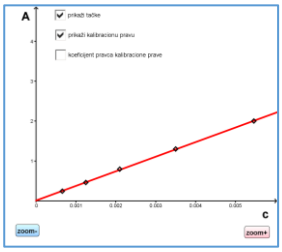


Figure 4. *Display of the molar absorptivity (ε)*

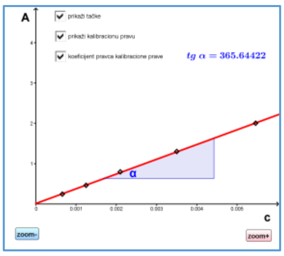
In the right window of the GeoGebra worksheet, the graph of the line $A = f(c)$ is displayed. There are also checkboxes for users to choose whether they want to see the points, the calibration line or the slope of the calibration line, Fig. 5. a), b), c).



a)



b)



c)

Figure 5. *Display of the points, line, and slope*

By clicking on the *Next* button at the bottom of the left window, the GeoGebra worksheet calculates the molar absorptivity (ε) for the entered data, Fig. 6.

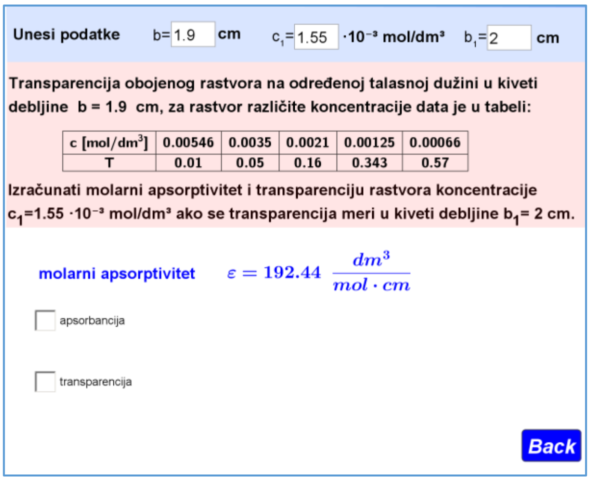


Figure 6. *Value calculation for the molar absorptivity (ε)*

In this window, there are also checkboxes for the calculation of the absorbance (A), (Fig. 7.) and transparency (T), Fig. 8.

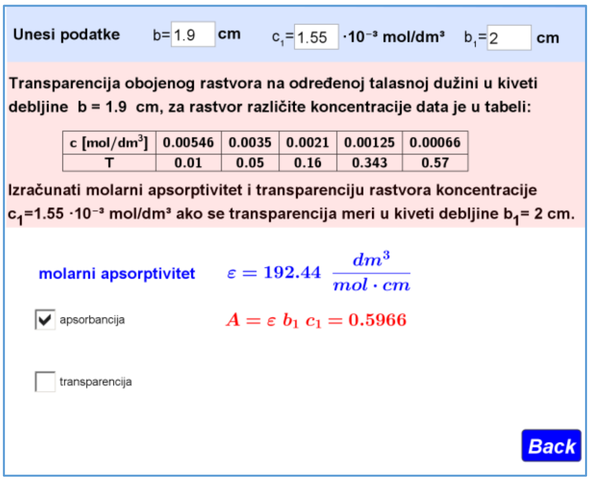


Figure 7. *Calculation of the absorbance (A)*

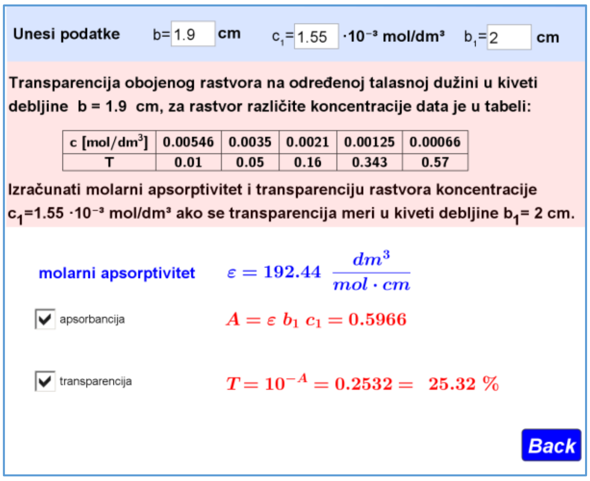


Figure 8. *Calculation of the transparency (T)*

It can be observed that, compared to the same example from section 4.1., the values for the molar absorptivity (ε) and the absorbance (A) slightly differs. That happened due to the calculation precision, which is more sensitive in the GeoGebra case.

At the same time, in the right window of the GeoGebra worksheet, the checkboxes for displaying the absorbance graph (Fig.9.) or absorbance of solution concentration (c_1) graph, (Fig. 10) appear.

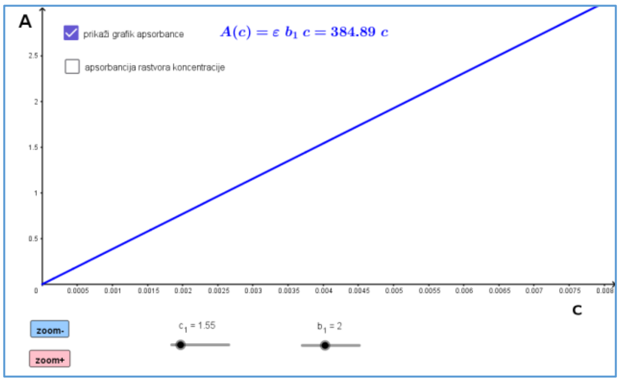


Figure 9. Display of the absorbance graph

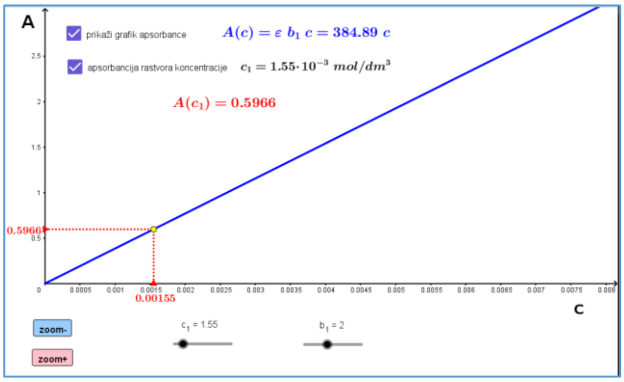


Figure 10. *Display of the absorbance of solution concentration (c_1) graph*

Also, at the bottom of the right window, it could be seen in GeoGebra so called "sliders", marked here by c_1 and b_1 and they correspond to those from the left window checkboxes for c_1 (solution concentration) and b_1 (cuvette thickness). By moving the sliders, it is enabled for values for c_1 and b_1 to be changed and by that users can explore new outcomes.

If the users want to create another example, they can return to the beginning by clicking the *Back* button at the bottom of the left window and input new entry values.

Moreover, the values in the table for the transmittance for solutions of various concentrations, from the left window, can also be altered by importing new values in the table.

By clicking the GeoGebra option *View* from the main menu and then choosing *Spreadsheet* from the option *View*, on the right side of the window appears Spreadsheet table, where the entry values can be changed, Figure 11.

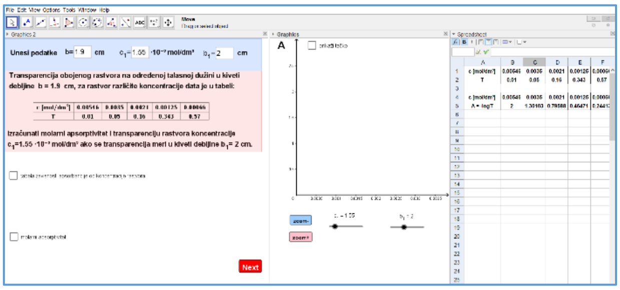


Figure 11. *Display of the Spreadsheet in GeoGebra*

In that manner, the GeoGebra worksheet allows students to explore a variety of examples and create their own virtual digital lab.

5. REMARKS AND DISCUSSION

The presented GeoGebra worksheet was implemented in the chemistry teaching and learning process at the university level. It was combined with traditional methods for problem-solving from the fields of colorimetry and spectrophotometry. The material was available to students for download and use in the classroom or anytime later for practicing and experimenting.

The worksheet is accessible to students and teachers on the official GeoGebra website. The chemistry students' interest in the material, as well as the students' interest in it, was noticed.

When asked for their impressions about the GeoGebra worksheet and the opportunity to learn via digital technologies and simulations, students expressed their satisfaction and positive experiences from the learning process. Students also highly rated the possibility of experimenting and creating different examples in the virtual lab.

The teacher's observations about implementing the GeoGebra worksheet in the teaching process was extremely positive. They observed that the students seemed to be more involved in the teaching process and more interested in the topic they had studied when using GeoGebra.

Future engagements and plans will focus on further developing digital materials, with an emphasis on simulations and dynamic materials that can contribute to various fields of education.

6. CONCLUSION

The classical graphical method in analytical chemistry, especially spectrophotometry, requires significant time and skill. Precision depends on accurate graphing on paper.

Integrating this method into STEM combines science with visual and mathematical reasoning. Using GeoGebra software in spectrophotometry highlights its potential in STEM education.

The interactive nature of GeoGebra makes tasks with diverse data more accessible. It provides precise results and graphical representations, enhancing understanding.

This approach promotes deeper learning and critical thinking in chemistry. Integrating such tools aligns with STEM, fostering lasting knowledge and skill development.

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Benefits of Digitalization of Textbooks for Improving the Educational Process – A Case Study in the Republic of North Macedonia

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Abstract: *Integration of key questions in teaching and studying is an important factor for a sustainable development of education, including the improvement of teaching quality too. Thus, encouraging critical thinking among students, solving logical tasks based on analyses, a motivation for participating in activities and problem solving, provides a sustainable educational development. Technology needs to support teachers, not to take over their place in education. The enlargement of professional ICT use will influence positively on the enlargement of ICT competencies of teachers. In this context is the research which has the aim to analyze the efficiency of the digital platform* ***www.nastava.mk****, the success of students in using the platform according to their academic level, the intensity of using the platform, way and reason for using the platform and the influence of ICT competencies of teachers for achieving a greater success of students. Results have shown that there is a significant connection between academic success and the success of using the platform among students, also, there are statistically significant differences of students' success on the platform according to the intensity of using the platform itself as well as existing statistically significant differences of students' success on the platform according to the teacher's ICT competencies.*

Keywords: digitalization, *digital platform, education, skills, competencies*

1. INTRODUCTION

Digital competencies represent an important part of contemporary education. Following contemporary ways of studying and teaching, technology and informatics in primary education are important for the educational process in The Republic of North Macedonia [1]. For a normal function of a contemporary society, according to the European frame for digital competencies, it is necessary to fulfill the parameter for producing digital contents. Thus, digitalization of teaching contents takes a particular place by using the digital platform **nastava.mk** [2]. This digital platform represents an innovative source of digital textbooks for fourth, fifth and sixth grade. The platform provides personal way of studying that is adjusted to every student by using contemporary digital and interactive contents. Through these multimedia contents, a teacher has the opportunity for a creative and dynamic way of acquiring knowledge using a fast, quality and simple method. The professional use of information and communication technology positively influences on the enlargement of ICT skills among teachers [3].

By registering on the platform and signing in with codes, students can use the platform and the textbooks in any time and from any place with an internet connection. This enables a flexible studying and an individual research. The digital platform does not replace textbooks, but it is an additional option for studying. Students can choose whether they use the digital textbook or the printed textbooks or both of them. After reading the content, students can check their knowledge through quizzes and interactive tasks. Except from immediately knowing whether the answer is correct or incorrect, the system gives the correct answer after several unsuccessful attempts [4].

The digital platform offers the opportunity for visual marking and pointing out the given contents by offering notes for personal thinking and reminders. The platform is available only for registered users through their own accounts with the highest standards for security of personal data. The system itself offers a fast and easy communication between teachers and students, assigning homework, revision tests, as well as individually following the development of every student.

1.1. Navigation of the platform

In the part of *my contents* there are all textbooks approved by the Ministry of Education and Science of the Republic of North Macedonia [5]. There are textbooks for fourth, fifth and sixth grade on the languages used for tutorials in North Macedonia. The teacher creates a grade for realization of tutorials with students. Parents can create a family group with their children who still study. It is especially significant that the platform offers data for the list of most successful students, grades and schools that joined the platform.

The most successful school in the country in the time of setting up of the platform is Municipal Primary School *Petar Zdravskovski Penko*, Butel, Skopje with 31003 points, on the second place is Municipal Primary School *Dituria,* Bogovinje with 231785 points. Also, on the platform you can notice the most successful students in the country and the number of points they have. The most successful student has got 21700 points, and the second student on the list has got 21600 points [2].

For a successful usage of the platform there was training for all teachers in North Macedonia who teach in these grades. These contents were included in the training: registration of teachers, usage of textbooks, registration of students, and how parents can monitor the process of using digital textbooks. Continually, through different channels, there is a technical support for all questions that arise related to the usage of the platform.

2. METHODOLOGY OF RESEARCH

As it was said in the introduction, this work analyses the efficiency of the digital platform nastava.mk, which presents an innovative resource of digital textbooks for fourth, fifth and sixth grade. The platform offers a personal studying adjusted to every student using contemporary digital and interactive contents. Except from external motivation caused by the interesting digital contents, an inner motivation in students occurs [6]. Students can individually progress, with their own intensity of studying and to compete with themselves collecting points from quizzes, solving tasks. Through these multimedia contents a teacher has the opportunity on a creative way and in a dynamic atmosphere to create a fast, quality and simple access in acquiring knowledge.

There is no strict connection between a student and a teacher when digital textbooks are used, because students can self-evaluate themselves in any moment, and teachers are there to encourage them in the process of learning, progress and studying. Therefore, students' success on the platform is analyzed by their points and the teacher's creativity for using contents from the platform itself.

There is data for students' results from half-term, the intensity of using the platform (I do not use it or I use it every day), as well as the way and the reasons for using the platform (from an assignment given by the teacher to using it just for fun). During the research all the interviewed students were with a high academic level of success because there was a very small number of students who had a low academic success. Students with a high level of academic success usually joined the platform. As we can conclude from the further analyses of the premises, the key point is that the students with a high level of academic success have not reduced their success. This fact can help students with a lower level of academic success to improve their success, but the most important thing is to motivate them to use the platform itself. The role of the teacher is important for this process. For the teachers, the level of ICT competencies is evaluated through a survey of 23 indicators for ICT competencies for mathematics as a subject (the influence of their creativity on the students' success by using the platform).

2.1. Aims of teaching

The aim of this research results from the above mentioned data, and that is analyses of mathematics in primary education according to the usage of digital tools in teaching, more precisely analyzing the efficiency of the digital platform nastava.mk which represents an innovative resource of digital textbooks for fourth, fifth and sixth grade. So we have analyzed the efficiency of the platform, students' success using the platform depending on the academic results of the students, the intensity of using the platform, the way and reason for using the platform and the influence of teachers' ICT competencies on students' success (as creativity for giving solutions in the platform).

2.2 Techniques, methods and examples of research

This research has been conveyed by using the two data bases from the platform for success analyses of students through fully acquired points, and on the other hand by using the technique Vetting (close-ended questions with Likert Scale), by using survey sheets as a research instrument for evaluating mathematics teacher's ICT competencies.

The analyses is done by using quantitative tests with a percentage frequency of the given answers according to the Likert scale by using descriptive statistics of numeric and percentage values as well as conclusive statistics with a quotient of connection and t-tests for the potential differences of arithmetic means.

There were 92 students in total from fourth, fifth and sixth that were being surveyed and 9 mathematics teachers, teachers from different ethnic groups were included, from Municipal

Primary School *Petar Zdravkovski Penko*, municipality of Butel, Skopje (310032 points in total) and municipal Primary School *Dituria*, Bogovinje (231785 points in total).

2.3. Research premises

Based on the presented aim and objective of the research, we have structured the following premises in continuation:

X1. There is a significant connection between the academic results of students in mathematics with the results from the platform nastava.mk.

X2. There is a significant difference in success between mathematics students according to the intensity of using the platform itself by students.

X3. There is a significant difference in success between students by using the platform according to the way and reason of using the platform by the students.

X4. There is a significant difference in success between students according to the level of ICT competencies of mathematics teachers.

3. FINDINGS AND RESULTS

By summarizing the results and working on data that are generated from the platform for 92 students in total, it is concluded that students have reached a maximum of 21700 points and a minimum of 18702 points with an arithmetic mean of M=20742 (sd=595,446) as presented in Table 1.

Table 1. *Description of students' success on the platform*

N	Valid	92
	Missing	0
Mean		20742,14
Median		20640,00
Mode		20604
Std. Deviation		595,446
Minimum		18702
Maximum		21700

In Table 2 there is a presentment of a statistical description of academic success of students from the first term of school year 2023/24, with a middle arithmetic mean of M=4,039 (sd=,703).

Table 2. *Description of the academic success of students in the first term of school year 2023/24*

N	Valid	92
	Missing	0
Mean		4,0387
Median		4,2150
Mode		3,36[a]
Std. Deviation		,70308
Minimum		2,40
Maximum		5,00

After working on data for students, results have shown that over 46% of them have used the platform several times a month, around 23% two or three times a week, 18% declared that they have not used it and 12% that they have used it every day (Fig. 1).

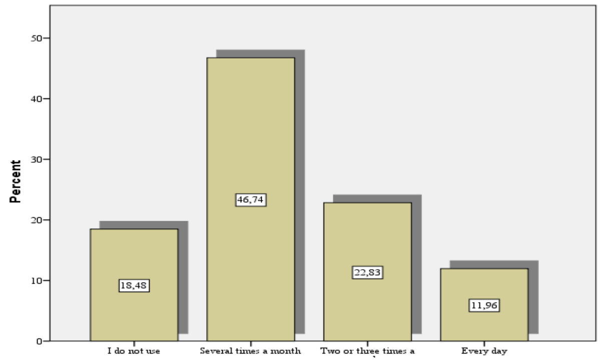

Figure 1. *The intensity of use of the platform by the students*

For the way and reason of using the platform, about 23% of students declared that they have used the platform as an assignment given by the teacher, 21% use it just to show their skills and knowledge, in a fewer percent they have declared that they use it as a substitute or replacement in studying and around 14% declared that they use it for other types activities (Fig. 2).

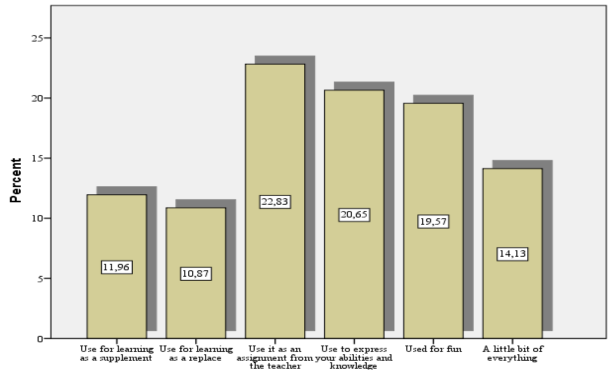

Figure 2. *Method and reason for using the platform by students*

On the other hand, after working on data for the level of ICT competencies of mathematics teachers, with the survey, results have shown that 39% of them have middle ICT competencies, 37% are with high ICT competencies, opposed to 24% with low ICT competencies (Fig. 3).

Based on the assumed premises between the potential connection of academic success of students in the platform *X1 the following results are given: There is a significant connection between the academic success of students with the success in mathematics in the platform* nastava.mk, in other words it is assumed that students with high academic success will also have a great success in using the platform. The platform has a great influence on the academic achievements of the students. These results enable the development of personalized programs for the support of students with a lower academic success in order to improve their results. It is a key fact that students' success has not reduced while using the platform.

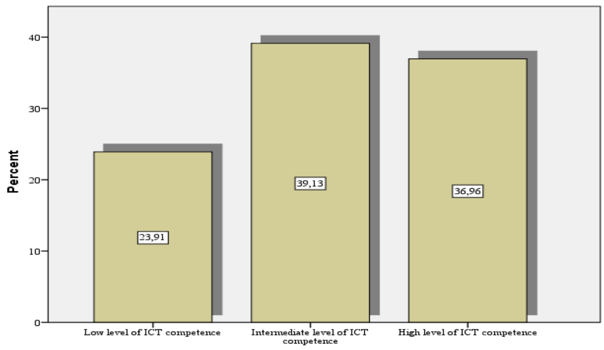

Figure 3. *The level of ICT competences of mathematics teachers who are responsible for the success of students in the platform*

The direction of the (a positive way up and right) line of connection in Figure 4 with R²Linear=0,400 means that there is a significant connection between the academic success and the mathematics success in the platform. In other words the good and the excellent students have good and excellent results in the platform.

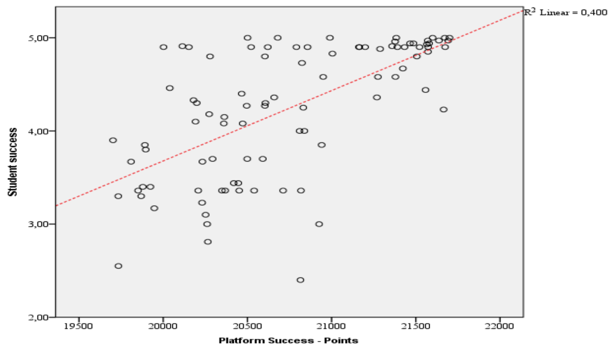

Figure 4. *The relationship between student success and platform success*

About *X2. There is a significant difference in the success of students in mathematics in the platform according to the intensity of using the platform itself by the student, in Table 3 there are arithmetic means of the success in the platform according to the intensity of using the platform itself by the students.*

Table 3. *Success of the digital platform according to the intensity of its usage by students*

	N	Mean	Std. Deviation	Std. Error	F	Sig.
I don't use	17	20781,18	619,032	150,137		
A couple of times a month	43	20765,98	539,475	82,269		
Two or three times a week	21	20446,38	584,080	127,457	3,854	**,012**
Every day	11	21153,27	577,960	174,262		
Total	92	20742,14	595,446	62,080		

For F=3,854 with Sig=,012 (p<0.05) we have concluded that there are statistically significant differences in the students' results on the platform according to the intensity of using the platform itself (Fig. 5). The differences are leveled in two groups thus in the first one there are students with a great success of using the platform every day opposed to the second group with a lower success of students who use the platform two or three times a week, a couple of times a month and those who do not use it (rarely, only the teacher).

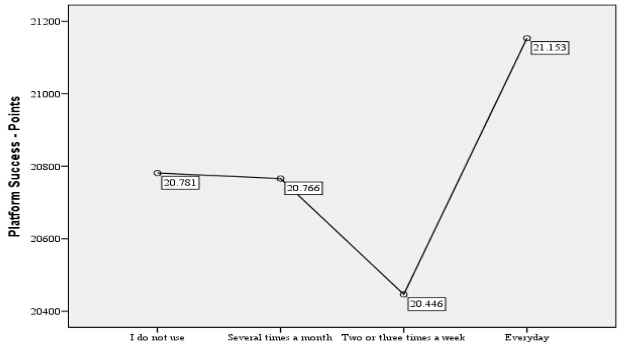

Figure 5. *Intensity of use of the platform by the student and success in the platform - Points*

Also about *X3. There is a significant difference in the success of students in mathematics on the platform according to the way and reason for using the platform itself by the student. In Table 4 there are arithmetic means of the success in the platform according to the way and reason of using the platform itself by the students.*

Table 4. *Success of the platform according to the way and the reason of its usage by students*

	N	Mean	Std. Deviation	Std. Error	F	Sig.
Used for additional studying	11	20690,18	606,642	182,910		
Used for studying as a replacement	10	20920,90	542,559	171,572		
Used as an assignment	21	20691,19	601,894	131,344	0,652	**,0189**
Used to show personal skills and knowledge	19	20658,16	530,755	121,763		
Used for fun	18	20525,28	648,593	152,875		
From different things	13	21153,92	489,805	135,848		
Total	92	20742,14	595,446	62,080		

For F=,652 with Sig=,189 (p>0.05) we have concluded that there are statistically significant differences in the students' results on the platform according to the intensity of using the platform itself.

About *X4. There is a significant difference in students' success in Mathematics in the platform according to the level of ICT competencies of the mathematics teacher, teachers who explain the usage of the platform with their own creativity and competencies, in Table 5 there are arithmetic means of the success in the platform according to the level of ICT competencies of the mathematics teacher.*

Table 5. *The success in the platform according to the way and the ICT competencies of the mathematics teacher*

	N	Mean	Std. Deviation	Std. Error	F	Sig.
Low level of ICT competencies	22	20822,73	475,331	101,341		
Middle level of ICT competencies	36	20652,78	627,222	104,537	2,689	**,025**
High level of ICT competencies	34	20784,62	633,865	108,707		
Total	92	20742,14	595,446	62,080		

For F=2,689 with Sig=,025 ($p<0.05$) we have concluded that there are statistically significant differences *in students' success in Mathematics on the platform according to the level of ICT competencies of the mathematics teacher.*

The differences are leveled in two groups thus in the first one there are students with a middle and high level of success of teacher's ICT competencies opposed to the second group with a lower success of students whose teachers have low level of ICT competencies (Fig. 6).

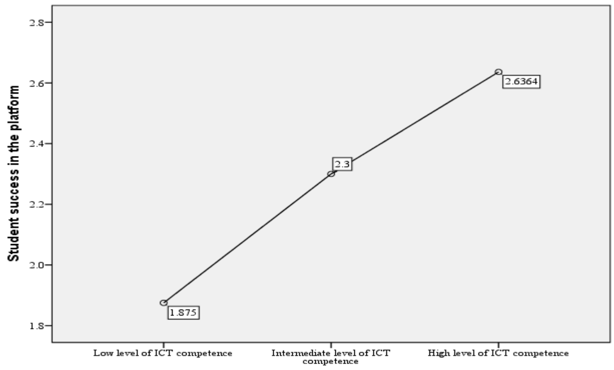

Figure 6. *Students' success in the platform and teachers' ICT competence*

4. CONCLUSION

Based on the collected data and results we have concluded that over 46% of students used the platform several times a month for Mathematics, about 23% two or three times a week, 18% declared that they have not used it and 12% that have used it every day. On the other hand around 23% of students have declared that they have used the platform as an assignment given by the teacher, 21% used it just to show their personal skills and knowledge, in a smaller percentage they have declared that they used it as an extra way of studying and around 14% declared that they have used it for other different activities. For the ICT competencies of teachers, it resulted that 39% of them have shown middle ICT competencies, 37% high ICT competencies, opposed to 24% with low ICT competencies.

Based on these data, after the analyses done for interpretation of the premises, we have concluded that there is a significant connection for achieving a greater success in mathematics for students who used the platform because of maintaining a high level of motivation. In other words the good and the excellent students have shown good and excellent results presented on the platform. Also, there are statistically significant differences in the success of students who used the platform according to the intensity of using the platform by them, a presentment of high results of students who use the platform.

There are statistically significant differences between the success of students shown in the platform according to the level of ICT competencies of the mathematics teacher, a presentment of high success of students corresponds to teacher's middle or low level ICT competencies opposed to a presentment of a low success of students that corresponds to a low level of teacher's ICT competencies. In reference to the significant contribution that the digital mathematics textbooks have for a greater success of students in future, it is necessary to convey certain research for quality and permanent knowledge among students for a longer period of time. Sustainability of motivation, which is obvious for using digital textbooks in all subjects, students, teachers and parents need be a matter of future research too. A special challenge is also the influence of key factors for a better motivation in using the platform and if students are really going to show higher results.

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Educational Technology – Benefits and Drawbacks in Enhancing Knowledge Acquisition Efficiency

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Abstract: *The paper provides an overview of the use of educational technology in the process of knowledge acquisition. The importance of educational technology as an indispensable factor in supporting education was highlighted. The study indicates the importance and necessity to study and apply modern educational technology in education. The development of innovative technology, starting with personal computers, through networking - the Internet, has led to creation of new opportunities for innovation and change in the educational process. Today, young people in the education system demand even more innovative ways of acquiring knowledge. Growing up with the daily development of technology enables them to become more independent and ready for self-education and lifelong learning.*

Keywords: *educational technology, innovative technology, teaching process, education*

1. INTRODUCTION

Education is one of the factors that influence changes in society. In order for education to have a stimulating effect on technological development, it is necessary to make some changes such as: changes in the educational process related to the education system, digitization of education and its impact on the forms, methods and ways of functioning. Problems in education, such as outdated curricula, poor working conditions, and a lack of essential teaching materials and aids, impact the outcomes of the educational process. Due to the constant development of technology, it is necessary to update program content, educate teaching staff, and introduce innovations into the teaching process.

2. EDUCATIONAL TECHNOLOGY- DEFINITION AND DEVELOPMENT

Educational technology can be defined as: 1) a systematic and organized process of applying modern techniques and technology in improving the quality of the educational process (efficiency, optimality, etc.); 2) a systematic way of conceptualizing the implementation and evaluation of the educational process, i.e. learning and teaching, with the application and help of modern educational teaching techniques. It includes teaching aids, methods and operations and relationships management, i.e. the behavior of all participants in the teaching process [1].

Educational technology includes being familiar with students, determining the goals of their education, specifying possible organization of teaching, planning the content of education, choosing methods and teaching tools, determining the position of teachers and students in teaching and evaluating the achieved teaching and learning results. Education technology includes the organization, implementation and verification of the teaching and learning process. That is why it is an essential factor of teaching and learning, and not simply a technique or a tool used by the teacher [2].

Educational technology is a set of techniques and procedures used to improve communication and knowledge transfer. Similarly, educational technology can be defined as the use of new technology to promote innovation in the educational field. The concept of educational technology can be defined in two ways:

- In a narrow sense – this includes those who limit educational technology to the use of technical tools in the classroom and believe that having full technical equipment is the best way to maximize teaching efficiency;
- In a broader sense – this includes those who encompass organization, teaching methods and procedures, and the application of teaching tools, including the most modern technical means within educational technology.

Application of educational technology plays a key role in providing new and innovative forms of support to teachers, students and the learning process itself. The digitization of all segments of society and the increasing demands for a highly qualified workforce increasingly require support in education. Determining the best tools to support learning and increase the efficiency of education systems is crucial. The popularity of the Internet and Information Technology has provided a platform for educational institutions not only to deliver information directly to students, but also to establish interactive communication [3]

Educational technology develops in three main directions: (1) mass communications; (2) individual learning and (3) group learning. Each of the directions consists of three subsequent phases: the research phase, the development phase, and the application phase, as shown in Table 1 [4].

Table 1. *Educational technology-historical development*

Mass communication (1940)	Research (1950)
	Development (1955)
	Application (1960)
Individual learning (1945)	Research (1960)
	Development (1970)
	Application (1975)
Group learning (1950)	Research (1975)
	Development (1980)
	Application (1985)

The rapid development of technology has an essential effect on the effects of the education system - techniques, methods and contents. Thus, for example, networking and the web have become a critical basis of computer technology, but at the same time one of the most important pedagogical tools, conditioning changes in the educational system itself, not only in computer science but also in other areas. The role of the lecturer is also constantly changing in the whole process, but it still remains crucial: although information globalization allows students to visit distant museums, archaeological sites, communication via video conferences, the lecturer is there to teach them critical thinking, social behavior, work discipline, personal responsibility, which develops and supports curiosity [5].

With the invention of computers and the Internet and the advent of the scientific and technological revolution, new teaching aids are slowly being introduced into teaching [6]. New sources of knowledge appear, in the form of modern teaching media such as computers, laptops, mobile phones, tablets, smart TVs, interactive whiteboards, electronic books and textbooks, which facilitate, complete and improve the learning process [7].

3. AN OVERVIEW OF VARIOUS TECHNOLOGIES/TOOLS IN USE

Web 2.0 tools can offer significant support to teachers in their working and classroom organization. Web 2.0 represents a new and improved generation of the World Wide Web [8]. It can be described as a platform that enables user interaction. Many of these tools are free to download and accessible to everyone, making them highly effective for use in schools as a supplement to traditional teaching.

The following categorization of Web 2.0 tools is most commonly found in the literature review [8]:

- Learning Management System (LMS) - Moodle, Blackboard, Canvas, WebCT, Claroline, etc.
- Media sharing tools - Flickr, YouTube, Google video, etc.
- Tools for communication and social networking - Skype, X (Twitter), Facebook, etc.
- Collaborative tools - Bubbl.us, Imagination Cubed, etc.
- Tools for creating teaching materials - Bitstrips, Prezi, Quiz Revolution, Crossword Labs, Slidestory, Nanolearning, Go Animate, etc.
- Tools for creative learning - Jot Form, Bubblr, Bubbleply, Mojiti, etc.

Learning management systems

Learning Management Systems enable the management, distribution, and publication of catalogs, courses, lessons, or lesson segments, and include, record, and manage information about learners, students, and teachers [9].

There are two groups of such systems: learning management systems with a free license and commercial systems [10].

1. Learning management systems with a free license [11]:
   - Moodle
   - ATutor
   - Claroline
   - Site@School
   - Dokeos
   - World Circle
   - OLAT
   - ILIAS
2. Commercial systems that provide electronic learning management [11]:
   - WebCT
   - Blackboard
   - Knowledge Presenter Learner
   - Learn2Learn
   - Sakai
   - eCollege
   - JoomlaLMS

4. EDUCATIONAL TECHNOLOGY - ADVANTAGES

Educational technologies are used by both teachers and students. They make it easier for teachers to improve students' knowledge and skills, while students, using educational technologies, improve their experience and facilitate the acquisition of new knowledge.

Students are in the focus of the teaching process (figure 1), and various forms of interactivity are incorporated into teaching:

- the structure of the learning environment is adjusted to suit the students' needs
- the teaching process is focused on the students
- students are encouraged not only to receive information, but also to do research as much as possible, to think critically about, to work independently or as a team
- both teachers and students are encouraged to be the members of the team that collaborate in the teaching and learning process.

Figure 1. *Student in focus of the teaching process*

Other advantages include [12]:

- increased collaboration: local or cloud computing systems can help to solve the task. On the other hand, this allows students to work as a team, without having to be physically present at the same time in the same place
- economical management of the teaching materials: Educational Technology tends to reduce the cost of educational materials, e.g. using the cloud for data storage
- better dissemination of content: content is available to students 24 hours a day, 7 days a week, e.g. pre-recorded lectures
- personalized education: students can be flexible when they need to organize studying process based on their own interest and pace. Also, educational technology makes it possible to assess students' progress.
- paying more attention: using different dynamic content keeps students focused on their activities.

By using educational technology, the number of teaching resources significantly increases. In traditional teaching, the textbook and teacher were the only sources of information. Today, educational technologies make teaching materials available to students, stimulating their interest and encouraging research to better master and memorize the content. Preparation, organization, and implementation of the teaching process with the help of educational technologies provide numerous opportunities such as [13]:

- achieving proximity to educational content through clear presentations, interactive software packages, and via the internet;
- enriching the learning environment and work environment with educational contents;
- engaging multiple senses when interacting with educational content;
- facilitating easier and continuous connectivity and the possibility of correlating educational content across multiple subjects.

4.1. Why do students need technology in the classroom?

1. It simplifies access to educational resources - students today use their smartphones and tablets outside of school hours, and they should be trusted with responsibility during school hours too. Educational technologies help students stay engaged during class by using familiar learning tools.
2. Promotes the learning experience - by incorporating educational technology, teachers can develop more creative and innovative lesson plans to maintain students' attention in their classes.
3. Students can learn at their own pace - educational technology can enhance individual learning by removing educational barriers that teachers may face. It enables online education, distance learning, and access to updated information. Since each student interprets information differently, technology can facilitate deeper exploration of subjects that are more challenging to learn.
4. It helps students prepare for their future careers - integrating educational technology in the classroom can help students feel more confident and comfortable as they approach the beginning of their careers. It can also enhance classroom interaction by encouraging collaboration among different learning styles.
5. Students demand it - students today feel comfortable using technology from a young age. When new material is presented to students using tools they have already mastered, they feel confident in their ability to learn new material [14].

5. EDUCATIONAL TECHNOLOGY - DRAWBACKS AND CHALLENGES

Although Educational Technology offers numerous advantages, its use can also lead to various problems, such as [12]:

- Adaptability: Technological changes tend to be faster than the willingness and capacity of teachers to accept these changes. Generally, it forces teachers to make a significant effort to master and adopt the use of new technologies.
- False information: The vast amount of available information presents a challenge for students, especially when it comes to distinguishing between true and false information. With more information, misinformation also increases.
- Outdated educational systems: The difference in quality between educational systems with different resources increases and those with fewer resources are less efficient.

The application of educational technologies in teaching has not resolved the issues of rationalization and efficiency in teaching. However, despite the fact that significant results have been achieved through the application of educational technologies in the teaching process, numerous problems still exist. These problems can be broadly categorized as follows:

- Problems arising from the definition and understanding of the concept of educational technology;
- Problems related to the teachers' ability to apply modern educational technology.

When it comes to defining and understanding the concept of educational technology, analyzing this issue leads to the conclusion that educational technology in the teaching process involves ICT technical means and resources, as well as applied knowledge from pedagogy, didactics, psychology, and communication. If educational technology were separated from these sciences and their disciplines, it would be reduced to mere technique and the use of machines. The tendency to reduce the content and functions of educational technologies to a set of technical means, machines, and apparatuses, while neglecting appropriate content, methods, and teaching principles, is unacceptable. Therefore, "educational technology is an interdisciplinary pedagogical discipline whose content integrates specialized technical-technological, cybernetic-informatics, pedagogical-psychological, and didactic-methodological knowledge and skills" [15].

One of the reasons that has contributed to the unfulfilled expectations regarding the implementation of educational technologies in teaching relates to teachers and their readiness for successful application of educational technology in organizing and implementing the teaching process. Numerous studies and analyses of the current state of practice show that "teachers generally possess basic, but not necessarily sufficient knowledge for functional use of educational technology, especially computers in teaching; even when modern educational technology is used, it is more often applied in lesson preparation than in actual teaching; the use of educational software is negligible; teachers often train themselves for its application using literature or with the help of more experienced colleagues; a small number of teachers keep up with innovations in educational technology; and a significant number of education professionals do not use the internet network at all" [16].

6. CONCLUSION

Educational technology has undergone rapid development in recent decades, with people embracing them eagerly because they make life more comfortable. The application of such technology is considered vital for education. Significant investments are made in the improvement of new technology, the development of new software that would integrate and replace many traditional teaching tools, and the training of teaching staff for more efficient use of new educational technologies in the teaching process. Moreover, educational software is also being created and designed so that students have access to online content both during classes and at home for independent study.

The application of educational technologies aims at achieving progress in acquiring new knowledge through various means and learning methods. Changes that have occurred in all spheres of life, driven by the development of science, technology, and modern technologies, impose a new approach in teaching, new learning technology, communication, information processing, classroom management, and educational planning.

Since students use various technologies daily outside of school, integrating educational tools into the classroom helps make the learning process much easier. Educational technologies simplify the way teachers do their job, providing efficient ways to establish relationships between teachers and students.

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Students' Satisfaction with Online and Traditional Teaching

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Abstract: *Students' satisfaction in higher education is a multifaceted concept that encompasses a wide range of factors influencing the overall student experience. Universities place significant importance on understanding and measuring this satisfaction as it provides essential insights into the effectiveness of their academic offerings and support services. By focusing on students' satisfaction, institutions can identify areas for improvement and tailor their approaches better to meet the diverse needs and expectations of their students. This paper compares students' satisfaction with online and traditional teaching methods at two technical faculties in the Republic of Serbia. The study involved 259 students who completed a questionnaire with closed questions in digital format using Google Forms surveys. Research findings indicate that students reported higher satisfaction with classroom teaching (M=3.994, SD=0.91145) compared to online teaching (M=3.8319, SD=0.91832), although the difference is relatively small. The factors that most significantly influence students' satisfaction with teaching include clearly defined assessment criteria, feedback on assignments, availability of literature in digital repositories, and the practical application of knowledge to solve real-world problems. The limitation of this study is that it focuses solely on students' perceptions, disregarding perceptions of other stakeholders.*

Keywords: *Students' satisfaction; higher education; online teaching; traditional teaching; technical faculty*

1. INTRODUCTION

Higher education is considered a pivotal driver for personal development as well as the social and economic progress of a country [1, 2]. This is reflected in current European policy guidelines, which focus on increasing the percentage of citizens holding higher education qualifications, whether through initial education or by enhancing professional competencies [1]. Higher education promotes innovation and creativity by generating and sharing knowledge, while also equipping students with essential skills to tackle future challenges.

Nowadays, the higher education sector is significantly influenced by globalization, intensifying competition among institutions. To stand out from their competitors and attract as many students as possible, higher education institutions are adopting market-oriented strategies to meet the needs and expectations of their primary stakeholders – the students [2, 3]. Students' satisfaction has become indispensable for the success of every higher education institution.

In recent years, higher education has experienced significant transformation with the growing prominence of online education alongside traditional teaching methods. This shift reflects a profound change driven by technological advancements and evolving student preferences [2]. The rise of online education as a viable alternative to traditional face-to-face methods has been accelerated by technological progress and the need to adapt to evolving circumstances, such as the COVID-19 pandemic, highlighting the importance of flexible and accessible learning options.

Understanding the dynamics between online and traditional education is crucial for exploring how institutions can effectively meet the diverse needs of today's learners while ensuring quality and inclusivity in higher education [1, 2, 4].

2. STUDENTS' SATISFACTION

Satisfaction is defined in various ways, but a common feature across all definitions is that it is founded on relationships where comparison and evaluation occur.

Satisfaction is defined as a „feeling of happiness that is obtained when a person fulfills his or her needs and desires" [2, p. 533]. The sense of pleasure or disappointment that arises from comparing the perceived performance with one's expectations. Satisfaction is a function of the relative level of expectation linked to people's perceptions. When a person perceives that the service encountered is good, they will be satisfied. Conversely, dissatisfaction arises when their perception conflicts with their service expectations [6]. Therefore, satisfaction is the perception of a service's pleasurable fulfillment of a service and is a complex mix of cognitions, emotions, and behavioral tendencies [2, 3, 5, 7].

If this definition is applied to students and universities, then students' satisfaction refers to the level of contentment or fulfillment experienced by students in their educational experience within an institution [3, 5, 6]. In ref. [2, p. 533], students' satisfaction is defined as a "short-term attitude" arising from the evaluation of their educational experiences. This is because it reflects a current evaluation of the educational experience. It is influenced by immediate factors such as the quality of teaching, facilities, administrative support, and social interactions. These elements can change over time, affecting how students perceive their satisfaction levels. Furthermore, as students advance in their academic careers, their expectations and requirements may change, influencing how satisfied they are with their educational institution. Therefore, student satisfaction is dynamic and can vary depending on continuous experiences and interactions within the educational environment.

Students' satisfaction is a positive precursor to students' loyalty and reflects the results and outcomes of the educational system [4, 5, 6]. Loyalty is demonstrated when students show interest in pursuing further studies (such as master's or PhD programs) at the same institution and are willing to recommend it positively to others, including prospective students and partners of the faculty. This, in turn, enhances the institution's public reputation [6]. High students' satisfaction boosts the institution's reputation, attracting new students and increasing applications, which are vital for financial stability and long-term growth [1, 4, 5]. Additionally, satisfied students actively participate in classes, effectively utilize institutional resources, and achieve superior learning outcomes, thereby promoting academic excellence and maintaining high educational standards [3, 4]. Satisfied students also enjoy improved prospects for employment and successful careers after graduation.

Students' satisfaction in higher education is a complex concept that includes many aspects of the student experience. It is an important measure for universities that want to improve their academic programs and support services. By thoroughly understanding the factors that contribute to student satisfaction, universities can make specific improvements to create a better environment for learning and support. Students' satisfaction is a key determinant of student loyalty and the spread of positive word-of-mouth, which influences the perception of the institution and its future success.

1.1. Measurement of students' satisfaction

Students' satisfaction is a multidimensional process and it is influenced by various personal and institutional factors [2]. Understanding what those factors are and how they combine to influence students' satisfaction is critical to educators who believe that student satisfaction, in addition to learning, is a desired outcome of their efforts [6, 8]. Key personal factors include grade (GPA), age, gender, employment and learning style. Institutional factors encompass the quality of instruction, feedback, expectations, teaching style, lecturers, physical facilities and technology use. Additionally, classroom quality, feedback, relationships with lecturers and peers, course content, learning resources, library facilities and overall campus climate significantly impact satisfaction. Other determinants include teaching ability, curriculum flexibility, university prestige, student growth and institutional effectiveness.

Measuring student satisfaction typically involves using various models and methods to gather feedback and assess students' perceptions of their educational experience. Researchers have devoted considerable efforts over the past few decades to enhance student satisfaction in higher education, utilizing diverse frameworks and models across various dimensions [2]. They initially adapted industry-based satisfaction models and later refined them specifically for higher education settings. These models, with their varied dimensions, have been implemented worldwide, revealing both conflicting and consistent relationships with student satisfaction in different contexts. Some of these models are:

- SERVQUAL model is a most popular widely used service quality model that has been applied to measure students' satisfaction around the world [2, 6]. It is developed in 1985 for business environments, it assesses service quality across five dimensions: tangibility, reliability, empathy, responsiveness, and assurance [2].
- The HEDPERF model was developed in 2005, and it is designed specifically for higher education, focusing on service quality dimensions such as teaching, learning, infrastructure, and support services [9, 2].
- The SAMR model (Substitution, Augmentation, Modification, Redefinition) was developed in 2006 and it assesses how technology is integrated into education, impacting student learning outcomes and satisfaction by categorizing levels from basic substitution to transformative redefinition of tasks and activities [10].

3. TRADITIONAL VS. ONLINE TEACHING

Educational theory and practice have undergone significant transformations in recent decades, driven by numerous societal changes. The COVID-19 pandemic has notably underscored the critical necessity for flexibility and adaptability in education [1, 7]. It forced educators and institutions to rethink traditional teaching methods and quickly adopt new strategies to ensure the continuity of learning. This period of rapid change emphasized the importance of integrating innovative approaches, such as online learning, to meet the diverse and evolving needs of students [1, 2, 7]. Educators worldwide have been compelled to incorporate technology into their teaching methods, regardless of their initial preparedness or preferences.

Technological advancements have provided educational institutions with opportunities to deliver educational content online, marking a shift from traditional in-person classroom lectures to electronic delivery methods.

Traditional and online teaching represent distinct educational approaches, each offering unique characteristics and benefits. Traditional teaching typically refers to the conventional methods of instruction that have been practiced in classrooms for decades. It involves face-to-face interaction between teachers and students in physical classrooms. In traditional teaching, the focus often lies on direct instruction, where educators convey knowledge through in-person lectures, discussions and interactive activities. Online teaching refers to the delivery of educational content and instruction via the internet or digital technologies, often outside of traditional physical classroom settings. This approach allows students to participate in learning activities remotely, accessing course materials, lectures and assessments through online platforms. Online teaching methods typically include video lectures, interactive assignments, discussion forums and virtual simulations. It provides flexibility in scheduling and access to resources, accommodating diverse learning styles and allowing for personalized learning experiences. Virtual classroom meetings facilitate interaction between teachers and students, as well as among students themselves.

The acceptance of online education by students is crucial for success of teaching process. If it is well-received and proves effective in achieving learning outcomes, increasing lectures in this format makes sense. If online teaching is poorly received and results in shallow learning or partial student engagement, institutions, where feasible, should prioritize classroom-based teaching [6].

Both traditional and online teaching methods have their advantages and are often integrated in blended learning approaches to leverage their respective strengths and enhance student learning outcomes. Blended learning is a new approach to teaching and learning created by combining traditional classroom learning with an online learning platform. In recent years, blended learning has become an increasingly popular form of e-learning. It is particularly suitable for transition from completely traditional forms of learning to online learning [7].

4. RESEARCH METHODOLOGY

In the past four years, after COVID-19 pandemic, several studies have explored student satisfaction with online teaching and compared it with traditional teaching. These studies revealed that students' satisfaction with online teaching is influenced by various factors such as access to technological resources, motivation, life circumstances, socio - emotional support, availability of materials, type of studies, and the inability to engage in practical exercises. Differences in satisfaction were also observed across countries; for instance, students in China and India reported high satisfaction rates (80.29%), whereas students in Jordan reported lower rates (26.77%) [1]. Additionally, research indicates that instructors of online courses received lower ratings compared to those teaching in traditional face-to-face settings, suggesting that the shift from conventional to online methods reduces student satisfaction with instruction [6].

This raises the question of whether face-to-face lectures in the classroom lead to greater student attention and better understanding compared to online lectures delivered through increasingly advanced technical presentations.

The aim of the survey is to explore and compare students' satisfaction with traditional teaching and online teaching based on the perceptions of students at two technical faculties in the Republic of Serbia, Faculty of Technical Sciences in Čačak and Technical Faculty „Mihajlo Pupin" in Zrenjanin.

Hypothesis:

- H1: Satisfaction of students with traditional teaching is higher than satisfaction with online teaching.
- H2: There is a statistically significant difference in the level of satisfaction with online teaching and teaching in the classroom between students who had some course online and those who did not.
- H3: There is a statistically significant difference in the levels of students' satisfaction with online teaching and teaching in the classroom between students at different years of studies.

After the COVID-19 pandemic, teaching approaches at several higher education institutions varied: some embraced online or hybrid models, while others continued with traditional face-to-face teaching. This study focuses on students from technical faculties because the use, understanding, and development of new technologies are essential parts of their education.

The questionnaire had three parts. The first part of the questionnaire was dedicated to general questions about students (faculty, year of study, study program, age, gender and their experience with online teaching). The second part comprises from factors that could influence satisfaction with teaching, which was adapted from ref. [11]. Third part was dedicated to students' satisfaction with online and teaching in the classroom, and items used in this part were adapted from [6].

Satisfaction with online teaching was measured using 9 items, where 2 items referred to teaching support, 2 items referred to teaching organization, 3 items referred to personal accomplishment and 2 items referred to teachers' skills. Satisfaction with teaching in the classroom was measured using 10 items, where 2 items referred to teaching support, 3 items referred to teaching organization, 3 items referred to personal accomplishment and 2 items referred to teachers' skills.

All items were rated on a five-point Likert-type scale ranging from 'strongly agree' to 'strongly disagree'.

Data were collected between May and June 2024 using Google Forms polling. Students were invited to participate in the research through announcements on Moodle, MS Teams, and Google Classroom. They were informed about the research's general aim, the anonymity of their answers and the voluntary nature of their participation.

Data analysis was conducted using the SPSS program. Descriptive statistics, independent samples t-tests and one–way ANOVA were done. Cronbach's alpha coefficient was calculated to assess the reliability of the variables.

A total of 259 students participated in the study. The structure of the respondents is presented in Table 1. There were 52.1% of students from the Faculty of Technical Sciences in Čačak and 47.9% of students from Technical Faculty "Mihajlo Pupin" in Zrenjanin from Serbia. Male students accounted for 56.4% of the sample, while female comprised 43.6%. The most students were 20-22 years old (63.7%). Regarding the study programs, 50% of students were enrolled in the Information Technology program, 26.6% of students were enrolled in the Management program, and other study programs were much less represented in the sample. Regarding the year of studies, 48.3% of students participated in the research were at second year of studies, 20.8% of students were at fourth year of studies. When asked if they had experience with online teaching, 47.1% of students said that they were enrolled in at least one subject which was held completely online. Hybrid model of teaching means that some lectures were presented in the classroom and for some lectures was used some kind of online teaching platform (for teaching or as a support for teaching). There were 28.2% of students who had some subjects in hybrid form. One quarter of students did not have any online course during their studies.

Table 1. *The sample structure*

Variables	Criterion	%
Sex	Male	56.4
	Female	43.6
Age	Less than 20 years	13.1
	20 to 22 years	63.7
	23 to 25 years	18.1
	More than 26	5
Year of studies	First	17.4
	Second	48.3
	Third	13.5
	Fourth	20.8
Study program	Information technology	50.2
	Management	26.6
	Electrical Power Engineering	1.2
	Mechatronics	0.4
	Computer and Software Engineering	5.4
	Environmental protection Engineering	6.2
	Clothing Engineering and Design	1.5
	Industrial Engineering in Oil and Gas Exploitation	5.8
	Mechanical Engineering	2.7
Faculty	Faculty of Technical Sciences Čačak	52.1
	Technical Faculty „Mihajlo Pupin" Zrenjanin	47.9
Experience with online teaching	At least one subject completely online	47.1
	Hybrid model	28.2
	All subject in the classroom	24.7

5. RESEARCH RESULTS

The reliability analysis for the Satisfaction with online teaching scale and Satisfaction with teaching in the classroom scale was assessed using Cronbach's alpha coefficient. Cronbach' alpha coefficient for the Satisfaction with online teaching scale was 0.956, while Cronbach' alpha coefficient for the Satisfaction with teaching in the classroom scale was 0.961, meaning high internal consistency (above the recommended value of 0.7). This analysis had proven good reliability and internal consistency of the scales for the sample used in this study.

Kolmogorov-Smirnov test of normality of distribution for students' satisfaction with online teaching was 0.102, $p=0.000<0.05$. Kolmogorov-Smirnov test of normality of distribution for students' satisfaction with teaching in the classroom was 0.135, p=0.000<0.05, which means that the assumption of normal distribution was not fulfilled for these variables. The distribution of values for satisfaction with teaching in the classroom was moved right from the mean value (-0.720), and it was lower than normal (-0.289). The distribution of values for satisfaction with online teaching was moved right from the mean value (-0.497), and it was lower than normal (-0.526). The Normal Q-Q plots showed good distribution of results and there were not any non-typical dots.

Descriptive analysis was conducted for all variables, including factors of satisfaction with teaching and students' satisfaction with online and teaching in the classroom. The results are presented in Table 2.

Table 2. *The results of descriptive statistics*

Factors influencing students' satisfaction with teaching	Mean	Std. Dev.	Var.
Availability of literature in digital repositories	4.36	0.930	0.866
Availability of literature in paper form	3.81	1.263	1.596
Technical support and equipment used in teaching	4.06	0.982	0.965
Independence in learning, in accordance with one's own pace, motives and time	4.17	0.947	0.896
Interaction with the teachers	4.15	1.067	1.139
Interaction with colleagues	4.02	1.073	1.151
Availability of professors and assistants	4.36	0.944	0.891
Clearly defined assessment criteria	4.50	0.886	0.786
Feedback on assignments	4.37	0.921	0.848
Connection between theory and practice and the application of knowledge to solve real problems	4.36	0.918	0.843
Final grade in the subject	4.02	1.071	1.147
Students' satisfaction			
Satisfaction with teaching in the classroom	3.9940	0.91145	0.831
Satisfaction with online teaching	3.8319	0.91832	0.843
Online teaching variable			
Teaching support	3.9286	0.93578	0.876
Teaching organization	3.7683	1.02885	1.059
Personal accomplishment	3.7426	1.01487	1.030
Teachers skills	3.8880	0.98389	0.968
Traditional teaching variables			
Teaching support	4.0463	1.00569	1.011
Teaching organization	4.0212	0.95262	0.907
Personal accomplishment	4.0193	0.95238	0.907
Teachers skills	3.8893	1.00589	1.012

Considering factors influencing students' satisfaction with teaching in general, the most important were clearly defined assessment criteria (M=4.5, SD=0.886), feedback on assignments (M=4.37, SD=0.921), availability of literature in digital repositories (M=4.36, SD=0.93) and connection between theory and practice and the application of knowledge to solve real problems (M=4.36, SD=0.918). The least important was technical support and equipment used in teaching (M=3.81, SD=1.263). But, when we consider all factors together, it can be concluded that almost all listed factors are highly significant for students' satisfaction with teaching. These findings are consistent with other research. García-Aracil's study (cited in [2]) on students' satisfaction across eleven European countries identified interactions with colleagues, course content, availability of learning equipment, library resources, teaching quality, and teaching materials as key factors influencing students' satisfaction. Students appreciate transparency in the assessment of their knowledge and seek a clear connection between lectures, tutorials, practical classes and subject resources. They need to know exactly what is expected of them to demonstrate in the course. They also want to understand the criteria for grading and expect timely feedback that [11, p. 107]: "explains their grade, acknowledges their accomplishments, provides suggestions for improvement, and can be used within the subject or course."

Despite the existence of online education before Covid-19, during the crisis it became the primary mode of teaching. The most of online teaching platforms continued to be used later on as either primary or supplementary tools in education. When considering available options for online teaching, students most frequently used Google's suite (Google Classroom, Google Chat and Google Meet), by almost 42% of them. Microsoft Teams and Moodle were utilized by 41% of students, while Zoom was used by 23% of students and Skype being used in a few cases.

Research findings suggest that students were more satisfied with teaching in the classroom (M=3.994, SD=0.91145) than with online teaching (M=3.8319, SD=0.91832), but that difference is not very big. These findings confirm our H1 hypothesis. Our findings are consistent with the results of previous study [12], which reported a slight preference among students for traditional educational formats over distance education formats, with minimal disparity in satisfaction levels.

The data reveals that traditional teaching received slightly higher ratings for support (M=4.046), organization (M=4.021) and personal accomplishment (M=4.019) compared to online teaching, where support received M=3.929, organization received M=3.768, accomplishment received M=3.742. When contrasting our findings with those from [6], it becomes evident that there are noteworthy disparities in the levels of satisfaction regarding aspects of online teaching. These differences in satisfaction may stem from varying levels of familiarity that students have with online learning methods, as well as the unique characteristics and academic demands associated with their fields of study.

Additional analyses was conducted to investigate whether there are differences in the levels of satisfaction with online teaching and teaching in the classroom among different groups of students.

One-way ANOVA was conducted to determine if there were statistically significant differences in the level of student satisfaction with online and teaching in the classroom between students who had subjects organized entirely online, partially online, or not online at all. Since Levene's test for equality of variances was 3.556, $p=0.03<0.05$ for satisfaction with online teaching and 3.989, $p=0.02<0.05$ for satisfaction with teaching in the classroom, which proved that the assumptions of equal variances were violated, so the results of Welch and Brown-Forsythe tests were used because they are robust tests. These results of Welch test (for satisfaction with online teaching: $F(2; 152.242)=0.208$, $p=0.813$; for satisfaction with teaching in the classroom: $F(2; 150.873)=0.313$, $p=0.732$) and Brown-Forsythe test (for satisfaction with online teaching: $F(2; 234.556)=0.223$, $p=0.800$; for satisfaction with teaching in the classroom: $F(2; 225.938)=0.354$, $p=0.702$) showed that there were no statistically significant differences in the levels of students' satisfaction with online and teaching in the classroom among students of these three groups. These findings lead to the rejection of our H2 hypothesis.

Additionally, a one-way ANOVA was conducted to determine if there were statistically significant differences in students' satisfaction levels with online compared to teaching in the classroom across different years of studies. Levene's test for equality of variances was 1.296, $p=0.276>0.05$ for satisfaction with online teaching and 1.19, $p=0.314>0.05$ for satisfaction with teaching in the classroom, which proved that the assumptions of equal variances were not violated. The results indicate that there were no statistically significant differences in the levels of satisfaction with teaching in the classroom ($F(3, 255)=0.536$, $p=0.658$) and online teaching ($F(3, 255)=1.801$, $p=0.148$) among the four groups of students. These findings lead to the rejection of our H3 hypothesis.

Wilkins & Balakrishnan (cited in [2]) revealed that there are significant differences in the levels of satisfaction at undergraduate and postgraduate levels. As this study exclusively examined undergraduate studies, upcoming research should broaden its focus to include postgraduate studies as well.

6. CONCLUSION

In today's competitive higher education environment, student satisfaction is crucial, driving universities to adopt more student-centric approaches. Factors like interaction quality, content structure, and flexibility were key to students' satisfaction with online teaching [9], but they were significant even in traditional and blended teaching.

According to the findings in this study, key factors for student's satisfaction include access to literature in both digital and paper formats, technical support, independence in learning, interaction with teachers and colleagues, availability of professors and assistants, clear assessment criteria, feedback on assignments, and the application of knowledge to real-world problems. While traditional teaching appears to hold a slight advantage in perceived support and organization, both modes are generally perceived similarly in terms of personal accomplishment and teacher skills. This suggests that both online and traditional teaching methods are effective, with minor variations in specific aspects of teaching quality. The study's findings indicate that there is no statistically significant difference in the levels of satisfaction with online teaching and classroom teaching between students who had some courses online and those who did not, nor between students at different years of study.

This study has several limitations. Firstly, the participants were only students from technical faculties, excluding students from other higher education institutions, which may limit the generalizability of the findings. Secondly, the focus was only on the perspective of students as service users, without considering the viewpoints of the teaching staff, potentially leading to an incomplete picture of the situation. Thirdly, the study was based on only four variables, which may restrict the depth of the analysis of student satisfaction. To provide a more holistic view, satisfaction with blended learning should also be include.

Future research should aim to overcome these limitations by including students from diverse institutions, incorporating perspectives from both students and teaching staff, and expanding the range of variables studied to include aspects of blended learning.

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Predictive Model for Early Detection of Students with Difficulties in Online Learning

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Abstract: *Online learning has become increasingly prevalent in all education levels during recent years. While in highly developed regions transition from traditional to online learning happens without significant difficulties, in underdeveloped and developing countries introducing students to online learning is typically followed by complications and frustration. Many researchers conducted studies to solve the issue of conforming to online learning and provide equal opportunities to all students regardless of their demographical characteristics and environmental factors. Introducing artificial intelligence tools to this problem can provide valuable insight into patterns and predictors in online education. This study proposes a machine learning model for predicting the low-level student adaptability to online learning. This model can indicate students who might have difficulties adapting to online learning with 94% accuracy based on their demographical and environmental characteristics. The model is developed using locally weighted learning with a C4.5 decision tree classifier. This paper contributes to understanding the problems underlying online learning adaptability and offers an accurate tool for detecting students prone to online learning issues, which can help persons of authority provide dependable and rapid aid.*

Keywords: *adaptability; artificial intelligence; education; machine learning; online learning*

1. INTRODUCTION

Distance education has a long history [1], but online education emerged in the 20th century during the 80's and 90's with the emergence of the Internet and Web [2]. Besides some benefits, this also introduced difficulties and challenges [3, 4], but even traditional education faced major challenges of online learning due to the pandemic of COVID-19 [5, 6]. Besides many other issues, the transition to online learning accentuated the problem of predicting student failure [7]. This paper presents one approach to early detection of students with difficulties in online learning.

In recent years, artificial intelligence (AI) has become increasingly prevalent in diverse areas of educational research. Machine learning (ML), a subset of AI within the realm of computer science, typically employs statistical methods to enable computers to learn from data autonomously, without explicit programming [8]. This discipline has a broad spectrum of applications, excelling in pattern recognition and adaptive learning across diverse fields. A plethora of research has utilized ML algorithms to predict outcomes from new inputs and to uncover underlying data structures and relationships. Significant discoveries have been made in education-related studies through the application of ML techniques. Online learning has gained significant traction across all educational levels in recent years. In highly developed areas, the shift from traditional classroom settings to online learning generally occurs smoothly [5]. However, in underdeveloped and developing nations, the introduction of online learning often brings challenges and frustration [9]. Numerous researchers have conducted studies to address the difficulties of adapting to online education and to ensure equal opportunities for all students, irrespective of their demographic and environmental backgrounds, concluding that the following ML techniques outperformed any other: Deep Neural Networks [10], Decision Tree Algorithm [11], Weighted Voting Classifier [12], and Locally Weighted Learning model [9]. For instance, in [13] ML techniques were used to estimate students' performance in Blended Learning and Complete Virtual Courses, while in [14] authors developed eight ML algorithms for predicting students' performance in STEM courses with recommendations for using ML models in education. In [15], authors analyzed the feedback in online courses to improve the quality of learning.

Papers [10, 11, 12, 9] investigated the prediction of students' pass rates as one metric of learning success. Thus, it can be assumed that the integration of AI tools into this field can offer valuable insights into the patterns and predictors of successful online education.

This research introduces an ML model specifically designed to predict low student adaptability to online learning environments. The model demonstrates a 94% accuracy in identifying students who may struggle with adapting to online learning, based on an analysis of their demographic and environmental characteristics. The development of this model utilizes locally weighted learning (LWL) in conjunction with a C4.5 decision tree classifier. By offering deeper insights into the underlying issues of online learning adaptability, this paper contributes significantly to the field. Furthermore, it provides an accurate and practical tool for detecting students who are likely to encounter difficulties, thereby enabling authorities to deliver dependable and swift assistance. The model's implementation can also guide the development of targeted interventions and support systems, ultimately fostering a more inclusive and effective online learning experience for all students.

The remainder of the paper is organized as follows. The second section describes the methods used, with emphasis on participants and data acquisition, ML models, and software and hardware requirements. Results are specified in the third section, while the discussion is described in the fourth section. The final section brings concluding remarks.

2. METHODS

2.1. Participants and data acquisition

The dataset used in this paper was acquired by a group of researchers from Daffodil International University (Dhaka, Bangladesh) [16] and was made publicly available on the Kaggle dataset repository [17]. The data was collected from 1205 students using online and paper surveys and preprocessed into a form suitable for ML algorithm training. A detailed explanation of the preprocessing phase can be found in [8].

The dataset consists of 13 input variables that represent mainly the demographical and environmental characteristics of participants:

- Gender – Gender type of student,
- Age – Age range of the student,
- Educational level – Education institution level,
- Institution type – Education institution type,
- IT student – Studying as an information technologies student or not,
- Town – Is student located in town,
- Load-shedding – Level of reduction of electricity supply,
- Financial condition – Financial condition of the student's family,
- Internet type – Mostly used Internet type,
- Network type – Network connectivity type,
- Class duration – Daily class duration,
- Self LMS – Institution's Learning Management System (LMS) availability, and
- Device – Mostly used device for online learning.

Output variable shows whether a student has issues with online learning or not using two values:

- Yes – in the case when a student has problems adapting to online learning, and
- No – in the case when a student can adapt to online learning with the minor to no difficulties.

All variables are of nominal type and have no missing values. Generalization of the output variable is performed comparing to the original dataset values in order to focus on indicating students with difficulties in online learning rather than recognizing levels of students' adaptability.

2.2. Machine learning

In this paper, the implemented model is based on lazy learning. Lazy learning is a type of ML where the model delays the generalization process until a query for prediction is requested from the model [18]. These methods do not involve an explicit training phase where a model is built. Instead, they perform computation during the prediction phase. This is in contrast to eager learning methods, where the model generalizes from the training data before receiving queries. This approach typically entails storing the training data in memory and retrieving relevant data from the database to respond to specific queries, which can lead to high memory usage and computational cost during prediction. Known also as memory-based learning, this method measures relevance using a distance function, where points closer to the query are deemed more relevant. Predictions are made based on local approximations of the target function around the query point, rather than a global approximation over the entire input space.

A variant of lazy learning used in this research, called LWL, utilizes locally weighted training to average, interpolate, extrapolate, or combine training data [18]. Instead of building a global model that captures the entire data space, LWL focuses on fitting simpler models to localized subsets of the data. This approach allows for flexible modeling of complex, nonlinear relationships in the data. LWL focuses on a small neighborhood around the query point, giving more weight to data points that are closer to the query point. The hypothesis is that points near the query are more relevant for making predictions. Each training example is assigned a weight based on its distance from the query point using the selected weighting function.

The main tasks of the LWL implementation process are presented in Fig. 1. First step is determining the neighborhood of training points given a query point.

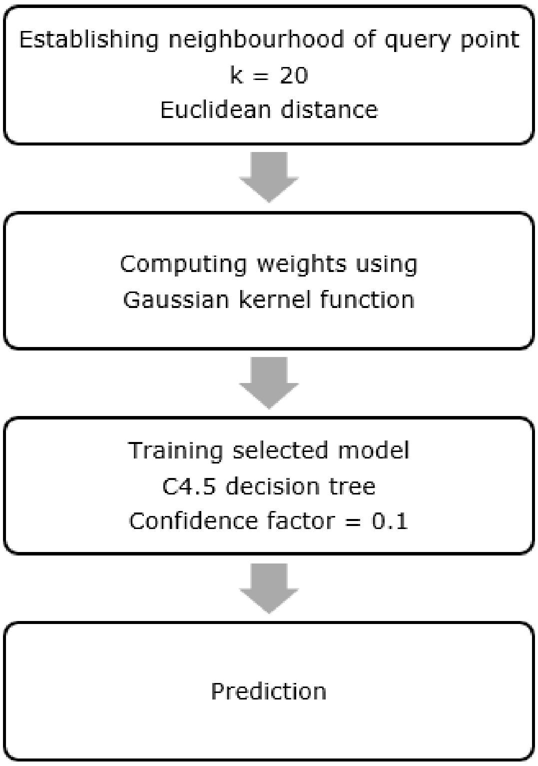

Figure 1. *Locally weighted learning based model for early detection of students with difficulties in online learning*

In this research, the number of neighbors was set to 20, whereas the search was performed using the Euclidean distance function. Further, the calculation of weights for each training point is performed using a chosen kernel function. The weight represents the distance of each point from the query point. In this paper, the Epanechnikov function is used for calculating the weights, which is mathematically represented as follows [19, 20, 21]:

$$K(x) = \begin{cases} \frac{3}{4}(1 - x^2), & |x| < 1; \\ 0, & \text{otherwise.} \end{cases} \quad (1)$$

After determining the query point space, an ML algorithm can be applied for training. The model proposed in this paper implements C4.5 decision tree as a base model for LWL with a confidence factor of 0.1. C4.5 is a prominent algorithm developed by Ross Quinlan in 1993 for generating decision trees, widely recognized for its effectiveness in ML tasks [22]. The model is presented in Fig. 1.

Building on its predecessor ID3, C4.5 uses the information gain ratio as its splitting criterion, which normalizes the information gain to mitigate bias towards attributes with many distinct values. The algorithm constructs the decision tree by recursively selecting the attribute with the highest gain ratio, splitting the dataset, and continuing the process until the stopping criteria are met. Once the full tree is generated, C4.5 prunes it to remove branches with a low contribution to the model's predictive power, ensuring better generalization. The main hyperparameter of the C4.5 algorithm is the confidence factor, which is used during the pruning phase of the decision tree construction. If the error rate with pruning is estimated to be within the confidence interval of the error rate without pruning, the node or branch can be pruned. A higher confidence factor results in less pruning, leading to a more complex tree that closely fits the training data. Conversely, a lower confidence factor results in more aggressive pruning, producing a simpler tree that may generalize better to unseen data.

2.3. Software and hardware requirements

Model development was performed in the Waikato Environment for Knowledge Analysis version 3.8.5. The hardware used for model implementation consists of NVIDIA GeForce GTX 1650 Ti GPU, AMD Ryzen 54600H 3.00GHz CPU, and 8GB of RAM.

3. RESULTS

This study is based on data that contains demographical and environmental characteristics of 1205 participants. In Table 1, the values of each input variable are presented, as well as their occurrence in relation to the output variable values. The occurrence is shown as the number of students and in a percentage format. Additionally, the total number of instances for each input value is calculated.

Within this research, multiple ML algorithms were tested in order to develop a model that can detect students with difficulties in online learning with high accuracy. The LWL-based model with the C4.5 decision tree achieved the best results with over 94% accuracy. As shown in Table 2, the classification model demonstrates a strong performance, with 94.02% of correctly classified and only 5.98% of incorrectly classified instances. This high accuracy is complemented by a Kappa statistic of 0.8753, indicating a strong agreement between the predicted and actual classifications. The model's errors are relatively low, as evidenced by a mean absolute error (MAE) of 0.0741 and a root mean squared error (RMSE) of 0.2071.

These metrics suggest that the predictions are close to the actual values. Additionally, the model exhibits a relative absolute error (RAE) of 15.46% and a root relative squared error (RRSE) of 42.30%, reflecting its robustness compared to a simple predictor. Overall, these results highlight the model's effectiveness and reliability in making accurate predictions with minimal error.

Table 1. *Participant characteristics*

Attribute	Value	Output NoP (%) Yes	Output NoP (%) No	Total NoP (%)
Gender	Female	235 (43.36)	307 (56.64)	542 (44.98)
	Male	245 (36.95)	418 (63.05)	663 (55.02)
Age	1-5	17 (20.99)	64 (79.01)	81 (6.72)
	6-10	24 (47.06)	27 (52.94)	51 (4.23)
	11-15	120 (33.99)	233 (66.01)	353 (29.29)
	16-20	144 (51.80)	134 (48.2)	278 (23.07)
	21-25	139 (37.17)	235 (62.83)	374 (31.04)
	26-30	36 (52.94)	32 (47.06)	68 (5.64)
Educational level	University	178 (39.04)	278 (60.96)	456 (37.84)
	College	120 (54.79)	99 (45.21)	219 (18.17)
	School	182 (34.34)	348 (65.66)	530 (43.98)
Institution type	Gov.	234 (61.26)	148 (38.74)	382 (31.70)
	Non-gov.	246 (29.89)	577 (70.11)	823 (68.30)
IT student	Yes	89 (29.28)	215 (70.72)	304 (25.23)
	No	391 (43.40)	510 (56.60)	901 (74.77)
Town	Yes	309 (33.05)	626 (66.95)	935 (77.59)
	No	171 (63.33)	99 (36.67)	270 (22.41)
Load-shedding	Low	380 (37.85)	624 (62.15)	1004 (83.32)
	High	100 (49.75)	101 (50.25)	201 (16.68)
Financial condition	Poor	129 (53.31)	113 (46.69)	242 (20.08)
	Middle	341 (38.84)	537 (61.16)	878 (72.86)
	Rich	10 (11.76)	75 (88.24)	85 (7.05)
Internet type	Wi-Fi	192 (37.65)	318 (62.35)	510 (42.32)
	Mobile data	288 (41.44)	407 (58.56)	695 (57.68)
Network type	4G	278 (35.87)	497 (64.13)	775 (64.32)
	3G	186 (45.26)	225 (54.74)	411 (34.11)
	2G	16 (84.21)	3 (15.79)	19 (1.58)
Class duration	0	144 (93.51)	10 (6.49)	154 (12.78)
	1-3	290 (34.52)	550 (65.48)	840 (69.71)
	4-6	46 (21.80)	165 (78.20)	211 (17.51)
Self LMS	Yes	52 (24.76)	158 (75.24)	210 (17.43)
	No	428 (43.02)	567 (56.98)	995 (82.57)
Device	Tab	2 (6.67)	28 (93.33)	30 (2.49)
	Mobile	438 (43.24)	575 (56.76)	1013 (84.07)
	Computer	40 (24.69)	122 (75.31)	162 (13.44)

* NoP – Number of participants; Gov. – Government; Non-gov. – Non-government; IT – Information technologies; LMS – Learning management system

Table 2. *Performance of the classification model*

Correctly Classified Instances	94.02%
Incorrectly Classified Instances	5.98%
Kappa statistic	0.8753
Mean absolute error	0.0741
Root mean squared error	0.2071
Relative absolute error	15.46%
Root relative squared error	42.30%

The confusion matrix which provides a detailed breakdown of the classification model's performance is presented in Table 3. Out of the actual positive instances, the model correctly predicted 444 and incorrectly predicted 36 as negative. Conversely, for the actual negative instances, the model correctly identified 689 and mistakenly classified 36 as positive. This demonstrates a high level of accuracy in both identifying true positives (444) and true negatives (689), with relatively low false negatives (36) and false positives (36). The balanced distribution of errors indicates that the model performs consistently well across both classes, maintaining a strong capability to correctly distinguish between positive ("Yes") and negative ("No") instances.

Table 3. *Confusion matrix of the classification model*

Real \ Predicted	Yes	No
Yes	444	36
No	36	689

The performance metrics that evaluate the model's effectiveness in distinguishing between two classes are presented in Table 4.

Table 4. *Performance metrics of the classification model*

Class	Yes	No	Weighted average
TP rate	0.925	0.950	0.940
FP rate	0.050	0.075	0.065
Precision	0.925	0.95	0.940
Recall	0.925	0.950	0.940
F-measure	0.925	0.950	0.940
MCC	0.875	0.875	0.875
ROC area	0.984	0.984	0.984
PRC area	0.972	0.979	0.976

* TP – true positive; FP – false positive; MCC - Matthews correlation coefficient; ROC - Receiver operating characteristic curve; PRC - Precision-recall curve

4. DISCUSSION

This study focuses on the development and validation of an ML model aimed at identifying students who are likely to face difficulties in adapting to online learning environments. This model is particularly relevant in the context of increased reliance on online education, amplified by the COVID-19 pandemic. The COVID-19 pandemic has profoundly impacted education systems worldwide, catalyzing an unprecedented shift from traditional in-person instruction to online learning [5]. This transition has highlighted both the potential and the challenges of online education, influencing students, educators, and institutions in various ways. The abrupt shift has forced educational stakeholders to adapt quickly, often with limited resources and preparation, leading to a range of outcomes that underscore the importance of effective online learning strategies and support systems [6]. This rapid transition necessitated a significant digital transformation, including the adoption of LMS, video conferencing tools, and digital resources. Institutions that were previously resistant or slow to adopt these technologies had to overcome logistical, technical, and pedagogical challenges swiftly. Despite the challenges, the pandemic-induced shift to online learning has also revealed several benefits and opportunities. Online learning can provide greater flexibility, increased accessibility, and expanded opportunities for students, allowing them to learn at their own pace and on their own schedule, breaking down the financial and locational barriers [4]. The model developed in this work leverages demographic and environmental data to achieve a highly accurate detection of students prone to difficulties in online learning, which is crucial for timely intervention and support.

The shift to online learning has been more challenging in underdeveloped and developing regions, where infrastructural and socio-economic factors play a significant role [3]. Creating inclusive educational tools that account for these disparities is of great importance, providing equal opportunities and quality education for all students around the world [4]. The predictive model proposed in this paper is a step towards ensuring that students at risk of falling behind are identified early and provided with the necessary support.

The dataset used in this study includes demographic and environmental characteristics of 1205 students. The dataset was preprocessed and used to train an LWL algorithm combined with a C4.5 decision tree classifier. The choice of LWL allows the model to adapt to local variations in the data, providing a more nuanced prediction compared to global algorithms. The model achieved a 94.02% accuracy rate, demonstrating its reliability in predicting students' adaptability to online learning.

The implementation of this predictive model holds a significant potential for educational institutions, especially in resource-limited regions. By pinpointing students who are struggling, educators and administrators can customize their support strategies to address individual needs, which could lead to improved educational outcomes overall. This model has the potential to enhance educational equity and inclusivity by ensuring that at-risk students in online learning environments are identified early. Such a proactive approach allows educators to provide tailored support and resources for all students.

In areas where disparities in access to technology and stable internet connections are common, this model can help bridge the gap for students from various socio-economic backgrounds. Educational institutions often face limitations in resources and manpower, and by employing this predictive model, schools and universities can allocate their limited resources more efficiently to the students who need them most. This targeted intervention can optimize the use of educational resources, such as tutoring, mentoring programs, and technical support, ensuring they have the greatest possible impact.

The insights gained from implementing such a predictive model can also inform policy decisions at both institutional and governmental levels. Policymakers can utilize the data to develop strategies that improve online learning infrastructures, address digital divides, and invest in areas where students are most vulnerable. This data-driven approach can lead to more effective educational policies that promote long-term improvements in online learning. Additionally, the model's ability to predict and identify students' difficulties in online learning can foster greater involvement from parents and the community. By providing timely information to parents about their children's learning challenges, educational institutions can encourage a collaborative effort between educators and families to support students' educational journeys. Community programs can also be developed to support students outside the school environment.

To enhance the model's robustness and generalizability, future research should focus on expanding the dataset to include a more diverse population. Incorporating students from different geographical regions, socio-economic backgrounds, and educational systems can help refine the model and ensure its applicability across various contexts. Future iterations of the model could also include additional variables that may influence online learning success, such as psychological factors like motivation and self-regulation, environmental factors like home learning conditions, and pedagogical factors like teaching methods and curriculum design. A more comprehensive set of predictors can improve the model's accuracy and provide deeper insights into the factors affecting online learning.

Integrating the predictive model into existing LMS can facilitate real-time monitoring and alerts. Such integration would allow educators to receive immediate feedback on students' performance and adaptability, enabling prompt interventions. Additionally, LMS integration can streamline the process by automatically collecting relevant data, ensuring the model has access to up-to-date information.

Given the constant evolution in technology and education, conducting longitudinal studies to track the long-term impact of early interventions identified by the predictive model can provide valuable insights. These studies can help understand how early support influences academic trajectories and overall student well-being, informing further refinements to the model and intervention strategies.

5. CONCLUSION

This study provides a robust framework for early detection of students with difficulties in online learning through an innovative application of ML. The high accuracy and reliability of the model suggest its potential for broad application, offering a valuable tool for educators aiming to provide equitable and effective online education. This research underscores the importance of leveraging technology to address educational challenges and highlights the need for continued innovation in this field. By ensuring that all students have the support they need to succeed, this model contributes to the broader goal of inclusive and accessible education for all.

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The Influence of Instagram Promotions on Young People's Purchasing Decisions: A Study on Persuasion, Credibility, and Influencer Impact

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Abstract: The study investigates the role of Instagram as a promotional tool and its influence on young consumers' purchasing decisions. Utilizing an exploratory, mixed-method approach, the research reveals that Instagram is perceived as a highly persuasive platform for product promotions, particularly due to its visual quality. Surprisingly, the study also highlights significant skepticism among young users (N=65) towards influencer endorsements, with low scores in trust and influence on purchasing decisions. These findings suggest that while Instagram effectively raises awareness, its ability to drive actual purchases is limited, underscoring the need for more authentic and engaging marketing strategies. Although Instagram is praised for its convenience and ease of shopping, concerns about fraud, the inability to inspect products physically, excessive ads, and the need for greater security make young people trust traditional purchases more. Low engagement scores indicate young users' reluctance to actively interact with ads, suggesting they may be noticed but fail to inspire direct engagement.

Keywords: *Instagram, promotion, corporate communication, public relations (PR), influencers.*

1. INTRODUCTION

Corporate communication refers to the strategic dissemination of information by organizations to internal and external stakeholders, aiming to build and maintain relationships, manage reputation, and achieve organizational goals [1]. It encompasses a range of activities designed to promote the organization's objectives, values, and image. This includes internal communications, public relations, investor relations, crisis communication, corporate branding, and corporate social responsibility initiatives.

Social media platforms, particularly Instagram, play a significant role in modern corporate communication strategies [2]. Instagram enables companies to engage with their target audience, share visual content, and communicate brand messages effectively. The platform's visual nature allows businesses to showcase products, services, and brand values creatively, enhancing engagement with followers. Instagram serves as a powerful tool for brand promotion, customer engagement, and reputation management. With 25 billion business account, Instagram is still the best platform to promote brand awareness [3], and companies frequently leverage Instagram to communicate promotional messages and interact with customers. The platform's interactive features, such as stories, live videos, and polls, facilitate two-way communication between businesses and their audience, fostering engagement and building customer relationships. Moreover, the use of influencers on Instagram has become a popular strategy for companies to reach a wider audience and enhance brand credibility.

However, despite the widespread adoption of Instagram in corporate communication, recent statistics reveal that the number of active Instagram users dropped. According to data recorded in 2023 and January 2024, Instagram's monthly active users declined by 4 million [4]. Much additional research is needed to help us understand the reasons that drive people to become Instagram users and the values they find in it. Additionally, there is a critical need to explore consumers' attitudes and behaviors in response to Instagram marketing efforts. Understanding these behavioral responses will provide valuable insights for organizations seeking to optimize their social media strategies and achieve enduring success in the digital age. This research aims to investigate how Instagram communicates promotional messages to young people and assess the extent to which these messages influence their purchasing decisions.

2. PUBLIC RELATIONS AND CORPORATE COMMUNICATION IN THE DIGITAL AGE

Corporate communication and Public Relations (PR) are closely intertwined within organizational structures. In the contemporary digital era, the landscape of Public Relations (PR) and corporate communications is undergoing transformation due to rapid advancements in digital technologies and communication channels. The advent of digital technologies has significantly altered organizational communication practices, blurring the traditional boundaries between PR and corporate communications [5].

The accelerated tech advances have had a dramatic impact on modern corporate communication [6], as social media have now become an inevitable element in companies' internal and external communication approaches [7]. Social media is extensively used to promote products, services, and corporate initiatives, and nowadays many companies integrate their Instagram account with their corporate website.

In a comprehensive sense, corporate communication encompasses marketing communications, organizational communications, and management communications, all aimed at establishing positive relationships with stakeholders crucial to the company's success [8]. This term also signifies a cohesive organizational approach directed at various target groups, emphasizing corporate identity. Particularly in the aftermath of the disruptions caused by the COVID-19 pandemic, the corporate communication landscape has evolved into a multidisciplinary ecosystem. This transformation has seen corporate communication strategies adapt to a more integrated and diverse approach, incorporating elements from various disciplines to effectively engage stakeholders and manage organizational reputation.

The role of social media has been confirmed in numerous studies; for example, Tsai & Men [9] conducted a study on the effects of CEOs' communication styles on social networking sites, highlighting the impact of social media interactions on organization-public relationships and public advocacy. Also, Floreddu & Cabiddu [10] explored social media communication strategies and their impact on corporate reputation, emphasizing the importance of managing corporate reputation through effective social media communication. Finally, it is argued that social media has allowed the firms to develop a timely and direct communication with stakeholders, further arguing that social media helps in achieving the efficiency level that simply cannot be achieved from the traditional medium of corporate communication [11].

3. INSTAGRAM AS A PROMOTIONAL TOOL

Since its inception in 2010, Instagram has served as an influential marketing instrument for businesses aiming to enhance their visibility and product recognition. Owing to its highly visual nature, Instagram proves to be an outstanding social media marketing platform for displaying stylish, innovative, captivating, and aesthetically pleasing products and services. The platform's architecture is centered around photo and video sharing, with distinct features such as tagging, filters, and the recognizable Instamatic-inspired shape of posts [12].

Instagram's visual focus, where users express themselves through images and captions, is a key aspect that sets it apart [13]. Sectors such as fashion, food, travel, beauty, home decor, gardening, and event planning have achieved significant success by incorporating Instagram engagement into their marketing strategies. Currently, Instagram has 362.9 billion users more than half of which (62.4%) are between 18 and 34 years old [4], and it is argued that Instagram ranks 4th among the most popular social media networks globally as of 2024, after Facebook, YouTube and WhatsApp [4]. Regarding Instagram users, the highest number of users is coming from India, USA and Brazil [4]. As Instagram's reach has been so powerful, the platform's features have been leveraged for various purposes, including advertising, influencer marketing, and educational activities [14, 15, 16]. With such a vast population of users, companies recognized the potential of Instagram for promotions, so they pay influencers collaborate with brands educators utilize its features for virtual instruction [14, 15, 16].

As a media-sharing platform, Instagram is a prominent participant in the influencer economy, where people partly receive money based on their follower count. According to Instagram [4], 87% of individuals report that influencers have influenced their purchasing decisions. Even if users do not directly shop from influencers, their impact solidifies Instagram's role as both a shopping destination and social media platform. Picture posts (78%) and stories (73%) are considered the most effective content types for those shopping through influencers. Instagram serves as a vital platform for building brand networks and enhancing engagement with both existing and potential consumers, regularly introducing new business features. Notably, 44% of individuals use Instagram for weekly purchases. 62% of people are more interested in a brand after viewing it on Instagram Stories. According to [3], Instagram hosts 25 billion business accounts, making it the premier platform for promoting brand awareness. It remains the most popular platform for influencer marketing.

Instagram's influence on consumer behavior, particularly among young customers, is profound and multifaceted. It is argued that Instagram social media marketing has a significant influence on young customers' purchasing intentions, with user-generated content (UGC) and influencer marketing playing a crucial role in shaping their propensity to make purchases [17, 18]. Customer engagement on Instagram positively affects emotions, purchase intention, and the dissemination of positive user-generated content (UGC), underscoring the importance of engagement in influencing customer behavior on the platform [19]. Additionally, Instagram serves as an effective promotional tool for attracting consumers, particularly the youth market, demonstrating the platform's efficacy in reaching specific target audiences.

4. METHODOLOGY

This research study deployed an exploratory, mix-method design. The objective of the research is to investigate how Instagram communicates promotional messages to young people and assess the extent to which these messages influence their purchasing decisions. The data collection was conducted in May 2024.

The research questions and hypotheses were as follows;

RQ1: To what extent do young people perceive Instagram as persuasive for product promotions?

RQ2: How do the visual and interactive features of Instagram influence the perceived credibility and attractiveness of advertised products?

RQ3: What is the extent of influencers' impact on the purchasing decisions of young people on Instagram?

RQ4: How do young people perceive the trustworthiness of traditional advertising methods compared to Instagram advertisements endorsed by influencers?

H1: Young people find Instagram a persuasive platform for product promotions.

H2: The visual and interactive elements of Instagram increase the perceived credibility and attractiveness of advertised products.

H3: Influencers on Instagram significantly impact the purchasing decisions of young people.

H4: Traditional methods of promotion are perceived as more trustworthy by young people compared to Instagram advertisements endorsed by influencers.

4.1. Instrument and sample

For the purposes of this research, an electronic survey was designed and administered through Google Forms Questionnaire to a number of people via e-mail, with a request to forward it to other people who use Instagram or know someone who uses it, applying the principles of person-to-person recommendations. The survey was administered anonymously to ensure respondents answer with openness and honesty. It comprised three sections: (1) demographic inquiries, (2) assessments of general attitudes toward Instagram, and (3) evaluations of attitudes specifically toward Instagram promotions. Part 1 focused on demographic information, while Part 2 explored responses to 14 statements about Instagram in general. Part 3 consisted of 10 statements regarding perceptions of Instagram promotions. Each statement in Part 2 and Part 3 utilized a 5-point Likert scale (1 indicating “totally disagree“, and 5 meaning “completely agree“). The Cronbach's alpha coefficient of 0.94 for the whole instrument indicates that the survey reliable and that the items included are consistently measuring the same construct. The data are analyzed using SPSS software for descriptive statistics. The results are interpreted with means categorized as follows: 1.00-1.79 (very low); 1.80-2.59 (low); 2.60-3.39 (moderate); 3.40-4.19 (high); 4.20-5.00 (very high). The research included N=65 respondents of different genders and age groups, which allowed us to get a broader picture of the attitudes and preferences of Instagram users.

5. RESULTS AND DISCUSSION

5.1. Demographic Questions

This section provides a comprehensive overview of the age, gender, occupation, social media usage, and Instagram follower base of the survey participants, offering valuable context for the subsequent analysis.

Age and gender Distribution: The results indicate that the majority of respondents fall within the 22-25 age range, with 37 respondents in this category. Additionally, there are 8 respondents aged 18-21, 8 respondents aged 26-30, and 5 respondents over 30 years old. Among our respondents, 24 identified as male, 4 as female, and 1 respondent chose not to disclose their gender.

Current Occupation: A significant portion, 46.2%, reported being students. Full-time employees constituted 33.2% of the sample, while the remaining respondents included part-time employees, self-employed individuals, unemployed individuals, and others.

Social Media Usage: We also examined the amount of time respondents spend on social media, daily. The data reveals that most respondents spend between 3-4 hours on social media, while the smallest group spends less than an hour daily. This information is critical in understanding the extent of social media engagement among the participants. Regarding the frequency of Instagram use on a daily basis, a significant 90.8% of respondents reported using Instagram every day (Figure 1).

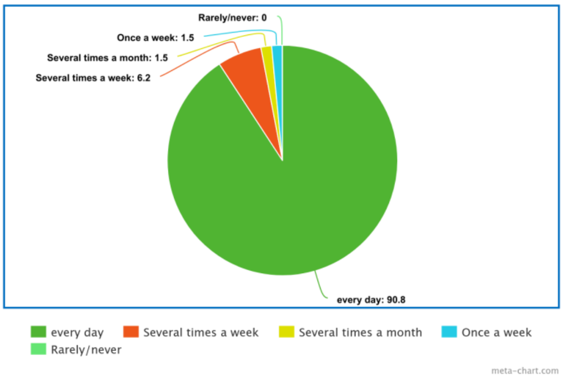

Figure 1. Frequency *of daily Instagram use*

Instagram Followers: As many as 70.8% of respondents follow an influencer on Instagram (Figure 2). Finally, we explored the number of Instagram followers our respondents have. The findings show that the majority have between 100-500 and 500-1000 followers. Fewer respondents have 1,001-5,000 followers, more than 5,000 followers, or less than 100 followers.

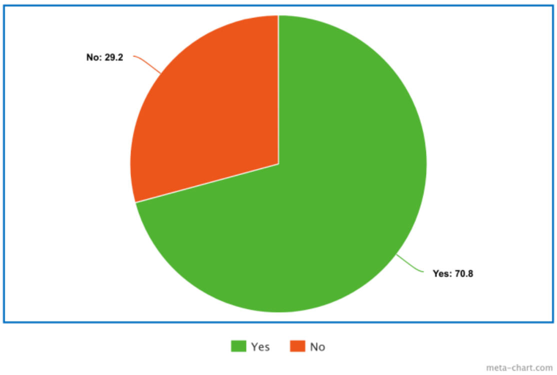

Figure 2. Percentage of respondents who follow influencers on Instagram

5.2. Attitudes towards promotional aspect of Instagram

To address the research questions and confirm or refute the hypotheses, we asked the respondents to rate 15 statements about Instagram, ranging from 1 to 5. The findings, given in Table 1, reveal several key insights where respondents' perceptions align most positively with Instagram's promotional aspects. The high means are observed in two categories Instagram's persuasiveness and visual appeal. The respondents reported that Instagram is a persuasive platform for product promotions (M=4.11). The high mean score indicates that respondents generally view Instagram as highly effective for promoting products, emphasizing its strong persuasive influence. The visual quality of advertisements on Instagram makes them more convincing (M=3.34). This statement highlights that the majority of respondents find visually appealing ads on Instagram significantly enhance their persuasiveness, indicating the importance of aesthetics in marketing on this platform.

Moderate attitudes were observed in “Interactive elements in Instagram ads enhance my engagement with the content” (M= 3.18) and “Advertisements on Instagram are more appealing to me compared to those on other social media platforms” (M= 3.17). The score indicates that while these interactive tools are appreciated, they may not universally captivate all users to the highest degree possible. Similarly, the moderate rating here indicates that while Instagram advertisements are generally perceived as appealing, they do not consistently outshine ads on other social media platforms by a significant margin. This suggests that while Instagram excels in certain visual and interactive aspects, other platforms may have unique strengths or reach different audience segments more effectively.

Table 1. *Descriptive statistics for part 1 attitudes*

PART 1 - Attitudes towards promotional aspect of Instagram	**Std. Dev.**	**Mean**
1. Instagram is a persuasive platform for product promotions.	1.25	4.11
2. I often feel influenced by the advertisements I see on Instagram.	1.21	2.88
3. Advertisements on Instagram are more appealing to me compared to those on other social media platforms.	1.23	3.17
4. The visual quality of advertisements on Instagram makes them more convincing.	1.15	3.34
5. Interactive elements (e.g., swipe-up links, polls) in Instagram ads enhance my engagement with the content.	1.23	3.18
6. I am more likely to trust a product that has high-quality visuals on Instagram.	1.38	3.00
7. My frequency of Instagram use affects my awareness of new products and trends.	1.32	3.03
8. I have purchased products as a direct result of seeing them advertised on Instagram.	1.29	2.57
9. The more time I spend on Instagram, the more likely I am to buy products promoted there.	1.25	2.49
10. I find Instagram advertisements more trustworthy when they are endorsed by influencers I follow.	1.29	2.88
11. I am skeptical of product promotions on Instagram that do not involve influencers.	1.22	2.40
12. The credibility of a product is enhanced when it is promoted by multiple influencers on Instagram.	1.27	2.68
13. Products promoted by inflncers on Instagram seem more credible to me.	1.08	2.38
14. Instagram influencers significantly influence my purchasing decisions.	1.41	2.22
15. I tend to trust product recommendations from Instagram influencers.	1.20	2.52

The lowest attitudes were scored in the following categories; Influence of Instagram on Purchasing Decisions (M=2.22), Credibility of Influencer-Endorsed Products (M=2.38), Skepticism Towards Non-Influencer Promotions (M=2.40), and Purchase related to the time spent on Instagram (M=49). Interestingly, a low score was also observed in “I tend to trust product recommendations from Instagram influencers” (M=2.52), indicating a notable degree of skepticism among young users towards influencer endorsements on Instagram.

This low score highlights that Instagram's impact on driving actual purchasing decisions is minimal. Despite high engagement levels on the platform, this influence does not necessarily translate into purchase actions. Users may perceive influencer promotions as driven more by financial incentives rather than genuine belief in the product.The notable skepticism towards promotions that do not involve influencers indicates that users rely on influencer credibility to some extent, yet remain wary of traditional advertising methods.The correlation between time spent on Instagram and purchasing behavior is low. This implies that even heavy users of Instagram are not significantly more likely to purchase products promoted on the platform, suggesting a disconnect between engagement and conversion.

In the second part of the questionnaire, surprisingly, no high attitudes were observed, as all categories scored either moderate or low scores. The findings (Table 2) indicate that the moderate scores in this segment were observed for the statements “I prefer Instagram ads that are entertaining or humorous” (M=3.26) and “Instagram ads help me discover products I wouldn't have found otherwise” (M=3.23). This highlights Instagram’s potential as a discovery platform, though variability in user experiences suggests that not all ads are equally effective in this regard, and also pinpoints that creative and engaging content is more likely to capture young people’s attention. Also, we must emphasize here users tend to trust ads more when they come from verified accounts or official brand pages, emphasizing the importance of perceived authenticity and legitimacy in ad effectiveness (M=3.18).

Table 2. *Descriptive statistics for part 2 attitudes*

PART 2 - General attitudes towards Instagram	Std. Dev.	Mean
1. I enjoy seeing product promotions on Instagram.	1.17	2.54
2. Instagram ads provide me with useful information about new products.	1.54	3.12
3. I often save or bookmark Instagram ads for future reference.	1.42	2.83
4. I often engage with advertisements on Instagram by liking, commenting, or sharing.	1.03	2.15
5. I prefer Instagram ads that are entertaining or humorous.	1.32	3.26
6. Instagram ads provide me with useful information about new products.	1.14	3.03
7. Instagram ads help me discover products I wouldn't have found otherwise.	1.63	3.23
8. I have made a purchase because of an Instagram ad.	1.40	2.97
9. I trust Instagram ads more when they come from verified accounts or official brand pages.	1.33	3.18
10. I am likely to purchase products promoted on Instagram in the future.	1.18	2.02

On the low spectrum of attitudes we can observe several categories: Likelihood of Future Purchases (M=2.02), Engagement with Ads (M=2.15), and Enjoyment of Product Promotions (M=2.54). The low score for engagement, such as liking, commenting, or sharing ads, indicates a reluctance among users to interact actively with advertisements. This suggests that while ads might be seen, they do not frequently inspire direct interaction or engagement. The likelihood of purchasing products promoted on Instagram in the future is low, highlighting a significant gap between ad exposure and purchase intent. This suggests that while ads may raise awareness, they do not effectively drive future purchasing behavior.

Overall, while Instagram ads are moderately effective in certain areas such as entertainment and product discovery, significant challenges remain in driving user engagement and converting ad views into purchases. By focusing on creativity, building trust, enhancing discovery, and encouraging interaction, marketers can improve the effectiveness of their Instagram advertising strategies and better align with user attitudes and behaviors. Future research should explore the specific factors that influence these attitudes and identify targeted approaches to address the identified gaps.

5.3. Perceptions of Promoting Products on Instagram versus Traditional In-Store Selling

To address H4, an open-ended question was asked to explore the perceptions of promoting products on Instagram compared to traditional in-store selling methods. The data reveals diverse opinions, categorized into positive, negative, and neutral sentiments, with a total of 127 mentions distributed across various aspects (Table 3).

Positive perceptions: The positive feedback, representing 42.52% of the total mentions, underscores the convenience and efficiency of Instagram as a shopping platform. The highest positive rating was given to the statement about ”availability and ease of shopping, efficiency, and home delivery", with 16 responses. This indicates that young people highly appreciate the convenience offered by Instagram in terms of facilitating easy and efficient shopping experiences. The focus on the visual aspects of products also received a high rating (10 responses), highlighting the importance of visual presentation on this platform. Users appreciate the easy availability and purchase process, home delivery, and the detailed product images that are crucial for visual assessments. Implications: The positive aspects suggest that businesses can leverage Instagram to reach a broader audience quickly and efficiently, potentially increasing sales and customer satisfaction. The emphasis on visual content and influencer partnerships can be strategically used to build trust and enhance product visibility.

Table 3. *Perceptions of Promoting Products on Instagram versus Traditional In-Store Selling*

Positive	No.	%
Availability and easy purchase, efficiency, home delivery	16	12.60%
Focus on product images where appearance is important	10	7.87%
Possibility of faster sales	9	7.09%
Greater assortment of products, cheaper than in-store	5	3.94%
Accessibility of products due to constant promotion on Instagram	4	3.15%
Accessibility of products due to constant promotion on Instagram	4	3.15%
Faster and more thorough marketing, possibility of faster information	4	3.15%
Influencers bring these products closer to us	4	3.15%
Easier to pay	1	0.79%
No disadvantages	1	0.79%
Negative	**No.**	**%**
Fraud	19	14.96%
Products cannot be tried or seen, tangibility issues	11	8.66%
Too many ads	7	5.51%
Quality issues	6	4.72%
Prices unknown in advance	2	1.57%
Paid influencer ads to promote	2	1.57%
Necessity of asking questions, longer search	2	1.57%
No advantages	2	1.57%
I shop only in stores	1	0.79%
Larger businesses with more money for marketing often overshadow smaller businesses	1	
Neutral	**No.**	**%**
No comment	11	8.66%
I don’t know	5	3.94%
Not interested	2	1.57%

Negative perceptions: The negative feedback, accounting for 41.73% of total mentions, highlights significant concerns about Instagram shopping. The primary issue is the risk of fraud, where users fear being deceived by fraudulent sellers. This highlights the need for greater security and trust in ads on this platform. Young people are aware that shopping via Instagram can be risky and often doubt the credibility of products and sellers. The inability to physically inspect or try products before purchasing is another major drawback (11 responses). Young consumers prefer the ability to physically inspect products before making a purchase decision, which Instagram does not offer. The excessive number of ads (7 responses) is another negative aspect. Many respondents feel overwhelmed by the number of ads, which can create frustration and reduce their interest in shopping via this platform. The reliance on paid influencer promotions can be perceived as biased, and the need for additional inquiries and searches for product details is time-consuming. Some users see no advantages in Instagram shopping, prefer traditional in-store shopping, or are concerned about larger businesses overshadowing smaller ones. Implications: The negative aspects indicate that businesses must address concerns about fraud, quality assurance, and transparency to build consumer trust. Reducing the ad clutter and providing clear, upfront pricing can improve user experience.

Neutral perceptions: Neutral feedback, comprising 14.17% of total mentions, reflects a range of opinions that neither strongly favor nor oppose Instagram shopping. A significant portion of respondents chose not to comment, indicating a lack of strong feelings or sufficient experience with the platform. Implications: The neutral feedback suggests that there is still a segment of the audience that is undecided or indifferent towards Instagram shopping. This presents an opportunity for businesses to target these users with informative and engaging content that could sway their opinion.

6. CONCLUSION

Corporate communication encompasses various strategies that organizations use to interact with stakeholders, build relationships, manage reputation, and achieve their goals. In the digital age, platforms like Instagram have become vital tools for these strategies, offering a visual and interactive medium for brand promotion and customer engagement. Despite its popularity, recent trends show a decline in Instagram's active user base, prompting a need for further research into its effectiveness in influencing consumer behavior and purchasing decisions.

The goal of this study was to explore the role of Instagram as a promotional tool and its influence on young consumers' purchasing decisions. Our findings challenge the claim that 87% of Instagram users report that influencers have influenced their purchasing decisions [4]. Our research shows that although 90.8% of respondents use Instagram daily and 70.8% follow some influencers, there is significant skepticism and distrust towards influencers' promotional activities. Instagram users may perceive these promotions as financially motivated rather than based on genuine belief in the product. While influencers' credibility is somewhat relied upon, traditional advertising methods still evoke wariness.

Our findings also indicate that Instagram's impact on driving actual purchasing decisions is minimal. Despite high engagement levels, this does not necessarily translate into purchase actions. The correlation between time spent on Instagram and purchasing behavior is low, implying that even heavy users are not significantly more likely to purchase promoted products. This suggests a disconnect between engagement and conversion. Ads on Instagram, though visible, do not frequently inspire direct interaction or engagement. Moreover, while Instagram advertisements are generally perceived as appealing, they do not consistently outperform ads on other social media platforms.

Our hypotheses yielded mixed results. The first hypothesis, that young people find Instagram a persuasive platform for product promotions, was confirmed. The second hypothesis, that the visual and interactive elements of Instagram increase the perceived credibility and attractiveness of advertised products, was also confirmed. However, the third hypothesis, that influencers on Instagram significantly impact the purchasing decisions of young people, was not confirmed. The fourth hypothesis, that traditional methods of promotion are perceived as more trustworthy than Instagram advertisements endorsed by influencers, was confirmed. A limitation of this study is that the sample is composed entirely of respondents from Serbia, which might affect the results, allowing us to discuss this context specifically.

In conclusion, our findings suggest that young people consistently track ads and promotions, follow influencers' posts and stories, and remain aware of products and services that businesses promote as part of their corporate communication, possibly due to a "fear of missing out" (FOMO). However, they are generally inactive "lurkers", reserved when it comes to making purchases and trusting brands promoted by influencers. This indicates that while Instagram is effective for brand awareness and engagement, its ability to drive purchasing decisions, at least in our context, remains limited.

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Digital Dialogue in Practice: Statistical Analysis of Teacher and Student Activities by Time and Number of Interactions

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Abstract: *This paper presents the results of research, which deals with the specifics of teaching using the digital dialogue method, in relation to traditional teaching. The research was conducted by three teachers, who recorded and wrote down their observations during the lessons. To quantify and categorize the obtained data, a modified Flanders' interaction analysis was applied. In a period of 14 days, in 3 classes, 9 classes held with traditional teaching and 9 classes with the application of digital dialogue were recorded. The goal of the research was to obtain more precise information about how digital dialogue improves the quality of teaching, as well as to propose measures for its improvement based on this information. By analyzing the recordings, the most significant activities of the participants and teachers during the lesson were highlighted. Based on the obtained results, a T-test was used to compare the degree of interaction for these two applied teaching methods. The research required the calculation of several significance parameters, so a special Java application was created for that purpose. The results of the analysis indicate significant differences in the distribution of time and the level of activity of students and teachers, depending on the teaching method.*

Keywords: *digital dialogue; mobile learning; interaction in teaching; classroom dialogue*

1. INTRODUCTION

Interaction in the classroom is verbal communication, which includes the teacher and students, as educational subjects, whose roles change during the learning process. Classroom interaction plays an important role in the learning process. Through interaction, the teacher can exchange ideas or information, share feelings or experiences, but also socialize [1]. One of the goals, which is expected to be achieved through the application of IT (Information Technologies), is to increase the level of communication among the participants of the teaching process.

From a sociocultural perspective, education and cognitive development are cultural processes; knowledge is not only possessed individually, but is created and shared among members of communities; and the ways of creating knowledge are shaped by cultural and historical factors. Support for this perspective comes from recent research suggesting that human intelligence is essentially social and communicative. An important implication of the sociocultural perspective is that it encourages the search for the causes of educational success and failure in the nature and quality of the social and communicative processes of education, and not only in the intrinsic abilities of individual students, didactic presentation, the skills of individual teachers or the quality of the resources used. This means that the quality of spoken interaction between students and teachers, as well as between students, can be of key educational importance [2]. Interaction in the classroom through dialogue is the subject of much contemporary research.

Dialogue today means having a written or oral conversation between two or more people. From that aspect, we can view the classroom as a place of various forms of dialogic interaction [3]. At the same time, dialogue can be said to be related to metacognition, as a process that leads to conceptual changes in learning and helps to retain what has been learned for a longer period of time [4]. We define it as a method, a way, a path, a procedure that helps correct reasoning and cognition [5].

On the other hand, digital classrooms are defined by the use of electronic devices or platforms such as social media, multimedia and mobile phones to teach students [6]. Digital learning is a learning strategy that uses technology to complement the entire curriculum and enables students to learn more easily and quickly (Fig. 1). Instead of recording what the teacher taught, most of the curriculum is delivered to students through an engaging and interactive platform. Despite its many facets, education is fundamentally a form of communication. The Internet has resulted in the growth of new communication channels, which have expanded the possibilities for transmission and access to educational information. These media and virtual places serve as learning facilitators [6].

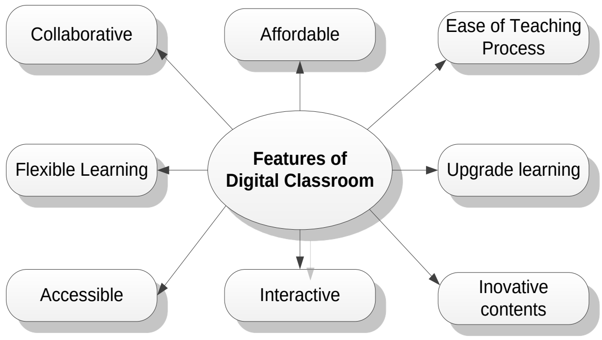

Figure 1. *Features of Digital Classroom [6]*

Most functions related to teaching are realized through verbal communication. Of course, non-verbal communication exists and is not unimportant. But non-verbal communication occurs less often than verbal communication and they are usually highly correlated. The first step towards systematic classroom management is made when the teacher understands how to control his verbal communication, so that he can use his influence as a social force. Unfortunately, this kind of knowledge and the corresponding skill do not always go together [7]. Verbal communication in the classroom does not always mean dialogue in class with an increase in the degree of interaction.

Dialogue in teaching is an educational approach that emphasizes two-way communication between teacher and student as a key element of the learning process. This approach is based on an interactive exchange of ideas, opinions, questions and answers, which help in better understanding and critical thinking. The goal of dialogue in teaching is to create a dynamic and engaging educational environment where students actively participate in their own learning [8].

"Dialogic teaching" and "dialogic pedagogy" mean an approach to teaching based on the active, extended involvement of students as well as teachers in spoken interaction in the classroom, so that teaching and learning become a collective endeavor, in which knowledge and understanding are shared construct (instead of teachers using speech only to convey the content of the curriculum and assess its acquisition by students) [9]. The use of digital technology to support dialogic pedagogy requires more research; research in this area is in its infancy, despite some encouraging results. Many schools are now introducing tablets and other similar mobile devices to support teaching and learning [9].

With the development of a new concept of direct teaching - the application of digital dialogue in the classroom, teachers are given the opportunity to achieve a significantly higher degree of involvement of educational subjects. Digital dialogue, as a modern and perspective concept, has become accessible primarily thanks to the introduction of digital devices and technological innovations in the education system [9]. It enables a system for creating a higher degree of interaction between teaching subjects - through wi-fi (wireless-fidelity) technology, mobile software applications and teaching methods that include learning and testing via the Internet (Web Based Training, Internet Based Test - IBT). At the same time, it enables the entire flow of the teaching process, during one course, to be transferred into electronic form, enriched with interactive multimedia and documented in appropriate databases [10]. Such systems are used in order to increase the interaction of students and lessons in class, obtain critical opinions of each student individually and create an environment for cooperative and active learning [11].

The concept of digital dialogue completes the system of hybrid learning by enabling to overcome the shortcomings of electronic learning and direct traditional teaching. Realization of digital dialogue in the classroom, as an asymmetric communication process, integrated into a hybrid learning system, is not only the application of new didactic tools, but it implies numerous changes in the educational process, such as new teaching methods, different teacher preparation, technical equipment of classrooms and offices, new competences of teachers, etc. [10].

Several studies have confirmed that digital dialogue significantly improves the quality of teaching as measured by knowledge tests [12]. However, there is little research that clearly identifies those key features of digital dialogue that contribute to teaching effectiveness. This research tries to find the key specificities of digital dialogue, which make it more effective than traditional teaching, by applying a modified Flanders' lesson analysis [7].

2. METHODOLOGY

The research is based on the methodology and results of the experiment described in [13], with additional modifications and extensions. Previous research [13] obtained more data that were not processed in the analysis and were not presented. In this paper, the research includes additional data and uses a different statistical analysis. The recording and measurement was carried out in the 2022/23 school year, in the secondary state school, ETŠ "Nikola Tesla" in Niš. The research was conducted by 3 teachers who taught the same classes, but different subjects. The focus was on research - how the 45-minute class time is spent on different activities, in different teaching scenarios.

The activity marked as Pt - the time in which the teacher speaks, includes parts of the lesson in which the teacher presents the material, asks questions, gives assignments and draws conclusions. It is expected that during that period of the lesson, students carefully follow the presentation, if necessary, note down key terms, but do not participate in a dialogue with the teacher.

At the moment when one of the students makes a remark or a question or when he answers the teacher's question, the previous activity is interrupted and the new activity is marked as Ut - the time in which the students speak. The time in which students answer the teacher's questions, through digital dialogue, is also recorded as Ut.

Quiet time - an activity marked Tt, is recorded in the parts of the lesson when the teacher writes the lesson, the students talk quietly to each other.

In a previous study [13], the experiment included the following steps:

- sample selection: three 3rd grade classes of the educational profiles Computer Electrical Technician and Information Technology Electrical Technician. Classes have approximately the same number of students (from 25 to 30).
- application of the methodology of recording the teaching process in the classroom,
- recording and quantifying the activities of students and teachers,
- analysis of video material.

In this paper, a modified Flanders' methodology and coding system (Flanders' Interaction Analysis System - FIAS) was applied, which are used for the study and analysis of verbal interaction in the classroom, according to [7]. Also, FIAS is often used to evaluate teaching effectiveness, identify educational styles and improve teaching methods.

In the classes that were implemented using the digital dialogue method, the teacher who led the class, according to the regular curriculum, asked a short question every 3 to 6 minutes, related to the teaching material just presented. At that moment, through a specially created web application, the question is forwarded to the students. At the beginning of class, all students started a dedicated application for digital dialogue [14], and logged into their account. They answer the teacher's question through their mobile devices. The teacher himself decides when to interrupt the time for students to answer, depending on the difficulty of the question and the number of answers received. After that, the teacher's presentation continues until the next question.

The teacher who observed and recorded the activities in the classes performed the following procedures:

- Observation: observes and records verbal interactions in the classroom at 60-second intervals; every 60 seconds, one of the current activities in the classroom is entered: Pt - time in which the teacher speaks, Ut - time in which students speak and Tt - time of silence.
- Record the number of questions the teacher asks and the number of answers he receives. Correct and especially incorrect answers are recorded separately.
- Coding: each verbal act is classified according to one of these categories.
- Analysis: data is analyzed to determine the pattern of interaction between teachers and students.
- Quantifying and comparing results from a database of digital dialogue and class videos.

If the term - analysis itself is defined as the process of breaking down a concept into simpler parts, in order to show its logical structure, in this study it refers to the process of breaking down the concept of interaction in the classroom, especially the part where teacher speaks.

A statistical analysis of the time distribution of student and teacher activities was applied to the obtained data. In all 9 classes held, for each of the teaching methods, the total time during which students spoke and the time during which the teacher spoke was calculated. In addition, the average frequency of teacher and student activities during one 45-minute lesson was also determined.

In the sample, two small independent groups were formed (classes conducted using the traditional method, labeled T-group and classes using the digital dialogue method, labeled D-group), approximately equal, with a normal distribution.

Teaching in the T-group is done in a traditional way. This implies the use of a blackboard and chalk, possibly a projector or a smart board, as teaching aids.

In the D-group, teaching was carried out using a special application for digital dialogue in teaching. This application consists of several modules, and in this experiment two modules were used: a module for the lecturer and a module for students [14].

The teacher started the application module for lecturers on his mobile phone and selected the appropriate, already prepared lesson.

The students also launched the appropriate student app module on their mobile devices and waited for the teacher-provided question to appear on the screen.

Modules for teachers and students are client applications that in digital dialogue software represent an interface through which data is passed to other components. The entire teaching process during one lesson is recorded in the database.

For each of the measured values, the initial hypothesis is: there is no significant difference between the mean values of the T and D groups. The alternative hypothesis claims that there is a significant difference between the means of these two groups. A conventional significance level of 0.05 was introduced (there is a 5% probability of error).

Based on the characteristics of the sample, the T-test was chosen to determine statistical significance. Due to the specifics of data processing, a special Java application was created for calculating significance parameters - *p*.

In the development of the application, the Java class library was used:

org.apache.commons.math3.stat.inference.T-Test;

from the hypothesis testing class collection:

Package org.apache.commons.math3.stat.inference.

By comparing the average values of these two experimental groups, the results were obtained in response to the question of whether the differences between the traditional teaching method and the digital dialogue method are statistically significant.

3. RESULTS

Table 1. shows the overall results of measuring activities in the classes held. It includes the number of questions asked, the number of answers received, as well as the time during which the teacher, students speak or the time of silence. The time is expressed with an accuracy of up to one minute. Marks "T-group" and "D-group" describe the number of classes with traditional teaching, that is, classes held using digital dialogue, respectively.

Table 1. *The results of measuring participation in speaking time and the number of questions and answers*

MEASURED VALUES	T-group total	D-group total
Number of questions asked by the teacher	49	54
The number of responses received was	47	237
Number of correct answers	45	166
Time in which the teacher speaks	287	237
Time in which students speak or send responses through digital dialogue.	88	111
Time of silence	30	57

A p value was calculated for each of the measured values from the table (Table 2).

Table 2. *T-test results for each of the analyzed activities*

CLASS ACTIVITY	***P* - VALUE**
number of questions asked	p= 0.179
	there is no significant difference
number of responses received	p= 1.124E-15
	there is a significant difference
the time when the teacher speaks	p= 0.001
	there is a significant difference
the time when the students speak	p= 0.012
	there is a significant difference
quiet time	p= 0.023
	there is a significant difference

4. DISCUSSION

Based on the data provided, different aspects of teaching between the two methods can be compared to answer the question of how different they are in practice. For each of the 5 measured values, a null hypothesis (H0) was set, which reads: there is no statistically significant difference between the mean values of these two groups. This hypothesis is rejected if $p < 0.05$. In this case, it means that there is a statistically significant difference between the digital and traditional methods.

Number of questions asked by the teacher: in both methods, the teacher asks a similar number of questions, with slightly more questions in D-group total (54) than in T-group total (49). Since the p-value (0.179) is greater than 0.05, we do not reject the null hypothesis. This means that there is no statistically significant difference between the digital and traditional methods regarding the number of questions asked.

Number of responses received: there is a significant difference in the number of responses received, with D-group total (237) showing a much higher number of responses than T-group total (47). This suggests that digital dialogue may be encouraging more student responses. Since the p-value (1.124e-15) is significantly less than 0.05, we reject the null hypothesis. This means that there is a statistically significant difference between the digital and traditional methods regarding the responses.

Number of correct answers: similar to the number of answers, D-group total (166) shows a significantly higher number of correct answers compared to T-group total (45). This may indicate that the digital method not only encourages more responses, but also increases response accuracy.

The p-value (1.124e-15) is significantly less than 0.05, so we reject the null hypothesis. This means that there is a statistically significant difference between the digital and traditional methods regarding the number of responses received.

Time in which the teacher speaks: in T-group in total, the teacher speaks longer (287 minutes) than in D-group in total (237 minutes). This may mean that in the traditional method the teacher is more of a central figure. Since the p-value (0.001) is less than 0.05, we reject the null hypothesis. This means that there is a statistically significant difference between the digital and traditional methods in the time the teacher speaks.

Time students' speak: students speak more in D-group overall (111 minutes) than in T-group overall (88 minutes). This may indicate that digital dialogue gives students more space to express themselves. Since the p-value (0.012) is less than 0.05, we reject the null hypothesis. This means that there is a statistically significant difference between the digital and traditional methods according to the time students speak.

Quiet Time: Quiet time is longer in D-group total (57 minutes) than in T-group total (30 minutes). Since the p-value (0.023) is less than 0.05, we reject the null hypothesis. This means that there is a statistically significant difference between the digital and traditional methods regarding the duration of silence time.

5. CONCLUSION

Based on the data presented, it can be concluded that the digital dialogue method encourages more student engagement and interaction, with more questions asked and many more answers received.

Based on the T-test, the only result in which there is no statistically significant difference is the comparison according to the number of questions asked. The results for the other 4 parameters show that there is statistical significance, which implies that the null hypothesis (H0) is rejected and the statement that there is a statistically significant difference between the digital dialogue and the traditional method in the number and intensity of interactions during teaching is accepted.

The teacher in the digital method speaks significantly less, allowing students more time to express themselves. This is confirmed by the fact that the average time students speak is 20% longer in digital dialogue classes.

Silence time in digital dialogue is also longer, which may indicate different class dynamics in a digital environment, where there may be more time for reflection or technical breaks in digital teaching. On the other hand, it can also indicate more breaks or less interaction between teacher and student.

The most significant difference is expressed in the data about the number of answers received by students and the number of correct answers received. This result is probably one of the answers to the effectiveness of digital dialogue on knowledge tests.

When it comes to the number of correct answers, the comparison was not made in percentages, in relation to the total number of answers received. This was done on purpose, because the practice in traditional teaching is for the teacher to ask for an answer from the student who has already raised his hand. In that case, the ratio of correct and obtained answers is usually 100%, so the comparison of these two teaching methods has no significance.

The presented information tells us that the digital and traditional methods are different in most observed aspects, except when it comes to the number of questions asked during classes. The research results can be useful for further analysis and improvement of teaching methods, in order to maximize the positive effects of both methods.

The application of the modified Flanders analysis provided more information, such as, for example, the frequency of teacher and student activity in the class, i.e. in which parts of the class the teacher spoke more and in which the students spoke more. However, although all the obtained data could not fit into this paper, they can be an interesting topic for some further research.

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The Pixel Art as Computer Graphics Artistic Expression in Digital Games

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Abstract: *The limitations of early gaming graphics hardware emerged Pixel Art as a technology necessity. Nowadays, it has undergone a remarkable evolution in contemporary digital graphics and gaming design. The paper explores the innovative ways modern pixel art is utilized to express artistic vision, evoke emotional resonance, and challenge conventional notions of graphical fidelity. Pixel art is a powerful tool for artistic expression, enabling developers to create visually stunning and thematically rich experiences that resonate with players on a profound level. By harnessing the aesthetic charm and its expressive potential, game creators are pushing the boundaries of contemporary computer graphics and redefining digital games' visual language. The key aspect of contemporary pixel art is its fusion of traditional techniques with modern design sensibilities. Artists employ advanced rendering methods, intricate animation techniques, and sophisticated color palettes to imbue pixel art with a level of detail and sophistication previously unseen in the digital medium. This blending of old and new results in visually captivating digital artwork and games that pay homage to the past while embracing the possibilities of the present, thus pushing the boundaries of what is possible in the medium and shaping the future of computer graphics and digital game design.*

Keywords: *pixel art; computer graphics; artistic expression; digital games*

1. INTRODUCTION

Pixel Art is a type of digital art in which representations are created and edited at the level of small digital image elements, commonly known as pixels. It became popular around the 1970s when computers and digital art began to gain wider social relevance. The Pixel Art is defined by its unique visual style, whereas each pixel function is a complete image's founding element. It is stipulated that this type of art is a visual style very similar to mosaic art, beading, cross stitch, and other types of embroidery techniques [1]. The first definition of the term Pixel Art was introduced in 1982 as a reference to an image designed to be reproduced using pixels. Each of the pixels is represented by its own chromatic and lighting values, and they are organized in an orthogonal matrix in the manner of mosaic tiles that generate the gross image through their juxtaposition [2]. Pixel Art is also observed as a representation in which the image, regardless of its form – digital or physical – is generated from an orthogonal matrix analog to low-resolution digital matrices [3]. The term Pixel Art was first published by Adele Goldberg and Robert Flegal of the Xerox Palo Alto Research Center in 1982 [4]. Etymologically, the term originated from the word *pixel* which is unified with the word *art* to give it a certain artistic intention, meaning the creation of an artistic piece using the data from information. Pixel Art owes its origin mainly to digital games. First video games were designed to be played on cathode ray tube (e.g., CRT) screens. It is important to refer since image representation on these monitors was made up of pixels per unit of length and height, i.e., they had resolution. The Pixel Art approach gained strength throughout the years, mainly in video and arcade games. To this day, digital games, programs, software tools, and objects, still use pixel approach in their construction or design. Pixel Art is an epistemology that still lacks knowledge of the full artistic potential that can be generated. As is the case with digital games, which provide us with support when it comes to the variation of elements, shapes, and colors to be able to link them to any field or context related to digital design.

2. THE PIXEL ART AND DIGITAL GAMES

2.1. Art and new technologies

In the world of contemporary communication, digital media became cultural objects developed through technologies that emerged in the digital revolution, computers, and networks. The term "new media art" arose from artists, gallery owners, and critics to refer to works based on digital technology, such as multimedia installations, interactive virtual reality environments, and online art [5]. The so-called new media art is also called "net art", "digital art" or "interactive art", and resorts to using digital technologies for artistic purposes. In addition to being a means of transmitting information, this art could also be a form of artistic expression such as painting, photography, or video. The conceptual and aesthetic roots of digital art can be found in the Dadaist movement, pop art, conceptual art, and video art, from which it used strategies and modes of expression, experimentation with new techniques, and finally reaching its recognition as an artistic movement in the 1990s [6]. On the other hand, advances in software and hardware in the 1990s made it easier for artists to become comfortable with new digital technologies as means of artistic expression. With the expansion of the Internet, net art was also consolidated as a new form of artistic expression. At the same time, new genres appeared such as software art, game art, and multimedia installations and performances.

2.2. Art and digital games

Digital game art, like other modalities of new media art, used digital technology for artistic purposes and appeared with the popularization of personal computers during the 1980s and 1990s. Even though video games had previously emerged without clear artistic intention (e.g., Pong, Tetris, etc.), the 1993 video game Doom created by Id Software can be considered a pioneer of game pixel art [7]. The studio launched a reduced and free version of the game online that revolutionized the game monetization model. As a result, millions of copies of software were distributed that allowed players to create new content, thus creating large player communities. This form of in-game creation possibility also attracted the attention of the artistic community which was given the tools to appropriate and modify elements of the audiovisual apparatus of the video game to use them in their artistic discourse [8]. A characteristic of new media art (and game art in particular) inherited from the 20th-century avant-garde ensured that the public became active participants, although in most cases it did not affect the final result. The players appreciated game art in different ways depending on their decisions, since the interactive game inevitably required their participation. The essential part of digital game identity is how it looks on screen and how the combination of its mechanics, visuals, and sound creates the game's aesthetic [9]. This combination evokes an emotional response in the player and defines the mood of the game. Mood is as important a part of design as any other element, just as important as gameplay or story. In recent years, digital games have gone from being just another example of new technologies to becoming key elements in digital media. Digital games now represent one of the essential vital art forms suited to the digital era we live in. They facilitate access to new aesthetic experiences and convert the computer screen into a widely accessible realm of experimentation and innovation. Computer games are interactive medium that imply the active participation of the viewer, converted into a user, who establishes a dialogic relationship with the machine. This interaction is not produced only on a theoretical or mental level, but also takes place on a physical plane, generating visible changes in the composition of the artwork.

2.3. Gaming aesthetics

The experiences and transformations that have taken place in the field of digital game art involve radical changes in the processes of creation, perception, and aesthetics. Interactive art is the starting point for the approach of a new aesthetic discourse that represents a reaction against the theory centered on the art object, a broad interconnection between disciplines, and a redefinition of the roles of the author and the observer [10]. Most researchers observe that game aesthetics is an ambiguous term. However, we can define game aesthetics as a sensory phenomenon that a player encounters when playing the game – we talk of a visual, auditory, and tactile experience. In this way, many game designers have sought inspiration from art books, giving rise to aesthetics influenced by expressionism and romanticism. Some authors define game aesthetics as an "experience" based on the pleasure or emotion that the player feels, explicitly excluding the audiovisual section. Anyway, technological improvements should not be confused with aesthetic advances. Some researchers even argue that digital games suffer a kind of envy of cinema tending towards clumsy realism with 3D graphics and that they should find their form of expression, capitalizing on unique properties such as dynamic systems and participatory player enrollment [11]. Finally, it seems that the consensus between various definitions may be the clue. Game aesthetics should not be referred to solely as the graphics and sound of the game, but as the empirical result that the player experienced by interacting with the design, that is, the player experience [12].

A classification of game aesthetics can be proposed:

- Sensory aesthetics – brings pleasure or sensation to the senses via audiovisual resources and other interfaces;
- Empirical or experiential aesthetics – refers to the emotional experience within the game and can be evoked by emotional factors such as drama or love, or physical factors such as fatigue, discomfort, or pain;
- Exploration aesthetics – discoveries that are made within the game are related to the

curiosity and pleasure of progressing and completing tasks;

- Immersive aesthetics – provides pleasure when entering the context that poses the game. As with works of fiction, the player has to give up a part of his beliefs to fully immerse in the narrative;
- Competitive aesthetics – refers to the challenge of overcoming obstacles, either intellectual or psychomotoric. It is related to power and success.

2.4. The Pixel Art

A digital image is an image designed to be reproduced using pixels or image elements and/or objects, each of which is represented by a chromatic value and organized in a matrix. This digital representation system was born from the need to adapt an image to the technological limitations of the first computers with very low image resolution. Specifically, the first application of pixel art was the design of icons for the visual interfaces of Xerox and Apple operating systems. Nowadays, once these technical limitations have been overcome, pixel art is the way of representing an image on any type of digital media, establishing a creative self-limitation that serves to relate the artistic discourse with the digital environment, its visual language and its forms of specific communication. On the other hand, the appearance of mobile devices brought digital games to an even broader audience, which is often satisfied with simpler graphic images typical of pixel art aesthetics. This approach allowed the possibility of competing small independent teams of programmers and artists, as opposed to traditionally large companies that dominated the digital gaming industry [13]. Therefore, we can affirm that in contrast to digital games with astonishing and realistic graphics many gaming studios nowadays also compete with pixel art as an alternative and artistic decision in the development of a creative project, especially as it can also be monetized in the form of non-fungible tokens (NFTs). Some game creators are adamant about not leaving pixel art aside, a clear example is Minecraft. This famous game still survives with this format, and in fact, there is a game mode that is precisely called pixel art.

There are two main Pixel Art styles:

A. Isometric – consists of creating angles in each pixel with the purpose of making a 3D projection within a 2D plane. It is one of the most used types, especially because it is not necessary to resize the objects or calculate their perspective distortion. To compose this type of pixel art, the artist must focus on the use of colors, since they give the perspective to the drawing. For example, the brightness of colors is used to represent the distance of objects. The further away it is, the less bright the object is. This technique was used in old-school video games such as Final Fantasy (Fig. 1), Metal Slug, Tarzan, etc.

Figure 1. *Final Fantasy game Pixel Art*

B. Non-isometric – type of pixel art only projects a flat image within a space, that is, instead of 3D drawings, with non-isometric pixel art only the dimensions of height and width matter. It can be observed as a style that allows the creation of pixel art in a simpler way, although its uses are more limited. The first installment of Mario Bros is a clear example of what non-isometric pixel art looks like.

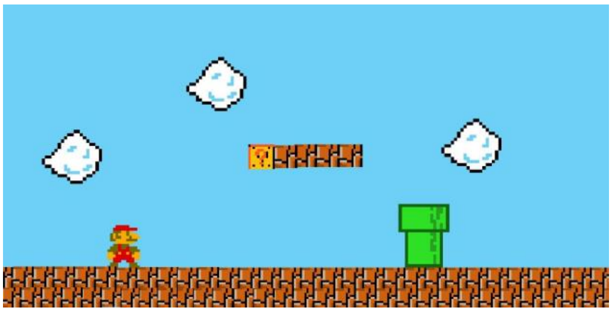

Figure *2.* *Mario Bros game Pixel Art*

The creation of pixel art is usually started based on the object morphological analysis, extraction of its form, and the conceptual approach. Through a process of abstraction and subtraction of forms, a variety of 2D patterns are created where breaking patterns and constant patterns are identified. This is how the formal decomposition of the pixel art object is achieved without losing its appearance. Once the idea process is conceived, the selection of proposals is analyzed in terms of the expressive and representative quality of the designed objects in addition to their formal and technological conditions. These are the mechanisms used for the selection and formal concretion. The functional match is determined based on the morphological, typological, and chromatic qualities and particularities of each element of the object. This is how the process appropriates ergonomic and anthropometric spectrums, so that, in turn, the proposed object line respects and executes the maximum requirements in terms of adaptability and adequacy to the original morphology.

2.5. Indie Developers

Opposite to the large video game companies, there are independent or indie video game studios, which still hold only a small part of the gaming industry's economics. Indie video games are developed by small groups or small companies that do not have adequate financial support and are focused more on creative than economic objectives. Their great advantage is that they have no creative limitations and do not require the approval of layers of managers as the large company does. On the other hand, individual participation in a small group encourages innovation, creativity, and artistic experimentation in development and user experience design [14]. The growing interest in indie video game production correlated with the popularization of the Internet and the possibility that games could be distributed online via commercial platforms such as Xbox or Steam, which allowed developers access to the global market. However, most indie digital games are not well-known due to the highly saturated market, especially in mobile games. The reason for publishing this type of product usually lies in the motivation to make teams known in the wider community or simply in individual programmers' passion. In general, it can be stated that indie video games are distinguished by their innovation in design and narrative, the result of creative freedom.

3. CONCLUSION

Pixel Art has carved a unique niche in the landscape of computer graphics and digital games, showcasing a blend of technical constraints and artistic expression that transcends its ostensibly simplistic form. This paper explored the intricate ways pixel art has been employed as a medium for artistic expression within digital games, highlighting its historical significance, aesthetic qualities, and evolving role in contemporary game design. The analysis indicates that pixel art's charm lies in its ability to evoke nostalgia while simultaneously offering a canvas for modern creativity. Despite the advancements in graphical fidelity and realism, the deliberate choice of pixel art by developers underscores a preference for stylistic distinctiveness and emotional resonance. The minimalist approach inherent in pixel art demands a high level of creativity and precision, pushing artists to innovate within a restricted pixel grid and limited color palette. Furthermore, pixel art fosters a unique connection between the gamers and the game world. The abstraction inherent in pixelated graphics allows for a more personalized and imaginative engagement, where players fill in the gaps with their interpretations and memories. This phenomenon contributes to a deeper, more intimate interaction with the game, enhancing the overall experience. The resurgence of pixel art in indie game development reflects a broader cultural and economic shift within the gaming industry. Indie developers, unbound by the commercial pressures that dictate hyper-realistic graphics, often embrace pixel art to convey originality and artistic integrity. This resurgence is not merely a nostalgic revival but a testament to pixel art's enduring relevance and adaptability in expressing complex narratives and emotions.

In conclusion, pixel art stands as a testament to the enduring power of artistic expression in digital games. Its unique blend of simplicity and sophistication continues to captivate audiences and inspire game developers. As the gaming industry evolves, pixel art remains a vital and dynamic form of digital artistic expression, proving that creativity thrives within constraints, and sometimes, less truly is more.

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Using Artificial Intelligence Concepts to Design Non-Playable Characters in Road Traffic Safety Games

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Abstract: *The integration of artificial intelligence concepts into digital games design has revolutionized the gaming industry. Among other elements, artificial intelligence significantly influenced modern gameplay mechanics, elevated player experiences, and streamlined game development processes. Road traffic safety driving simulation games are an emerging educational tool aimed at improving road safety awareness and skills among drivers. A critical component of these games is the AI-driven Non-Playable Characters (e.g., NPCs) that expand dynamic and immersive gameplay experience by exhibiting various realistic road users' behavior patterns, traffic conditions and player actions adaptation. The adaptive AI algorithms ensure balanced difficulty, catering to gamers' diverse driving skill levels, while procedural content generation opened endless possibilities in designing game levels, environments, and tasks, enhancing game replayability and longevity. AI-powered virtual assistants can provide players with seamless in-game guidance, enhancing their engagement without disrupting the gameplay flow. Additionally, adaptable intelligent road traffic conditions can challenge players to strategize and adapt, contributing to more compelling and immersive gaming experiences. Contemporary software tools and engines streamlined game development processes and accelerated asset creation, bug detection, and playtesting. Automated game design processes, such as AI-driven level and procedural generation, expedited prototyping and iteration phases, while AI-driven analytics tools offered valuable insights into player behavior and preferences, enabling developers to optimize game mechanics and its content for maximum impact. The impact of artificial influence concepts on digital game design is poised to grow even further, promising exciting innovations and possibilities for future game designers and enthusiasts alike.*

Keywords: *digital games; traffic safety; artificial intelligence; NPCs*

1. INTRODUCTION

The digital gaming industry has experienced exponential growth and evolution, driven by technological advancements and creative innovations. Among the pivotal technologies influencing this sector, artificial intelligence (AI) currently stands out as a transformative force [1]. AI has not only revolutionized the way digital games are designed and developed but also how they are experienced by players. The global increase in road traffic accidents has underscored the need for effective formal, informal and non-formal educational tools to promote road safety as traditional methods of driver education often lack the practical and engaging elements necessary to prepare drivers for real-world scenarios. Road traffic safety games offer a dynamic and interactive platform for learning safe driving practices and understanding traffic regulations. This paper explores the impact of AI concepts on designing NPCs in road traffic safety games, as they play a pivotal role in creating realistic traffic environments that challenge players to apply their knowledge and skills. The behavior of NPCs must mimic real-world entities such as other drivers, pedestrians, and cyclists to provide authentic experiences. The integration of AI in the NPCs design enhances their realism by enabling the exhibition of complex behaviors and dynamical interaction with the player and the game environment. Historically, digital games have progressed from simple, rule-based systems to complex, interactive environments [2]. The early days of game design were marked by limited computational power and rudimentary AI, which restricted the behavior of NPCs and the dynamism of game worlds. However, the integration of sophisticated AI algorithms and machine learning techniques has enabled the creation of more intelligent, adaptive, and realistic game objects and elements. These advancements have led to significant improvements in NPCs behavior, procedural content generation, adaptive gameplay, and immersive game environments [3].

One of the most noticeable impacts of AI in game design is the evolution of NPCs. Modern AI-driven NPCs exhibit lifelike behaviors, making them more than just scripted entities. They can learn from player actions, adapt their strategies, and interact with the game environment in a believable manner. This level of sophistication contributes to a more immersive and engaging gaming experience, as players can interact with NPCs in ways that mirror real-world interactions [4]. Moreover, AI has enabled the development of adaptive gameplay, where the game adjusts its difficulty, paths and challenges based on the player's level of skills and preferences [5]. This personalization ensures that games remain challenging and enjoyable for a wide range of gamers, from novices to experts. AI-driven adaptive systems analyze player behavior in real time, providing a tailored gaming experience that maintains a balance between challenge and reward. Procedural content generation (e.g., PCG) is another area where AI has made a substantial impact. By leveraging algorithms and machine learning, developers can create vast and varied game worlds without manually designing each element. PCG not only saves development time but also enhances replayability, as players can explore new content in each playthrough [6]. Games like *Forza Horizon*® exemplify the potential of PCG in creating expansive, dynamic, photo-realistic environments, as presented in Fig. 1.

Figure 1. *Forza Horizon 5 AI PCG environment*

AI has also contributed to the creation of intelligent game environments that respond to player actions and decisions [7]. These environments use AI algorithms to simulate realistic physics, dynamic weather conditions, and interactive elements, providing a more immersive and engaging experience [8]. As a result, players can experience a game world that feels alive and responsive, enhancing the overall sense of immersion.

2. AI MODELS IN DESIGNING NPCs

NPCs are fundamental components of digital games, contributing significantly to the game's narrative, environment, and player experience [9]. Historically, NPCs were driven by a simple rule-based system that limited their behavior and interaction capabilities. However, AI integration has revolutionized NPC control, enabling more dynamic, intelligent, and responsive characters. Road traffic safety games aim to simulate real-world driving conditions and traffic scenarios to educate players about safe driving practices and traffic regulations. NPCs in these games represent various road users and entities, creating a realistic traffic environment that challenges players to navigate safely and make informed decisions. In the early stages of digital game development, NPC behavior was largely predefined and scripted. Simple finite state machines (FSMs) were commonly used, which allowed NPCs to transition between a limited number of states based on specific conditions [10]. Implementing an FSMs involves defining the states, transitions, and actions in a way that can be processed by the game's AI system. For example, an NPC driver might have states for "driving," "stopping at a red light," and "yielding to pedestrians". FSMs are straightforward to implement and can effectively simulate simple traffic behaviors. This typically requires coding the FSM logic into the game engine using scripting languages or integrated development environments (IDEs) [11]. While these systems were sufficient for basic interactions, they often resulted in predictable and repetitive behaviors, reducing the overall immersion and realism [12]. The introduction of AI into NPC control marked a significant shift from these rudimentary systems. AI techniques such as pathfinding algorithms, decision trees, and machine learning models provided NPCs with the ability to make more complex decisions, adapt to player actions, and exhibit lifelike behaviors [13]. This evolution has been instrumental in creating more engaging and immersive gaming experiences.

2.1. Pathfinding Algorithms

Pathfinding algorithms are a crucial component in the design of NPCs in digital games, enabling characters to navigate complex environments efficiently and realistically [14]. Effective pathfinding algorithms enable NPCs to navigate complex traffic scenarios, avoid collisions, and adhere to traffic rules. Key metrics in pathfinding algorithms are *optimality* (finding the shortest or most efficient path), completeness (ensuring a path is found if one exists), and complexity (computational resources required to find the path). NPC control can be operationalized by several pathfinding algorithms:

- *Dijkstra's algorithm* computes the shortest paths from a starting node to all other nodes in a graph with non-negative weights [15]. While it guarantees finding the shortest path, it can be computationally intensive for large game environments. Dijkstra's algorithm is particularly useful in scenarios where NPCs need to follow specific routes or navigate through dense traffic networks, ensuring they take the most efficient routes to their destinations [16].
- *A* algorithm* combines the benefits of Dijkstra's algorithm and a heuristic approach. It is a widely

used technique, enabling NPCs to find the shortest path between points while avoiding obstacles [17]. The heuristic component enables efficient and realistic pathfinding, allowing units to move dynamically and strategically, particularly in complex and dynamic environments. NPCs can maneuver around obstacles and other units, reaching their destinations without unnecessary delays or collisions, thereby enhancing the strategic depth of the game. In road traffic games, the A* algorithm helps NPCs navigate the game environment by considering factors such as road layout, traffic signals, and the positions of other vehicles. The use-case scenario of hybrid A* algorithm implementation for self-driving NPC pathfinding in Unity environment is presented in Fig. 2.

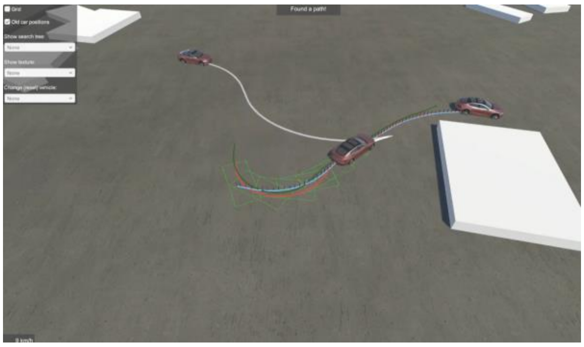

Figure 2. *Self-driving vehicle simulation using A* algorithm in Unity environment*

- *D* algorithm* is an extension of the A* algorithm designed for environments that change over time. In games with dynamic environments where obstacles can appear or disappear, D* ensures that NPCs can recalculate and adapt their paths, maintaining efficient navigation suitable for real-time applications [18].
- *Jump Point Search* (JPS) is an optimization of the A* algorithm for uniform-cost grids. It reduces the number of nodes evaluated by "jumping" over nodes that do not affect the final path, significantly improving efficiency [19]. Like A*, JPS uses a heuristic function to estimate the cost of reaching the goal from a given node. The heuristic function typically used in JPS is the Manhattan distance for grid-based environments, which calculates the distance between two points as the sum of the absolute differences in their x and y coordinates. JPS reduces the computational load of pathfinding by minimizing the number of nodes that need to be evaluated. This allows the game to support larger and more complex traffic environments without compromising performance. The reduced computational load also enables the game to handle more NPCs simultaneously, creating richer and more diverse traffic scenarios.
- *Navigation meshes* are a more advanced pathfinding technique where the areas of the environment are represented as interconnected polygons. Waypoints are predefined points in the game environment that guide NPC movement along specific paths. They are commonly used in games to define patrol routes or navigation paths for NPCs. Traffic flow models, such as the Cellular Automata Model, simulate the movement of vehicles and pedestrians by dividing the environment into a grid of cells, each representing a portion of the road [20]. NPCs move from one cell to another based on traffic rules and interactions with other NPCs, creating a realistic simulation of traffic flow. Navigation meshes can be easily scaled to handle large and complex environments, making them suitable for open-world games and large-scale simulations. For instance, the Unreal Engine development environment has a built-in navigation mesh system that provides tools for automatic mesh generation and real-time updates, simplifying the implementation of advanced navigation in games [21]. A traffic training simulator developed using Unreal Engine and NavMesh provides a realistic and interactive environment for driver training (Fig. 3). The simulation includes a complex road network with various traffic scenarios, such as congestion, road closures, and accidents. NavMesh enables the vehicles to navigate the environment smoothly and realistically, providing drivers with valuable training on safe driving practices.

Figure 3. *Unreal Engine NavMesh NPC vehicle navigation*

A hierarchical pathfinding model is used for breaking down the environment into multiple levels of abstraction where the high-level paths are calculated first, followed by detailed paths at lower levels. Large-scale massively multiplayer online (MMO) games use hierarchical pathfinding for NPC optimization by simplifying complex environments into manageable sections, ensuring efficient and scalable pathfinding [22]. The flow fields technique provides a vector field across the environment that guides NPCs toward their goals. In cases where NPCs operate in close proximity to each other, a cooperative pathfinding technique is used to avoid collisions and optimize group movement.

2.2. Decision Trees and Behavior Trees

Decision tree algorithms are a versatile and powerful tool in the NPCs design. A decision tree is a flowchart-like structure where each internal node represents a decision point based on certain conditions, each branch represents the outcome of a decision, and each leaf node represents an action or end state [23]. This hierarchical structure allows for clear and logical decision-making processes. Implementing a decision tree involves defining the conditions and actions at each node and creating the logic to traverse the tree based on the current game state. This transparency allows developers to fine-tune AI behavior for a more challenging and realistic experience. Decision trees can be easily expanded by adding more nodes and branches, making them flexible to accommodate complex behaviors and scalable to handle a wide range of scenarios. This model also allows modular design, where individual branches or sub-trees can be developed and tested independently. The modularity simplifies development and facilitates the reuse of decision logic across different NPCs.

Behavior trees have become a popular framework for controlling NPCs due to their flexibility, modularity, and ease of understanding. Originating from robotics and AI research, behavior trees provide a structured way to model complex decision-making processes, enabling NPCs to exhibit realistic and adaptive behaviors. A behavior tree is a hierarchical model that represents the execution flow of an NPC’s behavior. It consists of nodes, which can be of different types: control nodes (such as sequences and selectors) and execution nodes (tasks or actions) [24]. Control nodes manage the flow of execution. Sequence nodes execute the child nodes in order until one fails, while selector nodes execute the child nodes in order until one succeeds. Execution nodes perform specific actions or checks. They return to success, failure, or running states. For instance, the casual traffic sequence in an NPC car can be reused across different NPCs, each with its specific waypoints, by simply plugging in different action nodes. Rule-based systems use predefined rules to guide NPC behavior. These systems are particularly effective for simulating complex traffic interactions and ensuring that NPCs adhere to traffic laws. For example, rules can be defined for stopping at red lights, yielding to pedestrians, and maintaining safe following distances. Rule-based systems provide a straightforward way to implement traffic regulations in the game. Behavior trees are highly flexible and can be expanded or modified with minimal impact on the overall structure. They scale well with increasing complexity, making them suitable for games with complex NPC behaviors. An NPC’s behavior tree can be expanded to include additional sequences or selectors for new actions. Tools like Unreal Engine’s Behavior Tree editor provide a visual representation of the tree, allowing designers to intuitively adjust the flow of behaviors without deep programming knowledge (Fig. 4).

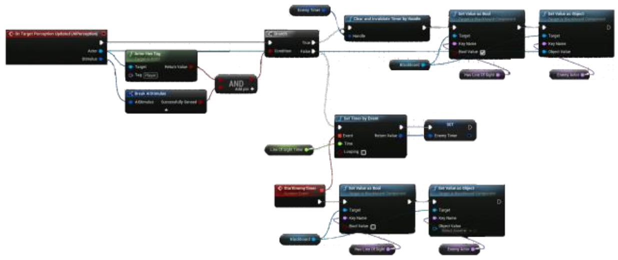

Figure 4. *The example of Unreal 4 behavior tree NPC control*

For instance, the Far Cry game series relies heavily on behavior trees to control both enemy and wildlife NPCs. These trees enable NPCs to exhibit a wide range of behaviors, from patrolling and engaging in combat to hunting and fleeing, contributing to the series' immersive open-world gameplay.

2.3. Fuzzy Logic

Traditional approaches often struggle with the inherent uncertainties and variabilities in driving environments and behaviors. Fuzzy logic, with its ability to handle imprecise information and model human-like reasoning, offers a robust solution for enhancing driving simulations. Fuzzy logic is an approach to computing that handles the concept of partial truth, with truth values ranging between completely true and completely false. In the NPC context, fuzzy logic algorithms allow for more nuanced decision-making processes, enabling NPCs to exhibit realistic and adaptive behaviors. Fuzzy logic extends classical binary logic to handle the concept of partial truth by introducing variables that can have a degree of truth represented by values between 0 and 1. Fuzzy rules are if-then statements that define the relationship between fuzzy sets and the decisions made based on those sets. The fuzzy inference system evaluates these rules to make decisions [25]. Fuzzy logic handles uncertainty and imprecision effectively, allowing NPCs to make more nuanced decisions. Integrating fuzzy logic into Unreal Engine or Unity created NPCs significantly improves the fidelity and adaptability of driving simulations in total. Fuzzy controllers are designed to manage various aspects of the driving simulation, such as vehicle dynamics and driver behavior. Variables such as speed, distance, and steering angle are defined as inputs to the fuzzy controller, while acceleration, braking force, and steering adjustments are defined as outputs. A set of fuzzy rules must also be created to define the relationship between input and output variables. The following example demonstrates a creation of simple fuzzy logic controller visual script for controlling NPC vehicle speed based on distance to an obstacle using Unreal Engine's Blueprint system:

```
- Event Tick
   - Get Distance to Obstacle
   - Call EvaluateFuzzyLogic
      - Input: Distance to Obstacle
      - Output: Throttle
   - Set Throttle on Vehicle
```

For basic control, we can use C++ to implement the fuzzy logic system. First, we create the membership functions to handle distance evaluation:

```
float MembershipFunction(float x, float a, float b, float c)
{    if (x <= a || x >= c) return 0.0f;
     if (x < b) return (x - a) / (b - a);
     return (c - x) / (c - b);}
float Close(float distance)
{return MembershipFunction(distance,0.0f,0.0f,10.0f);}
float Medium(float distance)
{return MembershipFunction(distance,5.0f,10.0f,15.0f);}
float Far(float distance)
{return MembershipFunction(distance,10.0f,20.0f,30.0f);}
```

Next, we implement the fuzzy rules based on the input membership values:

```
float EvaluateThrottle(float distance) {
    float closeMembership = Close(distance);
    float mediumMembership = Medium(distance);
    float farMembership = Far(distance);
    // Fuzzy rules
    float throttleLow = closeMembership;
    float throttleMedium = mediumMembership;
    float throttleHigh = farMembership;
    // Weighted average for defuzzification
    float totalWeight = closeMembership +
     mediumMembership + farMembership;
    float throttle = (throttleLow * 0.3f + throttleMedium *
     0.6f + throttleHigh * 1.0f) / totalWeight;
    return throttle;}
```

Finally, we use the computed throttle value to control the vehicle in Unreal Engine:

```
void UpdateVehicleControl(float DeltaTime) {
    float distance = GetDistanceToObstacle();
    float throttle = EvaluateThrottle(distance);
    // Apply throttle to vehicle
    SetThrottle(throttle);}
// Called every frame
void Tick(float DeltaTime)
    {UpdateVehicleControl(DeltaTime);}
```

We can easily extend this by adding more complex rules, integrating with other vehicle dynamics parameters, and enhancing the membership functions to suit specific simulation requirements.

2.4. Interaction with Environment and Players

For NPCs in road traffic safety games, interaction with the game environment and the player is crucial for creating a realistic and educational experience. NPCs must be able to sense their surroundings, respond to dynamic changes, and interact with the player in meaningful ways. Perception systems allow NPCs to detect and interpret information from the game environment. Techniques such as Raycasting [26] and Sensor Fusion [27] enable NPCs to sense traffic signals, other vehicles, and obstacles. These systems provide the necessary data for NPCs to make informed decisions and navigate the environment safely. Flocking algorithms, such as the Boids algorithm [28], simulate the collective movement of groups of NPCs, such as pedestrian crowds or vehicle convoys. These algorithms help NPCs maintain cohesion, avoid collisions, and navigate crowded environments realistically. Flocking behavior is essential for simulating realistic traffic scenarios where multiple NPCs must interact and move together. Predictive collision avoidance techniques enable NPCs to anticipate and avoid potential collisions. By calculating the future positions of other vehicles and pedestrians, NPCs can adjust their paths to prevent accidents. These techniques are critical for creating realistic and safe traffic scenarios in road traffic safety games. Safety Driving Simulator® is a road traffic safety game that uses AI to create realistic traffic scenarios. The game employs the A* algorithm for pathfinding, FSMs for decision-making, and rule-based systems to enforce traffic regulations. NPCs in the game adapt their behavior based on player actions, providing a dynamic and educational learning experience that emphasizes safe driving practices (Fig. 5).

Figure 5. *Safety Driving Simulator GUI*

2.5. Machine learning

Machine learning techniques introduced a higher level of adaptability and intelligence to NPC control. By training NPCs on large datasets of player interactions, machine learning models can predict player behavior, optimize NPC strategies, and continuously improve their performance over time. This results in NPCs that can learn and adapt, providing a more personalized and engaging experience [29]. In *supervised learning*, the model is trained on labeled data, meaning the input data is paired with the correct output. The goal is to learn a mapping from inputs to outputs that can be applied to new, unseen data. For NPCs in traffic safety games, supervised learning can be used to model specific driving behaviors based on historical traffic data. Common algorithms include decision trees, support vector machines, and neural networks. *Unsupervised learning* deals with finding patterns in data without labeled outputs. Techniques include clustering (e.g., k-means) and dimensionality reduction (e.g., principal component analysis). Clustering algorithms can group NPC behaviors based on similarities, allowing the creation of different behavior profiles without predefined labels. This approach is used to cluster driving behaviors and identify typical traffic scenarios that NPCs should be able to handle.

The first step in applying machine learning to NPC design is collecting and preparing relevant data. This can include player interactions, game states, and desired NPC behaviors. Once data is prepared, the next step is to train and validate machine learning models. This involves selecting appropriate algorithms and tuning their parameters to optimize performance. For example, a neural network can be trained using backpropagation to learn complex behaviors from the dataset. The network adjusts its weights based on the error between predicted and actual outcomes. After training, the machine learning models are integrated into the game's NPC control systems, enabling real-time decision-making and adaptation.

Reinforcement learning involves training agents to make sequences of decisions by rewarding desired behaviors. Agents learn to maximize cumulative rewards through trial and error [30]. Q-learning is a reinforcement learning algorithm where an NPC learns a policy to take actions that maximize its expected future rewards, adjusting its strategy based on received rewards and penalties. In the context of traffic simulations, reinforcement learning has been used to optimize traffic signal control, model driver behavior, and develop intelligent transportation systems.

The first step in applying RL to NPC design is defining the environment. This includes specifying the road layout, traffic rules, and the types of vehicles and obstacles that the NPCs will encounter. Several environment components must be defined: *state space* (current situation in the traffic simulation, including the positions and velocities of vehicles, traffic light statuses, and road conditions), *action space* (set of actions available to NPCs, such as acceleration, braking, lane changing, and turning), and *reward function* (feedback to the NPCs based on their actions, encouraging safe and efficient driving behaviors). The following Python code can be used for defining the traffic environment:

```
import numpy as np
class TrafficEnvironment:
    def __init__(self):
        self.state = None
        self.reset()
    def reset(self):
        self.state = np.array([0, 0]) # Init state:[pos, vel]
        return self.state
    def step(self, action):
        position, velocity = self.state
# Apply action: 0 = accel, 1 = brake, 2 = maintain speed
        if action == 0:
            velocity += 1
        elif action == 1:
            velocity -= 1
# Update position
        position += velocity
# Define a simple reward function to encourage
  maintaining a velocity of 10
        reward = -abs(velocity - 10)
# Update state
        self.state = np.array([position, velocity])
# Check if simulation is done
        done = position < 0 or position > 100
        return self.state, reward, done
    def render(self):
        print(f"Position: {self.state[0]}, Velocity:
        {self.state[1]}")
# Example of using the environment
env = TrafficEnvironment()
state = env.reset()
print(f"Initial state: {state}")
# Example action: accelerate
action = 0
next_state, reward, done = env.step(action)
print(f"Next state: {next_state}, Reward: {reward},
  Done: {done}")
```

The NPCs are treated as reinforcement learning agents that learn to navigate the environment. The agent's goal is to maximize the cumulative reward by making optimal driving decisions. A simple Q-learning algorithm without any external libraries will be used to keep it straightforward and understandable.:

```
class QLearningAgent:
    def __init__(self, num_states, num_actions,
     alpha=0.1, gamma=0.9, epsilon=0.1):
        self.num_states = num_states
        self.num_actions = num_actions
        self.alpha = alpha  # Learning rate
        self.gamma = gamma  # Discount factor
        self.epsilon = epsilon  # Exploration rate
        self.q_table = np.zeros((num_states,
          num_actions))  # Q-value table
    # Explore or exploit
    def choose_action(self, state):
        if np.random.rand() < self.epsilon:
            return np.random.choice(self.num_actions)
        else:
            return np.argmax(self.q_table[state])
    def update_q_table(self, state, action, reward,
        next_state):
        best_next_action =
          np.argmax(self.q_table[next_state])
        td_target = reward + self.gamma *
          self.q_table[next_state, best_next_action]
        self.q_table[state, action] += self.alpha *
          (td_target - self.q_table[state, action])
# Define states and actions
num_states = 10  # Example number of discrete states
num_actions = 3  # Accelerate, brake, maintain speed
# Create Q-learning agent
agent = QLearningAgent(num_states, num_actions)
# Training example
for episode in range(100):
    state = env.reset()
    state = int(state[1])  # Use velocity as simple state
    for step in range(50):
        action = agent.choose_action(state)
        next_state, reward, done = env.step(action)
```

```
        next_state = int(next_state[1])  # Use velocity as
                                          next state
        agent.update_q_table(state, action, reward,
          next_state)
        state = next_state
        if done:
            break
print(f"Q-table after training:\n{agent.q_table}")
```

The training process involves the agent interacting with the environment, collecting experiences, and updating its policy based on the received rewards. The following code implements reinforcement learning based NPCs:

```
class NPC:
    def __init__(self, agent, environment):
        self.agent = agent
        self.environment = environment
        self.state = self.environment.reset()
    def act(self):
        state = int(self.state[1])  # Use velocity as state
        action = self.agent.choose_action(state)
        self.state, reward, done =
          self.environment.step(action)
        return self.state, reward, done
# Instantiate NPC with trained agent
npc = NPC(agent, env)
# Simulate NPC behavior in the game
for step in range(100):
    state, reward, done = npc.act()
    env.render()
    if done:
        break
```

Reinforcement learning provides a powerful framework for designing adaptive and realistic NPCs in road traffic safety games. By leveraging various techniques, developers can create NPCs that exhibit complex and human-like driving behaviors.

2.6. Deep learning

Deep learning involves the use of artificial neural networks (ANNs) with multiple hidden layers (hence "deep") to model and learn complex relationships within data. Deep learning has revolutionized various fields, including computer vision, natural language processing, and autonomous driving, by enabling systems to learn complex patterns from large datasets. In the context of NPC design for traffic simulations, deep learning can be used to model and predict driving behaviors, making NPCs more adaptive and realistic. By leveraging neural networks with multiple layers, deep learning models can learn complex patterns and behaviors from large datasets, enabling NPCs to exhibit more sophisticated and realistic interactions [31]. Deep neural networks (DNNs) consist of multiple layers of neurons that process input data to produce an output. DNNs can model complex relationships in data, making them suitable for tasks such as behavior prediction and decision-making in NPCs. Convolutional Neural Networks (CNNs) can be employed to enable NPCs to recognize and interpret visual data from the game environment, such as identifying objects, obstacles, scene understanding, and navigation [32]. CNNs are specialized for processing grid-like data structures, such as images. In traffic simulations, CNNs can be used to analyze visual inputs, such as traffic camera feeds, to detect and respond to various traffic scenarios. CNNs can process visual data in real time, allowing NPCs to respond immediately to changes in the game environment. An NPC using a CNN can perform detailed scene analysis, identifying multiple objects and their relationships within the environment, leading to more informed decision-making.

Recurrent Neural Networks (RNNs) and *Long Short-Term Memory* (LSTM) networks are designed to handle sequential data, making them suitable for tasks requiring memory of past events [33]. In NPC control, these networks enable characters to remember and learn from previous interactions, leading to more coherent and contextually appropriate behaviors. An NPC can use an RNN to analyze sequences of player actions and predict future actions, adjusting its strategy accordingly to create more challenging gameplay.

Reinforcement Learning (RL) involves training an AI agent to make decisions by rewarding desired actions and penalizing undesired ones. It is a type of machine learning where agents learn to make decisions by taking actions in an environment to maximize cumulative rewards. RL involves an agent, environment, actions, states, and rewards. Training NPCs involves defining the states, actions, and rewards within the game environment and iteratively improving the NPC's policy through exploration and exploitation. Designing an appropriate reward function is crucial for guiding the NPC toward desired behaviors. Creating a simulation environment that mimics the actual game is essential for training NPCs without the constraints of real-time gameplay. This allows for accelerated learning and extensive experimentation.

Combining deep learning with reinforcement learning (*deep reinforcement learning*) allows NPCs to learn complex strategies by interacting with the environment and maximizing cumulative rewards. Deep reinforcement learning can be used to train NPCs to develop advanced strategies, such as planning and adapting tactics based on player actions and game state changes. When combined with deep learning, RL can be used to train NPCs to navigate complex traffic environments by learning from interactions with the environment. Deep reinforcement learning models require substantial amounts of data for training. This involves collecting relevant gameplay data and preprocessing it to ensure it is suitable for neural network training. Data might include player actions, NPC responses, environmental conditions, and game outcomes. Preprocessing steps can involve normalization, augmentation, and segmentation of this data. Training learning models involves feeding the preprocessed data into the neural network, adjusting the weights through backpropagation, and validating the model to prevent overfitting. Once trained, deep reinforcement learning models are integrated into the game's NPC control systems for real-time decision-making and behavior generation. This model excels at processing complex and high-dimensional data, enabling NPCs to understand and react to intricate game environments and scenarios. This adaptability results in more challenging and unpredictable gameplay, as NPCs can dynamically modify their strategies and tactics.

3. ETHICAL CHALLENGES IN NPC DESIGN FOR ROAD TRAFFIC SAFETY GAMES

Road traffic safety games serve as critical tools for driver training, education, and research. The specificity of NPCs used in these games are that they simulate realistic traffic behaviors, providing learners with scenarios to practice driving skills and understand traffic dynamics, which are crucial and critical elements in real-world traffic environment movement and orientation. AI techniques, particularly machine learning and deep learning, enable NPCs to exhibit complex behaviors and adapt to diverse traffic conditions, enhancing the effectiveness of these informal and non-formal educational tools. While AI-driven NPC design offers numerous benefits, it also introduces ethical challenges that must be addressed:

- *Safety* and *reliability* by ensuring that AI-driven NPCs make safe and reliable decisions in all traffic scenarios, especially in dynamic and unpredictable environments. The NPC algorithms must be extensively tested and validated in order to verify their appropriate behavior across a wide range of scenarios and realistic situations [34];
- *Fairness* by avoiding bias in NPC behaviors that may disproportionately affect certain groups or communities. Biased behaviors can be efficiently suppressed and prevented by including diverse demographic groups and traffic scenarios into training datasets. In addition, various techniques can be implemented to detect and mitigate biases in AI models during its development and deployment.
- *Transparency* of how NPCs make decisions to build trust among users and stakeholders. Explainable AI (XAI) [35] should be utilized to provide users with insights into the decision-making process of NPCs in combination with user interface design that effectively communicate NPC behaviors;
- *Accountability* for establishing mechanisms to attribute responsibility for NPC actions and decisions, particularly in the event of accidents or incidents. Legal and regulatory frameworks that outline responsibilities and liabilities for AI-driven NPCs in gaming environments should be integrated in combination with clear ethical guidelines [36];
- *Societal impact* and *societal implications* of AI-controlled NPCs in shaping player attitudes and behaviors towards road safety. Comprehensive assessments and evaluation of potential ethical and/or societal consequences of AI-driven NPCs should be conducted in combination with raising awareness about the role and impact of AI in road traffic safety games [37];
- *Data privacy* concerns arise from the collection, storage, and utilization of personal information in AI-driven NPC design. User consent regarding the collection and use of their data for NPC design purposes should be obtained. Data anonymization or pseudonymization techniques should also be implemented to protect individual identities.

4. CONCLUSION

AI-driven NPCs contribute to a more immersive gaming experience by exhibiting lifelike behaviors and interactions. This realism is crucial for maintaining player engagement and creating believable game worlds. NPCs that can react dynamically to the player and the environment make the game world feel alive and responsive. AI models add layers of strategic depth to games. In strategy and tactical games, intelligent NPCs can challenge players with sophisticated tactics, requiring players to think critically and adapt their strategies. This complexity enhances replayability and keeps players engaged over longer periods. Adaptive AI allows NPCs to tailor their behavior to individual player styles and preferences. This personalization ensures that games remain challenging and enjoyable, catering to both novice and experienced players. By analyzing player behavior and adjusting NPC strategies, AI creates a more dynamic and satisfying gaming experience.

Advances in deep learning, natural language processing, and AI ethics will further enhance NPC capabilities, enabling more sophisticated interactions. Future research should focus on improving AI efficiency, reducing development costs, and exploring new ways to integrate AI seamlessly into game design.

Implementing advanced AI techniques in NPC control is computationally intensive, and can potentially affect game performance. Balancing the complexity of AI algorithms with the available computational resources is a critical challenge for developers. Deep learning models require significant computational resources, which can be a limiting factor for real-time applications in games.

Additionally, training deep learning models necessitates large datasets that can be difficult to obtain and curate. Ensuring the quality and diversity of training data is essential for developing robust and generalizable NPC behaviors. The use of AI models raises ethical questions regarding the behavior and representation of NPCs. Ensuring that NPC behavior aligns with ethical standards and does not perpetuate harmful stereotypes or behaviors is essential.

The future of using AI in NPC control is promising, with potential advancements in unsupervised learning, transfer learning, and explainable AI. These techniques will further enhance NPC intelligence, making characters more autonomous and capable of even richer interactions. While challenges remain, the continued evolution of AI integration promises even greater innovations in NPC control, pushing the boundaries of what is possible in digital game design. As AI continues to evolve, it is essential to ensure that it complements and enhances the creative aspects of game design rather than overshadowing them.

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A New Curriculum-Oriented 5G ICon Platform: Lab Exercises and Projects

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Abstract: *The results of our ongoing efforts to develop an ICon curriculum on intelligent wireless connectivity are presented in this paper. The new core curricula encompass a range of subjects, including the fifth-generation (5G) mobile networks, Internet of Things (IoT), cloud computing (CC), and artificial intelligence (AI). It is emphasized that it is necessary for students to learn about the 5G architecture, protocols, and applications, understand the fundamentals of IoT and CC infrastructure, as well as learn about the various AI techniques and their applications and limitations. We suggest that educators design hands-on Lab exercises and projects that include simulation, emulation, and analysis of 5G networks that allow students to gain hands-on experience in understanding the details of the system. In the development ICon platform, Matlab interactive environment is selected for modeling and simulation 5G-NR connectivity links and open source project open5GS core network with end-to-end perspective. The development requires interdisciplinary collaboration, and new ICon core curricula should reflect this by bridging gaps between traditionally separate fields of study.*

Keywords: *5G mobile networks; AIoT; ICon curriculum; Lab; open source projects*

1. INTRODUCTION

The concept of 5G smart connectivity includes the combination of 5G-IoT networks and artificial intelligence AI for advanced technological development and structural changes in industry and society. Intelligent connectivity is not about a single product or device, but a very complex technological ecosystem [1, 2].

Developing an effective ICon curriculum is a multi-stage, continuous and cyclical process of course creation and improvement [3, 4, 5]. The process begins with the evaluation of existing programs in the subject areas, moves to the design of an improved program, continues with the implementation of the new program, and then returns to the evaluation of the revised program. Ideally, the development process is a process of continuous improvement. The iterative process allows educators the flexibility to improve the course. It is necessary to review, revise and update lesson plans frequently as new and different requirements emerge. Continuous additions are necessary due to intensive research, development and innovation in the subject areas [6, 7, 8].

In the first part of paper, a subject-oriented ICon curriculum development model is proposed. Hands-on Lab exercises and projects, are presented in the second part of paper.

2. ICon CURRICULUM DEVELOPMENT

A subject-focused ICon curriculum development model with an emphasis on specific student skills and knowledge is related to the areas of 5G, IoT, CC and AI. The motivation for the curricula is the integration of 5G-AIoT [9, 10, 11]. The application of AI is justified for the huge amounts of data generated by IoT devices. Mobile networks support large data transmission and processing capabilities. It is therefore necessary for educational institutions to update their curricula to reflect the latest developments in these areas and prepare students with the necessary skills to succeed in the market.

The iterative process of ICon program development allows for continuous improvement of the course. In the first step, we evaluate the existing programs, designed an improved program, work on the implementation of the program, and planning to evaluate the revised program. Lesson plans must be revised and updated as changes and new requirements appear [8].

Different approaches were used in the development of curricula. We follow usual approach consists of analysis of needs/tasks, design of goals, selection of appropriate learning/teaching methods and appropriate knowledge assessment methods, formation of curriculum implementation, evaluation and review [12, 13, 14].

The development of the new curriculum is crucial for the preparation of the next generation of professionals in the ICon fields. The curriculum covers the fundamentals of technology, new applications, as well as regulation and professional ethical implications. Preparing students with the necessary skills and knowledge, educational institutions also initiate innovations in these areas:

- ✓ it is essential that students learn 5G system architecture, protocols and deployment, as well as challenges and opportunities in different industrial sectors
- ✓ students are required to understand IoT fundamentals, communication protocols, data analytics and security solutions
- ✓ IoT applications are numerous (smart residential buildings, cities, transport and logistics), so IoT includes the interconnection of ubiquitous devices (sensors, actuators, smart devices) to the Internet, enabling data collection, analysis and automation
- ✓ it is essential that students acquire basic knowledge of cloud computing CC, including architecture, service models, and application models
- ✓ finally, it is necessary for students to learn different AI methods, such as machine learning ML and deep learning DL, as well as their applications and current limitations.

3. 5G Lab EXERCISES AND PROJECTS

Our recommendation to educators is to design hands-on exercises and projects that include simulation, emulation and analysis of networks. Students are allowed to gain hands-on experience in understanding details of 5G system [6, 7].

3.1. 5G NR simulation model

A Matlab simulation model was developed with a detailed explanation of the program codes for a understanding of the principles of 5G NR system. The key procedure for transporting data blocks of PDSCH (Packet Data Shared Channel) shared channels on the physical (PHY) layer is modeled, because it significantly determines overall performance of the system. Matlab 5G Toolbox functions of signal processing blocks are used to simulate the complete 5G system in the downlink (DL) direction [6].

The stages of 5G NR pre-processing are illustrated in detail, as well as the call of Toolbox functions. Additionally, the signal processing of the PHY physical layer are covered in detail with elaborate numerical examples to illustrate the functioning of each processing block:

- ✓ transport block TB size
- ✓ CRC (Cyclic Redundancy Check) bits calculation
- ✓ transport code block CB segmentation
- ✓ parity check matrix
- ✓ LDPC (Low-Density Parity-Check) enc/dec
- ✓ rate-matching (exact number of bits)
- ✓ code block concatenation (into single data stream)
- ✓ scrambling/de-scrambling
- ✓ QAM (Quadrature amplitude modulation)
- ✓ modulated symbols mapping
- ✓ precoding codebook-based transmission
- ✓ 3-layer transmission using 4-antenna ports
- ✓ synchronization signals transmission
- ✓ minimum NR guard bands
- ✓ resource block RB mapping
- ✓ IFFT fast algorithm in OFDM modulation
- ✓ Layer (PHY, MAC, RRC) de-mapping
- ✓ bit de-interleaving process

The 5G NR processing blocks on the transmit and receive side (DLSCH downlink shared channel encoding/decoding, PDSCH physical channel that carries user data, Cyclic Prefix-OFDM digital transmission) have the corresponding call to the Matlab Toolbox functions of the simulation model. Figure 1 shows the results of running Toolbox scripts in the Matlab computer environment:

- ✓ Code Block Segmentation
- ✓ LDPC Encoding
- ✓ Modulation
- ✓ SSB Waveform generation
- ✓ OFDM (Orthogonal Frequency-Division Multiplexing)
- ✓ CDL Channel
- ✓ TDL Channel
- ✓ CP-OFDM Demodulation
- ✓ Layer Demapping
- ✓ Demodulation
- ✓ LDPC Decoding
- ✓ Code Block de-Segmentation

The system and model are complex, and that is why the simulator was developed for educational purposes in the Matlab development environment. The simulator is based on a user-friendly graphical user interface (GUI) for input open parameters of the 5G NR system and starting experiments. After starting the simulator, the results of the 5G NR bandwidth calculation are displayed. System performance metrics are also displayed as transmission error probability BER diagrams that enable educational data flow analysis for given input parameters.

The App Designer development environment is used to create an educational interactive 5G NR simulator. The first step of the procedure for converting a Matlab script into an application is to create GUI user interface in Design View for input the values of the simulation parameters. The GUI of the app can easily be built by adding visual components (drop-down menus and editing fields) using drag-and-drop operations. The App Designer automatically generates the object-oriented codes for the GUI and the behavior of those visual components defined in the Code View. For each visual component interacting with the student, a callback function is written so that user input can be used in the simulation [6].

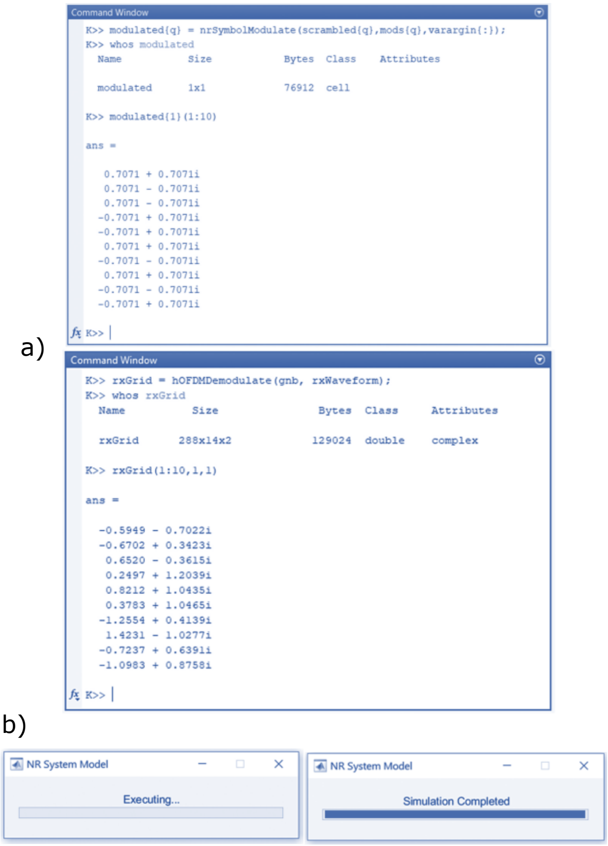

Figure 1. *Running the 5G NR model in Matlab: a) start-results scripts of transmitter-receiver; b) start-stop 5G NR simulator [6].*

The Matlab project 5GNRSystemSimulator is saved in the App Designer mlapp format file. By opening the file, the student launches a GUI to enter simulation parameters. Then, by pressing the SIMULATE button, the program starts and the operation indication is displayed. After the completion of the program, in text-box of RESULTS application, values of BER/BLER and throughput of the ThroughputPDSCH channel for the input parameters are displayed, as well as diagrams generated in the NRSistemModel module [6].

3.2. 5G Core server

Open source projects, development kits, and programming tools are useful tools for integrating the ICon course into educational programs. 3GPP compliant features, simulation capabilities and educational resources provide a valuable teaching tool for educators and students. In the context of ICon education, open source initiatives and projects occupy a significant role. Open source encourages activity of complete technological ecosystem in which different actors contribute to development, testing and improvement of technology [7].

The availability of open source software and hardware components promotes competition, reduces vendor dependency and enables telecom operators to customize and optimize their network applications. However, openness to different vendors presents a challenge for configuration management and debugging solutions. Open source projects for 5G contribute to the development of innovative solutions and at the same time drive the adoption of the technology in education.

Open source projects in the telecommunications sector, such as O-RAN and open5G, focus on creating open, modular and interoperable network solutions and system frameworks for a programmable and virtualized 5G system. Projects are developed with the aim of separating hardware and software components, supporting flexibility and innovation in network implementation. Although the specific adoption of projects in education may require further research, the openness and modularity offered by open source initiatives support the integration of 5G technology into the curriculum and laboratory exercises [7].

We recommend the main open source solutions for 5G system Core network. Open5GS is a C-language implementation of 3GPP Release-17 5G Core network and distributed under the AGPLv3 License. It is compatible with a variety of Linux distributions. Repository contains a series of software components and network functions that implement the 5G NSA and 5G SA core functions (Fig. 2).

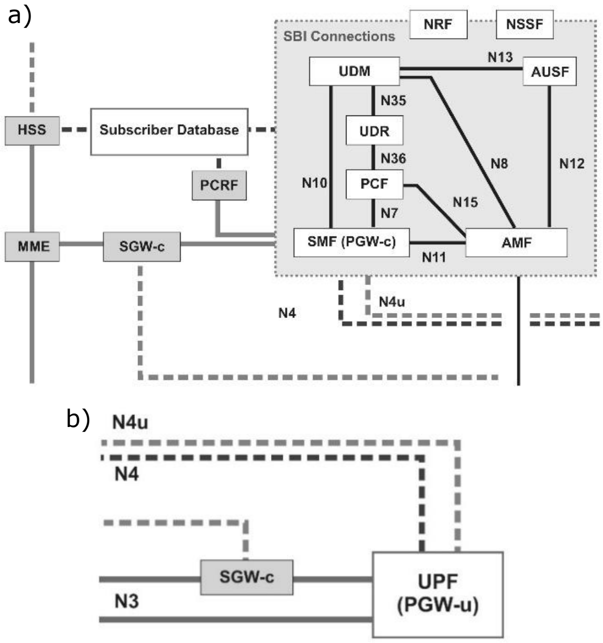

Figure 2. *a) Control Plane server, and b) User Plane server https://open5gs.org/*

This implementation supports the management of user access, mobility, and sessions (AMF and SMF), and the discovery of the services offered by other network functions (NRF). It also includes network functions to select which network slices to allocate to UEs (Network Slice Selection Function NSSF), to manage, store and retrieve user data (Unified Data Management (UDM) and Unified Data Repository UDR), to perform UEs authentication within the network (Authentication Server Function AUSF). Functions for the operation, administration and management of the core network (Operations, Administration and Maintenance OAM), and to perform network orchestration, among others, are also included [7].

The 3GPP interfaces implemented by Open5GS are:

- ✓ N1/N2 connect the AMF to the UE and RAN, respectively and used for session and mobility management.
- ✓ N3/N4/N6 connect the UPF to the RAN, SMF, and data network, respectively, and support user plane functions.
- ✓ N8 connects the UDM and the AMF, and enables user authorization procedures.
- ✓ N10/N11 connect the SMF to the UDM and AMF, respectively, and handle subscription and session management requests.
- ✓ N12/N13 connect the AUSF to the AMF and UDM, respectively, and they enable authentication services.

In the Lab, we recommend two exercises for network configuration:

- ✓ demonstration of 30 Gbps Load Testing for Accelerated UPF (User Plane Function)
- ✓ measurement of UPF performance.

4. CONCLUDING REMARKS

The key advantage of the previously presented approach to improving education is the unification of more modern advanced technologies compared to current separate curricula. The paper specifically discusses the importance of hands-on Lab exercises and projects that include simulation, emulation, and analysis of 5G networks that allow students to gain hands-on experience in understanding the details of such complex systems within the new ICon smart connectivity curriculum.

The curriculum is creating continuously through a multi-stage cyclical process of improving the course with focus on a strong methodological foundation. In the first step, the results of the analysis of current situation are interpreted in order to obtain a series of learning-teaching experiences with the ultimate goal of achieving a certain level of knowledge among the participants. It is necessary for students to explore 5G architecture, procedures, protocols and applications, understand the fundamentals of IoT, as well as various artificial intelligence AI techniques, applications and current limitations. The second step is development teaching material and design practical Lab exercises and projects with developded interactive Matlab 5G NR model. Also, we have proposed hands-on Lab exercises and open source programmable framework for Core network functions and interfaces of complete 5G system.

Future work will include specification of ICon plan and program in details, evaluation teaching material and testbed platforms as well as testing procedures. Due to the importance of an interdisciplinary approach, the need to prepare adapted curricula is also recognized for other non-engineering professions.

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Modeling and Simulation of CNC Feed System Using MATLAB/Simulink Software Package

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Abstract: *The CNC feed system is one of the most important mechatronics assemblies in CNC machine tools. That is why it is of great importance, in the education of future engineers, to pay special attention to analysis of CNC feed systems through the modeling of its components and the simulation of its control structure. This paper presents an educational laboratory setup - a simulator of CNC machine tools, modeling of the drive system of the laboratory setup, and control of CNC feeding system within the MATLAB/Simulink software package. Also, the control simulation of the execution of some program instructions of the G code was presented, as well as the connection of the Simulink model with the microcontroller of the CNC machine tool simulator.*

Keywords: *CNC systems; MATLAB/Simulink; Arduino; modeling; simulation*

1. INTRODUCTION

CNC machine tools, as typical mechatronic systems, are dominant and indispensable factors in production engineering, in many branches of industry [1,2]. Like any mechatronic system, CNC machine tool has their own control system, which is the "brain" of production automation and its value is about 30% of the total value of the machine tool [3]. In the industry there are CNC control systems from various renowned global manufacturers such as Siemens, Fanuc or Heidenhain, which are very expensive. In addition to professional CNC machine tools, the market for "hobby" solutions of these machines is increasingly developing [4,5]. Accordingly, it is of great importance, in the education of future engineers, to pay special attention to the analysis of the architecture of CNC machine tools (mechanical components, drive systems, sensor techniques, control system).

This work aims to present an educational setting that enables students to become better acquainted with CNC systems through control software visualization and its implementation in the mentioned education setting.

2. SIMULATOR OF CNC MACHINE TOOLS

The simulator of CNC machine tools was developed as part of teaching activities at the Faculty of Technical Sciences in Čačak, with the idea of having a modular character. So, depending on the choice of the manufacturing process, the machine can be transformed into a desktop CNC milling machine, 3D printer, laser cutting machine, etc. A CAD model of the CNC simulator with a motor for machining, which makes it a desktop CNC milling machine as a whole, is given in Figure 1a, while Figures 1b, 1c, and 1d show the X, Y, and Z axis CAD model views, respectively.

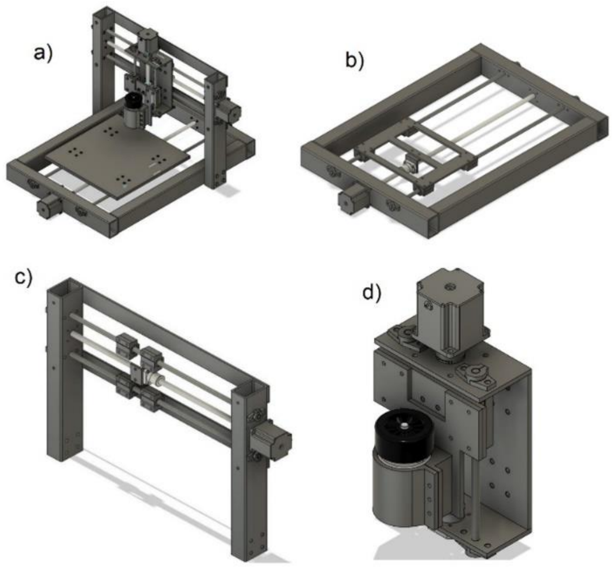

Figure 1. *a) CAD model of desktop CNC milling machine, b) CAD model of X axis, c) CAD model of Y axis, d) CAD model of Z axis*

There is a work table on the X-axis, and the length of the maximum stroke along the mentioned axis is 300 mm. The X-axis drive system is a NEMA23 servo stepper motor. The translational movement of the table is realized using linear guides and a threaded spindle (pitch 5 mm) with a nut. The connection between the threaded spindle and the motor rotor is achieved with the coupling. The construction consists of a frame made of aluminum box profiles with dimensions of 60x40 mm.

The Y axis is essentially no different from the X axis. Aluminum box profiles 60x40 mm were also used. As with the X axis, the drive is a NEMA23 servo stepper motor. The working stroke of the Y-axis is 300 mm.

The Z axis is intended to carry the machining motor or some other tool of the machine, depending on the purpose. The drive of this axis is a NEMA17 stepper motor, and the working stroke of the Z axis is 100 mm. All other components are identical to the previous axis, with the necessary dimensional adjustment.

The machine is powered by a 500W AC/DC converter, which outputs 24VDC and that voltage is used to power the drive, the drive driver, and the control unit, which in this case is the Arduino Uno board. Also, the machine has integrated limit switches and an all-stop button (latching mushroom type emergency stop switch). Figure 2 shows the layout of the laboratory simulator of CNC machine tools.

Figure 2. *Laboratory simulator of CNC machine tool*

3. DRIVE AND CONTROL SYSTEMS FOR X AND Y AXIS

As already mentioned, the drive system consists of NEMA23 servo stepper motors (X and Y axis) and NEMA17 stepper motor (Z axis). In this paper, the emphasis will be on modeling and simulation of control of the X and Y axes, so the characteristics of the Z-axis motor - NEMA17 will not be analyzed. The servo stepper system for X and Y axis NEMA23 allows to achievement of very high positioning resolutions, using the micro-stepping technique, and with the help of an incremental encoder (resolution 4096), the number of steps can be reliably increased from 200 per revolution to 4000 per revolution, resulting in a resolution of 25μm to a resolution of 1.25μm.

The HBS57 driver is used for the NEMA23 drive system. Its basic characteristics are given in Table 1 [6]. The driver has printed plates on its surface that explain the setting of current limiting and micro stepping using the microswitches located on the side.

Figure 3. *NEMA23 hybrid servo stepper motor with driver*

Table 1. *Characteristics of the HBS57 driver*

Parameters	**Min.**	**Typically**	**Max.**
Current per phase	0 A	-	8 A
Supply voltage	9 VDC	36 VCD	40VDC
Signal current	7 mA	10 mA	16 mA
Pulse frequency	0 kHz	-	200 kHz
Isolation	500 MΩ	-	-
Micro-stepping/1.8 °	200	-	4000

The control system is an Arduino Uno microcontroller on which there is a CNC shield that facilitates the connection of the driver with the Arduino Uno microcontroller pins. Table 2 shows the basic characteristics of the Arduino Uno controller, and Figure 4 provides a graphical show of the Arduino Uno controller.

Table 2. *Characteristics of the Arduino Uno controller*

Input voltage (recommended)	7-12VDC
Digital inputs/outputs	14
PWM digital inputs/outputs	6
Analog inputs	6
Current per pin (maximum)	20mA
Flash memory	32kB
SHAME	2kB
EEPROM	1kB
Oscillator frequency	16 MHz

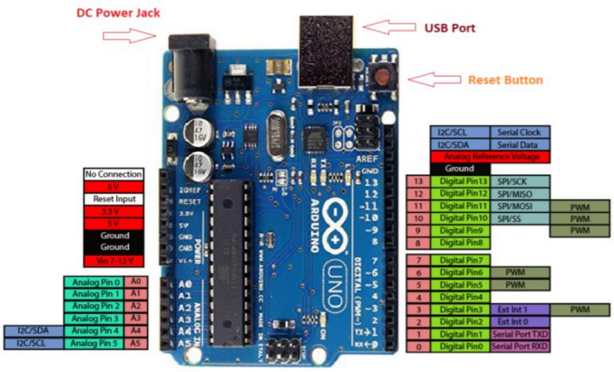

Figure 4. *Arduino Uno controller layout with pin labels and functions*

4. MODELING AND SIMULATION OF MOTION CONTROL

Modeling of the CNC positioning system for the X and Y axis was performed within the MATLAB/Simulink software package. All the mentioned drive and control components are represented by the corresponding blocks, and their characteristics are entered as values in the variables of the corresponding blocks (Figure 5).

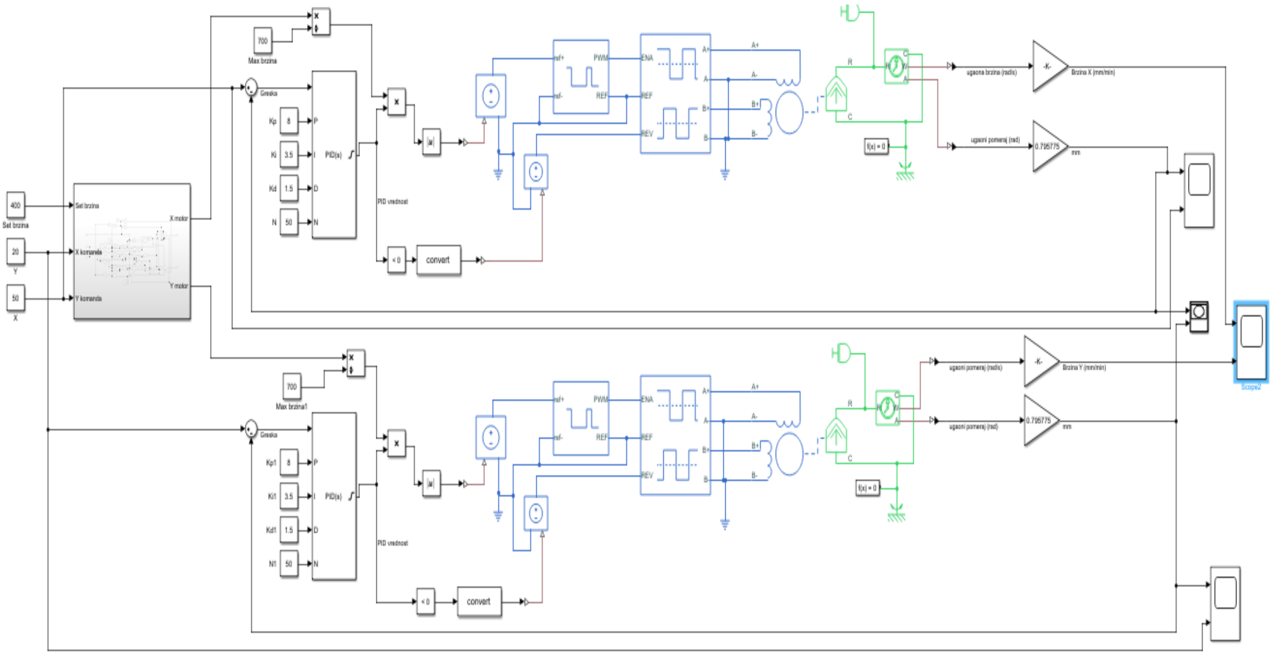

Figure 5. *Simulink model of CNC positioning system for X and Y axis*

As the components for both observed axes are identical, their Simulink interpretation is also the same, so in Figure 5 it can be noticed that the upper and lower half of the picture have the same elements. The "Controlled PWM voltage" block represents the Arduino microcontroller that sends impulses to the "Stepper Motor Driver" which represents the HBS57 driver. The driver outputs are connected to phases A and B of the "Stepper Motor" block, which is a NEMA23 motor located on the X and Y axes. This shows the electronic connection and control, marked with blue lines. Green lines indicate mechanical connections. The "Inertia" and "Ideal Rotational Motion Sensor" blocks are attached to the motor rotor, representing the inertia seen by the motor from the side of the rotor and the position sensor representing the encoder, respectively. The output from the sensor block is the position in radians, so by simply multiplying with the constant 0.795775 (knowing that the pitch of the threaded spindle is 5 mm and the transmission from the rotor to the threaded spindle is 1:1), the output is translated into millimeters. Also, in Figure 5, you can see the PID block related to PID regulation, and the constants used are P=8, I=3.5 and D=1.5, which were obtained by advanced software setting of the mentioned constants. If the program instruction G1 X50 Y20 F400 is written, it practically means that, after its execution, the work table will be at a distance of 50 mm along the X axis and 20 mm along the Y axis from the coordinate origin. The display of linear interpolation specified by the specified program instruction is given in Figure 6.

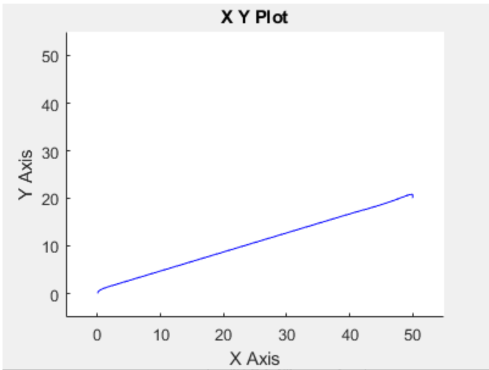

Figure 6. *Linear interpolation - function G1*

The speed profiles along the X (yellow color) and Y (blue color) axes are given in Figure 7, where it is clearly seen that the speed along the X axis is significantly higher, which is logical given that the distance along the X axis is greater.

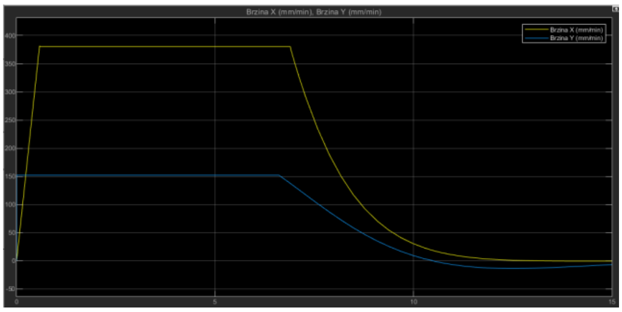

Figure 7. *Speed profile of two axes during execution of program instruction G1*

Also, it is possible to software test the behavior of the system for different types of interpolation, so if you write the program instructions G2 X80 Y80 CR80 F700, whose representation is given in Figure 8, you get speed profiles along two axes (X and Y) that differ significantly in compared to linear interpolation. The axes speeds shown in Figure 9 produce uniform movements of the work table at a speed of 700 mm/min in a circular arc of radius 80 mm.

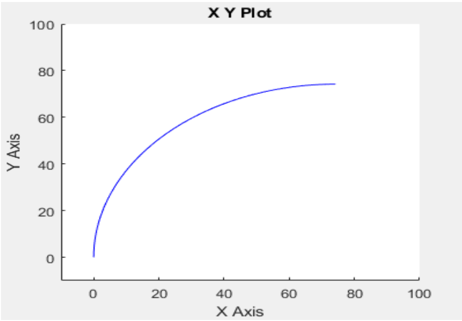

Figure 8. *Circular interpolation - function G2*

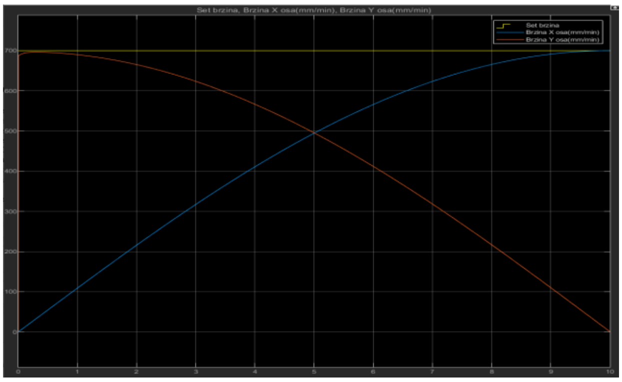

Figure 9. *Speed profile of two axes during execution of program instruction G2*

In addition to software simulations of control, with great possibilities of its visualization that facilitates the understanding of cause-and-effect relationships in the CNC position system, in MATLAB/Simulink it is possible to embed an Arduino block and thus control the simulator shown in Figure 2. Figure 10 shows a view of connecting the Simulink model of one axis to the pins of the Arduino microcontroller.

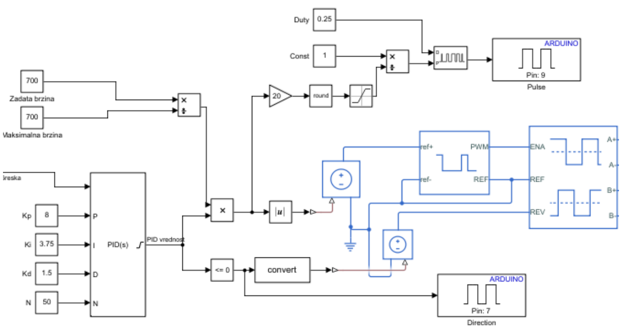

Figure 10. Connecting control functions to Arduino controller pins

5. CONCLUSION

The presented MATLAB/Simulink models are extremely important for the education of future engineers. With knowledge of the MATLAB/Simulink software package, students can simulate the operation of a CNC positioning system for various instructions defined through standard G code. The developed models provide the opportunity for students to see the importance of PID regulation in CNC systems, and to adjust PID regulation constants using standard techniques, but also in some more advanced ways such as phase adjustment of PID constants. The special value of the presented models and educational settings is that they are connected using Simulink Arduino blocks and everything that is demonstrated by simulation in the software can be implemented in real-time on a laboratory simulator of a CNC machine tool.

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Computational Analysis and Simulation of Geiger-Müller Counter Instrument F-factor Using Wolfram Mathematica Software: Case Study of LARA 10 as integrated part of Radiation Laboratory LR-M2

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Abstract: *This paper introduces an interactive simulation developed using the Wolfram Mathematica software package for determination of the device F-factor for the Geiger-Müller counter component LARA 10, within the context of the LR-M2 radiation laboratory. LR-M2, a military-origin laboratory established in the early 1980s, houses the LARA 10 device, which is crucial for radiation detection and measurement. The simulation focuses on computing the F-factor based on the registered radiation intensity with different radiation filters. Through an interactive interface, users can explore the impact of varying radiation levels and filter types on F-factor calculations, providing valuable insights into the device's performance characteristics. This interactive approach enhances understanding and facilitates experimentation, enabling users to optimize radiation detection processes in the LR-M2 laboratory setting. The findings contribute to the advancement of radiation monitoring technology, particularly in civilian applications, ensuring enhanced capabilities for effective radiation hazard management.*

Keywords: *Interactive simulation; Geiger-Müller counter; Wolfram Mathematica; Radiation Laboratory; Fission products*

1. INTRODUCTION

The accurate measurement and assessment of radiation levels are paramount in various fields, ranging from nuclear safety and environmental protection to public health. Geiger-Müller (GM) counters have long been employed as effective tools for detecting and quantifying ionizing radiation due to their sensitivity and versatility. In this article, we present a comprehensive analysis of the performance of the LARA 10 GM counter, integrated within the LR-M2 radiation laboratory, through the utilization of an interactive simulation developed using the Wolfram Mathematica software package. The LARA 10 radiometric laboratory is a mobile laboratory that is used for radiation-hygiene analysis of environmental samples, food samples of plant and animal origin, water, as well as animal feed that are radioactively contaminated with a Mixture of Fission Products (MFP), especially biologically dangerous radionuclides - ^{90}Sr, ^{131}I and ^{137}Cs and others.

The utilization of interactive simulations, facilitated by the Wolfram Mathematica software package, offers a dynamic approach to computing the instrument F-factor of the LARA 10 GM counter.

LR-M2, a radiation laboratory with military origins established in the early 1980s in the former Socialist Federal Republic of Yugoslavia, serves as a cornerstone facility for radiation monitoring and analysis. The LARA 10 GM counter is a vital component of LR-M2's instrumentation, specifically designed for the precise measurement of radiation intensity in various environmental samples. These samples include food, water, and soil contaminated with radionuclides resulting from fission products [1]. Additionally, the LARA 10 plays a critical role in civilian applications, aiding in the detection of radioactive elements in consumables and environmental samples.

The primary objective of this research is to develop an interactive simulation within the Wolfram Mathematica environment to calculate the instrument F-factor of the LARA 10 GM counter based on the registered radiation intensity for specific radiation filters. This simulation-based approach enables a thorough analysis of the F factor's dependency on various factors, such as environmental conditions, radiation sources, and filter configurations [2, 3]. By incorporating user interaction, the simulation provides researchers and practitioners with a powerful tool for optimizing the performance of the LARA 10 device in diverse radiation monitoring scenarios.

To ensure the reliability and accuracy of the simulation results, this study relies on a comprehensive review of relevant literature and established methodologies for GM counter calibration and performance evaluation. References include studies on GM detector theory, radiation measurement techniques, and computational methods for radiation analysis. By drawing upon established principles and methodologies, we aim to validate the effectiveness of our simulation approach and contribute to the advancement of radiation detection technology.

1.1. Ecological significance of radionuclide presence in the environment

Radiation and radionuclide toxicity can have significant consequences on ecosystems, affecting biodiversity, genetic integrity, and overall ecological balance [4, 5]. The presence of radionuclides in the environment can lead to bioaccumulation and biomagnification, where organisms higher in the food chain accumulate higher concentrations of radionuclides, posing potential risks to human health through consumption of contaminated food and water [6]. In addition to its implications for human health and ecological integrity, radionuclide contamination can also have socio-economic ramifications, particularly in regions heavily reliant on agriculture and natural resources. Contaminated agricultural products and water sources can lead to economic losses and disruptions in food supply chains [7].

Therefore, understanding the dynamics of radiation and radionuclide contamination in the environment is essential for effective environmental management and mitigation strategies. By integrating computational simulations with ecological modeling, we can gain insights into the long-term effects of radiation contamination on ecosystems and develop strategies for remediation and restoration [8, 9, 10, 11, 12, 13].

2. GENERAL CHARACTERISTICS OF LARA 10

The radiometric laboratory LARA 10 is intended for measuring the mass activity of A_z mixtures of fission products that are contaminated with radionuclides such as ^{90}Sr, ^{131}I and ^{137}Cs characteristic of nuclear incidents. Using this laboratory, it is possible to prepare and measure samples of the environment and objects of health surveillance (food, water, animal feed), as well as other samples (blood, urine and others).

The MFP activity of the given samples is measured from the raw sample in a thick layer (absolute A_z measurement method) using the filter technique. This method also enables the determination of the age of the MFP, because this information is necessary for making a recommendation on the usability of the tested foods and foods.

Depending on the type of samples and the method of their collection, surface beta activity (A_p) and volume beta activity (A_z) can be measured. The units used to express these specific activities are: [$kBq\cdot kg^{-1}$] of fresh sample – for solid samples, or [$Bq\cdot l^{-1}$] for liquid samples.

The device is placed in two boxes whose total weight is about 100 kg (Fig. 1). In the first box there is a sampling kit with a capacity of 800 samples. They can be done continuously for 5-6 days. In the second box there are: a built-in lead housing, with a GM counter, a scaler with a timer, a scaler Svit 10 on which there is a display and control buttons, a built-in rectifier in case of power supply from the mains voltage, filters, radioactive radiation sources, etc.

Figure 1. *Parts of LR-M2 radiation laboratory: housing, filters, radioactive calibration source, scaler Svit 10 with timer*

The device can work in the conditions of the radiation field of the environment when the strength of the exposure dose is: $\dot{X} < 1.4\, nC/kg\cdot s$, that is, less than 20mR/h. The activity level measurement range is very large, which means that the speed of counting samples whose Az is on the order of kBq can be measured. The permissible measurement error is less than 20%.

3. PRINCIPLE OF THE METHOD OF MEASURING BETA ACTIVITY OF MFP

The sample count rate R^*_{bf} is determined via a GM counter into which a sample contaminated with MFP is placed. The obtained value of the counting speed can be represented by the relation

$$R^*_{bf} = A_z \cdot m \cdot F_g \cdot F_{ras} \cdot F_{sa} \cdot F_{ra} \cdot F_{ap} \cdot F_{\tau} \cdot F_{\varepsilon} \quad (1)$$

where: R^*_{bf} sample counting speed without filter (imp/s), A_z – mass/volumetric activity expressed in Becquerel (Bq), m- mass of measured sample (g), F_g – geometric efficiency factor, F_{ras} – correction factor for radioactive decay, F_{sa} - correction factor for the self-absorption effect, F_{ra} - correction factor for the scattering effect, F_{ap} - correction factor for the absorption effect in the air layer between the counter and the absorption source in the counter window, F_τ - correction factor for the "dead time" of the counter, F_ε - correction factor for the efficiency of the counter as a function of energy. All the mentioned factors were determined experimentally and the obtained results were expressed by one F-factor. By using the filter method, some of the factors are eliminated and thus it is possible to get the result faster, with a slightly higher measurement error. It follows from equation (1) that if all corrections are represented by one factor F, the principle of determining A_z from MFP (^{90}Sr, ^{131}I and ^{137}Cs) in a sample is equal to the expression

$$A_z = R^*_{bf} \cdot F \tag{2}$$

where F is the factor that is expressed in kBq/kg and whose values are closely related to the choice of one of the offered five Aluminum beta radiation filters of different thickness (Fig. 2).

Figure 2. *Aluminum beta radiation filters from 1 to 5 in radiation laboratory LARA 10*

In order to be able to determine the factor F, it is necessary to determine the quotient between the sample counting speed without a filter corrected to the level of background radiation, i.e. R^*_{bf} and count rates with some filter R^*_{fx} also corrected for background radiation (x=1, 2, 3, 4, 5). Which type of filter is suitable for measuring the tested sample depends on the quotient

$$1.5 < \frac{R^*_{bf}}{R^*_{fx}} < 2.5\,. \tag{3}$$

After determining the value of R^*_{bf}/R^*_{fx} for a given filter, the device F-factor is determined from Table 1.

Table 1. *Relationship between filter serial number and value of R^*_{bf}/R^*_{fx}*

R^*_{bf}/R^*_{fx}	Serial number of the filter				
	1.	**2.**	**3.**	**4.**	**5.**
1.5	39.2	16.3	6.7	2.7	1.2
1.55	43.3	17.8	7.3	2.9	1.3
1.6	48.1	19.3	7.8	3.1	1.4
1.65	50.8	20.7	8.4	3.4	1.5
1.7	56.3	22.2	9	3.6	1.6
1.75	61.7	23.7	9.6	3.8	1.7
1.8	65.9	25.2	10.1	4.1	1.8
1.85	70.3	26.7	10.6	4.3	1.8
1.9	76.2	28.5	11.1	4.6	1.9
1.95	81.4	30	11.7	4.8	2
2	85.8	31.5	12.2	5	2.1
2.05	92.1	33.3	12.6	5.2	2.2
2.1	96.2	34.8	13.3	5.3	2.3
2.15	102.1	36.6	13.7	5.6	2.4
2.2	106.2	37.7	14.1	5.7	2.5
2.25	111	39.2	14.8	5.8	2.5
2.3	116.6	41	15.2	5.9	2.6
2.35	122.1	42.9	15.5	6.1	2.6
2.4	126.9	44.8	15.9	6.3	2.7
2.45	132.8	46.6	16.7	6.4	2.7
2.5	136.9	48.1	17	6.4	2.8

From equation (3), it becomes evident that a significant challenge in measurements with the LARA 10 device is the identification of a suitable filter that reliably satisfies the condition described in relation (3), acknowledging that finding such a filter is not always feasible. In practice, it often happens that the first selected filter is not suitable, which is why it is necessary to repeat the measurements with another filter. This procedure is repeated until the R^*_{bf}/R^*_{fx} value is between 1.5 and 2.5. Then we know we got the right filter.

The next problem is to find the appropriate value of the F-factor in Table 1. In this table, the R^*_{bf}/R^*_{fx} quotient values for different types of filters are shown in different columns. The problem is that the R^*_{bf}/R^*_{fx} value does not change continuously but in certain steps. This requires the user of the device to round the obtained quotient to the nearest value that he can find in the column in Table 1. During this procedure, due to the need to round the obtained division result, an additional measurement error is introduced.

4. MATHEMATICA SOFTWARE SIMULATION CODE FOR F-FACTOR CALUCATION

Our application presented in the software package Wolfram Mathematica avoids this quotient rounding step. This problem is solved by moving the locator, in the application which is an interactive simulation of R^*_{bf}/R^*_{fx} values, along the curve marked in red until the calculated R^*_{bf}/R^*_{fx} value is found on the fitted curve (Fig. 3). The curve connecting the F-factor in the function R^*_{bf}/R^*_{fx} is linear and can be represented in the form

$$F = a_x \cdot \frac{R^*_{bf}}{R^*_{fx}} + b_x \quad (4)$$

where the coefficients a_x and b_x depend on the ordinal number of the filter selected. In the next step, the value of the instrument F-factor is read. It should be noted that the measurement error is significantly reduced with this kind of procedure.

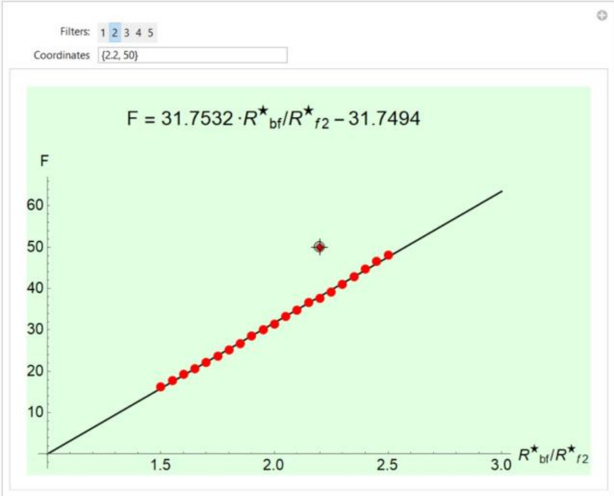

Figure 3. *Layout of the F-factor calculation application window with filter number two selected.*

The application is made to be interactive, that is, the user can choose the type of filter that is used in the device. In doing so, a linear fit of the data from Table 1 for the given filter is displayed in a separate window. Also, the application window shows the slope of the curve as well as a locator that can be moved on the graphic and read its coordinates (Fig. 4).

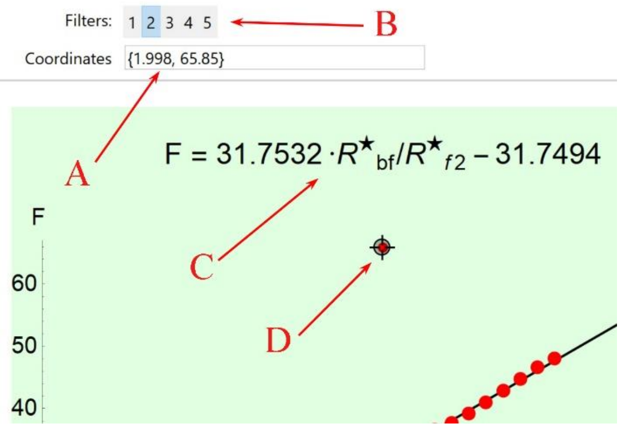

Figure 4. *A - coordinate values x, y - axis of the current position of the locator; B - window for selection of the serial number of the filter; C- coefficient of the straight line for the selected filter; D - current position of the locator*

The x-coordinate represents the quotient R^*_{bf}/R^*_{fx}, while the value of the F factor is read on the y-coordinate.

Another advantage of using the application is that it is not necessary to use a large number of filters, but in case the quotient R^*_{bf}/R^*_{fx} is outside the allowed limits (i.e. between 1.5 and 2.5), the locator can be moved along the fitted curve and for values significantly below 1.5 and for values significantly above 2.5. This means that A_z can most often be measured using the first choice of filter. In this way, significant savings in time are achieved and the capacity of the LARA 10 measuring device is increased.

5. MATHEMATICA SOFTWARE SIMULATION CODE FOR F-FACTOR CALUCATION

The Mathematica code of the application used to calculate the instrument F-factor is as follows:

```
filter={{1.5`,39.2`,16.3`,6.7`,2.7`,1.2`},
{1.55`,43.3`,17.8`,7.3`,2.9`,1.3`},{1.6`,4
8.1`,19.3`,7.8`,3.1`,1.4`},{1.65`,50.8`,20
.7`,8.4`,3.4`,1.5`},{1.7`,56.3`,22.2`,9,3.
6`,1.6`},{1.75`,61.7`,23.7`,9.6`,3.8`,1.7`
},{1.8`,65.9`,25.2`,10.1`,4.1`,1.8`},{1.85
`,70.3`,26.7`,10.6`,4.3`,1.8`},{1.9`,76.2`
,28.5`,11.1`,4.6`,1.9`},{1.95`,81.4`,30,11
.7`,4.8`,2.`},{2,85.8`,31.5`,12.2`,5.`,2.1
`},{2.05`,92.1`,33.3`,12.6`,5.2`,2.2`},{2.
1`,96.2`,34.8`,13.3`,5.3`,2.3`},{2.15`,102
.1`,36.6`,13.7`,5.6`,2.4`},{2.2`,106.2`,37
.7`,14.1`,5.7`,2.5`},{2.25`,111,39.2`,14.8
`,5.8`,2.5`},{2.3`,116.6`,41,15.2`,5.9`,2.
6`},{2.35`,122.1`,42.9`,15.5`,6.1`,2.6`},{
2.4`,126.9`,44.8`,15.9`,6.3`,2.7`},{2.45`,
132.8`,46.6`,16.7`,6.4`,2.7`},{2.5`,136.9`
,48.1`,17,6.4`,2.8`}};
novalista=List[filter];
MatrixForm[filter]
Manipulate[LocatorPane[Dynamic[filter],
resenje1=FindFit[novalista[[1,All,{1,fakto
r}]],b*x-a,{a,b,c},x];
  a1=a/.resenje1[[1]];
  b1=b/.resenje1[[2]] ;
  c1=c/.resenje1[[3]] ;
  Show[ Plot[ b1*x-a1,{x, 1,3},
LabelStyle->{Black,FontSize->16},
PlotStyle->Black, ImageSize->Large,
Background->LightGreen,
AxesLabel->{"R*bf/R*f"faktor-1,Row[{Style["
         F ",Black,FontSize->16]}]},
    PlotLabel->Row[{Style["
        F = ",Black,FontSize->20],
Style[ b1 "· R*bf/R*f"faktor-1-
a1,Black,FontSize->20]}]],
ListPlot[{novalista[[1,All,{1,faktor}]]},A
xesOrigin->{1,Automatic},
    PlotStyle->Red,
LabelStyle->Black,PlotStyle->Black,
ImageSize->Large,Background->LightGreen],
   Epilog->{Red,PointSize[Large],
Point[Dynamic[filter]]}]
  ],
 {{faktor,2,"Filters:"},
   {2->"1",
   3-> "2",4-> "3",5-> "4",6-> "5"}},
 {{filter,{2.2,50}},"       Coordinates"}}]
```

The list of numbers defined by the name filter represents the data presented in Table 1.

5.1. Explanations for parts of the code

Here are some explanations for parts of the code written in the Wolfram Mathematica programming language, and also for the commands that we used:

- `MatrixForm[filter]`: This command uses the `MatrixForm` function to format and display the `filter` matrix as a table.
- `Manipulate[...]`: This command defines an interactive manipulation that allows the user to control simulation parameters. The manipulation consists of `LocatorPane` and `Show` functions.
- `LocatorPane[Dynamic[filter], ...]`: The `LocatorPane` function creates an interactive surface where the user can place points (locators). The dynamic attribute `Dynamic[filter]` ensures that changes in the locator's location are reflected in the overall interactive display.
- `resenje1=FindFit[novalista[[1,All, {1,faktor}]],b*x-a,{a,b,c},x]`: It is used to find the parameters a, b, and c that best fit the `novalista` data using the `FindFit` function to fit an exponential model of the form `b*x-a`. The `FindFit` function uses a method of parameter estimation in regression analysis based on minimizing the sum of squared residuals - the Least Squares Method.
- `a1=a/.resenje1[[1]]; b1=b/.resenje1[[2]]; c1=c/.resenje1[[3]];`: The values of the parameters a, b, and c are extracted from the solution `resenje1` and assigned to the variables a1, b1, and c1.
- `Show[...]`: This command combines several plots into one display. It includes a plot of the fitted model function, a plot of the `novalista` data points, and an epilog of points that the user sets interactively.
- `Plot[...]`: Displays a plot of the fitted model function with the corresponding parameters a1 and b1.
- `ListPlot[...]`: Displays a plot of the `novalista` data points that the user can interactively place.
- `Epilog->{Red,PointSize[Large], Point[Dynamic[filter]]}`: This option adds an epilog to the plot, consisting of red points with a dynamic location corresponding to the location of the locators set by the user.
- `{{faktor,2,"Filteri:"}, {2->"1", 3->"2",4->"3",5->"4",6->"5"}}`: Defines an interactive controller that allows the user to select the value of the faktor parameter from the list of filters, labelled with numeric values and corresponding names.
- `{{filter,{2.2,50}}}`: Defines the initial value for the `filter` locator as `{2.2, 50}`.

6. CONCLUSION

The advantages of using interactive simulation in determining the instrument F-factor in the Wolfram Mathematica software application are multiple. Using the application, it is possible to determine the quotient R^*_{bf}/R^*_{fx} and calculate the instrument F-factor in the first measurement, which avoids the need for multiple measurements and the use of multiple filters. This is especially important if it is known that one measurement per one sample can take at least 15 minutes. By using interactive simulation, the whole procedure becomes much more efficient and faster, thus increasing the capacity of the radiometric laboratory.

Furthermore, as mentioned, the allowed measurement error on the device must be less than 20%. However, since now we can read the data continuously because we have a linear dependence of F on R^*_{bf}/R^*_{fx} via Eq. (4), the precision of the measured data is greatly increased because the rounding of the data presented in Table 1 is avoided. This means that now the data can be continuously read in a wide range of R^*_{bf}/R^*_{fx} coefficients, which significantly reduces the measurement error and increases the accuracy of measured radiation values.

Also, our research offers a novel approach to analyzing and simulating the performance of the LARA 10 GM counter within the LR-M2 radiation laboratory context. Through the integration of computational simulation and interactive visualization, we provide a valuable tool for enhancing radiation monitoring capabilities and ensuring public safety.

Our findings contribute to the ongoing efforts to improve radiation detection and measurement technologies for both military and civilian applications.

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Mathcad PTC Software Towards IM Static/Dynamic Characteristics Simulation

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Abstract: *The paper presents the advantages of Mathcad software for simulating both static and dynamic characteristics of induction machines based on known mathematical models. Mathcad allows for the direct entry of differential and other complex equations that mathematically describe any system or process, automatically calculating the results based on input parameters and conditions. The results can be easily visualized and adjusted by changing the input data, thanks to Mathcad's dynamic updating feature. This paper demonstrates Mathcad's use in visualizing the dynamic characteristics of induction machines (IM) during the startup, rotor resistance starter design and steady-state thermal analysis with varying duty types or machine losses.*

Keywords: induction machine, dynamic characteristic, Mathcad, rotor resistance starter, thermal analysis.

1. INTRODUCTION

The advancement of modern technologies has led to an increasing reliance on simulation tools in engineering disciplines, including the field of electrical machines and motor drives. Simulation plays a vital role in the design, analysis, and optimization of electrical machines' performance, allowing engineers to model and study dynamic states without the need for expensive prototypes. Electrical machines and motor drives are at the core of many industrial systems and applications. Their efficiency and reliability are critical factors in manufacturing processes, transportation, energy, and numerous other sectors. The dynamic behaviour of these systems, including starting, stopping, speed, and torque variations, requires thorough understanding and precise control. Simulation enables engineers to predict the behaviour of electrical machines under various operational conditions. This includes analysing transient states, such as motor startup and short-term disturbances, as well as steady states under different loads. By using simulation tools, potential problems can be identified and corrected before implementation in real-world conditions, resulting in significant time and resource savings [1].

Mathcad is a well-known software tool in technical and scientific calculations, recognized for its ability to combine text, mathematical expressions, and calculations in a single working environment. This software allows users to input and solve complex mathematical problems, create interactive graphics, and visualize data intuitively. One of the key advantages of Mathcad is its capability to simulate dynamic states in electrical machines. Dynamic simulation involves analysing how a system responds to changes in input parameters over time. In the context of electrical machines, this can include simulating motor startup, analysing transient states during load changes, and simulating various control strategies [2, 3 ,4].

Mathcad enables users to model and analyse differential equations, which are the basis of most dynamic models of electrical machines. It provides tools for solving these equations easily, including numerical methods for complex systems. Users can visualize simulation results through various graphical representations, allowing for detailed performance analysis of machines under different conditions. Mathcad can be integrated with other software tools and programming languages, offering flexibility and extended functionality. This is particularly useful when using specific algorithms for control and optimization. The intuitive user interface of Mathcad allows engineers to focus on analysis and design without needing deep programming knowledge [5].

The use of Mathcad in simulating electrical machines can be illustrated through several examples. Simulating the startup of an induction motor is a critical moment in its operation, often accompanied by large currents and torques. Mathcad allows modelling of this process, analysis of currents, torque, and speed over time, identification of potential issues, and optimization of startup characteristics. Variable load analysis is another example where variable load can cause fluctuations in motor performance. Mathcad's dynamic simulations enable engineers to study how the motor responds to load changes, and develop and test strategies for performance stabilization. Developing control algorithms often requires complex algorithms that can be modelled and tested in Mathcad, including PID controllers, adaptive controls, and other advanced techniques [6, 7].

Using software tools such as Mathcad is an essential component in the modern engineering approach to the design and analysis of electrical machines and motor drives. Mathcad offers powerful capabilities for dynamic state simulation, providing engineers with a tool for in-depth analysis and performance optimization. These capabilities enhance the efficiency of the design process and reduce risks and costs associated with the development of new technologies and systems.

In the following chapters, specific applications of Mathcad will be explored in more detail, present case studies, and analyse the advantages and challenges this tool brings to electrical machine simulation.

2. MATHCAD SOFTWARE ADVANGAES

Mathcad is a powerful software application for engineering calculations, combining a robust mathematics engine with an intuitive interface that allows users to solve, document, and share their calculations. Mathcad uses a worksheet interface where equations, text, and images can be input in a free-form manner. This format simplifies documenting calculations and adding explanatory notes and graphics. The worksheet allows for live, dynamic updating of results as changes are made, providing immediate feedback. Equations can be entered in standard mathematical notation, enhancing readability and comprehension of complex equations. Mathcad supports a wide range of mathematical functions, including algebra, calculus, differential equations, and linear algebra.

One of Mathcad's significant features is its built-in support for units, enabling users to perform calculations with units and handle unit conversions automatically. This is particularly beneficial in engineering and scientific applications where units are crucial.

Mathcad supports both symbolic (exact) and numeric (approximate) calculations, allowing users to solve equations either symbolically for exact solutions or numerically for practical, approximate solutions. The software can perform symbolic manipulation of equations, such as simplification, differentiation, and integration.

The software can generate 2D and 3D plots and graphs, allowing users to visualize data and functions, which is useful for analysing trends and patterns. These graphs and plots are interactive and update automatically when the underlying data or equations change.

Mathcad can import and export data from various sources, including Excel and other data formats, allowing for seamless integration with other tools and datasets. It provides tools for data fitting, interpolation, and statistical analysis.

Additionally, Mathcad includes a simple programming language for writing scripts and functions within worksheets, automating repetitive tasks, and extending the software's capabilities. Users can create custom functions and use control flow statements like loops and conditionals.

Key Benefits of Using Mathcad can be formulated as follows: **Ease of Use:** The intuitive interface and natural math notation make it accessible to engineers and scientists who may not be programming experts. **Integration of Documentation and Calculation:** Combining both documentation and calculations in one place ensures clarity and reduces the risk of errors. **Dynamic Updating:** Automatic updates of results in response to changes help maintain accuracy and save time.

3. IM MATH. MODEL AND CORRESPONDING DYNAMIC CHARACTERISTICS

To develop the mathematical model of an Induction Machine (IM), Clarke and Park transformations should be applied to the 3-phase stator and rotor voltage equations [2]. After applying these coordinate transformations, the IM model related to the stator and rotor circuit can be represented by a set of equations in the stationary αβ reference frame (1).

$$
\begin{aligned}
u_{s\alpha} &= R_s \cdot i_{s\alpha} + \frac{d\psi_{s\alpha}}{dt} \\
u_{s\beta} &= R_s \cdot i_{s\beta} + \frac{d\psi_{s\beta}}{dt} \\
u_{r\alpha} &= R_r \cdot i_{r\alpha} + \frac{d\psi_{r\alpha}}{dt} + p \cdot \omega \cdot \psi_{r\beta} \\
u_{r\beta} &= R_r \cdot i_{r\beta} + \frac{d\psi_{r\beta}}{dt} - p \cdot \omega \cdot \psi_{r\alpha}
\end{aligned}
, \qquad (1)
$$

where: $u_{s\alpha\beta}/u_{r\alpha\beta}$ are stator/rotor voltages, $i_{s\alpha\beta}/i_{r\alpha\beta}$ stator/rotor currents and $\psi_{s\alpha\beta}/\psi_{r\alpha\beta}$ machine stator/rotor flux linkages in stationary αβ frame. R_s/R_r stands for stator and rotor resistances, p number of pole pairs and ω machine speed.

Corresponding expressions for stator and rotor flux linkages can be given by set of equations (2):

$$
\begin{aligned}
\psi_{s\alpha} &= L_s i_{s\alpha} + L_m i_{r\alpha} = \Lambda_s i_{s\alpha} + L_m \left(i_{s\alpha} + i_{r\alpha}\right) \\
\psi_{s\beta} &= L_s i_{s\beta} + L_m i_{r\beta} = \Lambda_s i_{s\beta} + L_m \left(i_{s\beta} + i_{r\beta}\right) \\
\psi_{r\alpha} &= L_r i_{r\alpha} + L_m i_{s\alpha} = \Lambda_r i_{r\alpha} + L_m \left(i_{r\alpha} + i_{s\alpha}\right) \\
\psi_{r\beta} &= L_r i_{r\beta} + L_m i_{s\beta} = \Lambda_r i_{r\beta} + L_m \left(i_{r\beta} + i_{s\beta}\right)
\end{aligned}
. \qquad (2)
$$

Additionally, mechanical part of the corresponding machine model can be described by (3):

$$\frac{J_m}{p}\frac{d\omega}{dt}=\frac{3}{2}p\left(\Psi_{s\alpha}i_{s\beta}-\Psi_{s\beta}i_{s\alpha}\right)-m_l-m_{fv}\,, \tag{3}$$

where: L_s/L_r are stator and rotor inductances, L_m mutual inductance, λ_s/λ_r stator and rotor leakage inductances, J_m moment of inertia, m_l load torque, m_{fv} friction torque and $M_t=m_l+m_{fv}$.

To simulate the machine dynamic characteristics in Mathcad, it is necessary to define all the drive parameters as well as the supply conditions. After defining the motor parameters (given in Table 1), the load and friction torque profile, it is also necessary to define in Mathcad the complete mathematical model of the IM machine given by the voltage equations (1), the flux-current relationships of the machine (2), and the mechanical equation (3).

Table 1. *3-ph IM 1ZK 160 L-6 parameters*

***U*ₙ [V]**	400	***R*ₛ [Ω]**	1.2	***L*ₛ [H]**	0.148
***I*ₙ [A]**	25.7	***R*ᵣ [Ω]**	1.3	***L*ᵣ [H]**	0.149
***P*ₙ [kW]**	11	***n*ₙ [min⁻¹]**	957	***L*ₘ [H]**	0.142

After entering the described mathematical model of the machine, it is necessary to select an ODE solver (Ordinary Differential Equations solver) in Mathcad. The chosen ODE solver is the function **rkfixed**, which uses the fourth-order Runge-Kutta fixed-step method and provide satisfactory results with small computational burden needed. The definition of the differential matrix, as well as the initial conditions, simulation time frame, and calculation step, is given by the following system of equations (4):

$$D(t,x):=\begin{bmatrix}\sqrt{2}U_f\cos(\omega_1 t)-R_s i_{s\alpha}\left(x_0,x_2\right)\\ \sqrt{2}U_f\sin(\omega_1 t)-R_s i_{s\beta}\left(x_1,x_3\right)\\ -R_r i_{r\alpha}\left(x_0,x_2\right)-px_4x_3\\ -R_r i_{r\beta}\left(x_0,x_2\right)+px_4x_3\\ \frac{1}{J_m}\left[\frac{3p}{2}\left(x_0 i_{s\beta}\left(x_1,x_3\right)-x_1 i_{s\alpha}\left(x_0,x_2\right)\right)-m_l\left(x_4\right)-m_{fv}\left(x_4\right)\right]\end{bmatrix} \tag{4}$$

$$t_0:=0 \qquad t_k:=2 \qquad N:=30000$$
$$z:=\mathrm{rkfixed}\left(x,t_0,t_k,N,D\right)$$

where variables $x_0 \ldots x_4$ represent $\Psi_{s\alpha}$, $\Psi_{s\beta}$, $\Psi_{r\alpha}$, $\Psi_{r\beta}$ *and* ω respectively and N number of samples.

For a graphical representation of the results of characteristic dynamic quantities of the machine within a given time frame during acceleration (t_0=0 - t_k=2s), it is necessary to define a 2D graph X-Y plot by simply defining the quantities for the abscissa and ordinate. The obtained results are shown in Fig. 1 (in SI units).

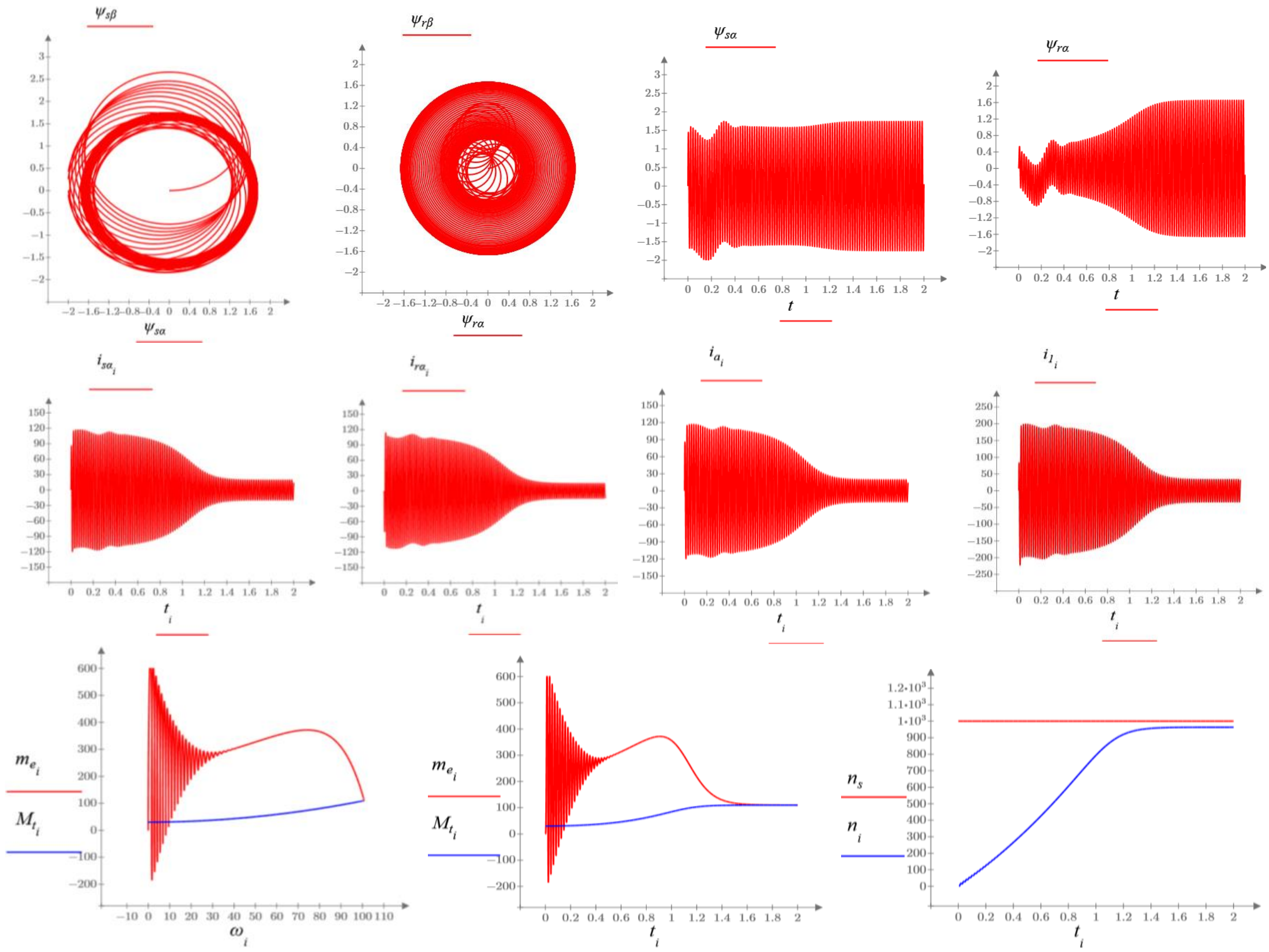

Figure 1. *IM characteristic during the startup: machine stator and rotor flux in αβ plane and corresponding time shapes (top row); stator/rotor (isα/irα) current in α axis, phase/line (isa/il) stator currents (middle row); torque-speed characteristic, electromagnetic (me), load torque (Mt) and machine speed (bottom row)*

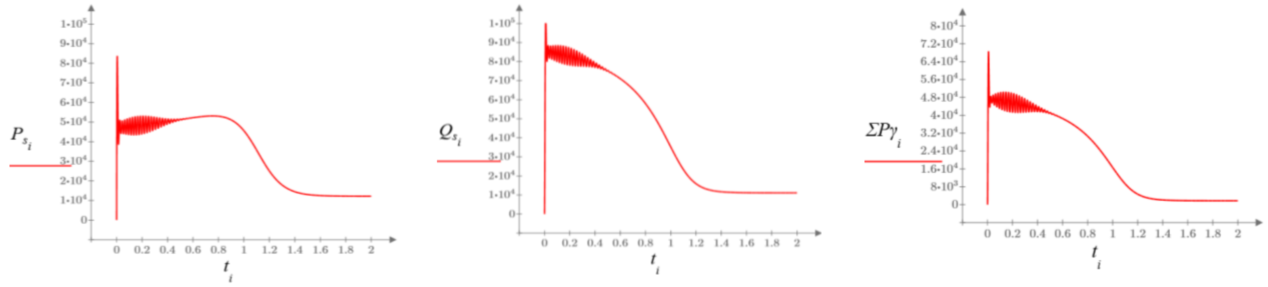

Figure 2. *Active, reactive power and overall machine losses during the startup*

Besides the quantities showed in Fig. 1 other important machine variables during the described time frame can be visualised and analysed. One of these are active/reactive power and overall machine losses during the startup shown in Fig. 2.

The time-domain representation of the displayed quantities is significant for the power flow analysis within the machine, total losses, as well as the change in reactive power that can be efficiently compensated by appropriate power factor correction devices. A significant advantage of using Mathcad software is its ability to dynamically update results and corresponding graphical displays with each change in input parameters or simulation conditions. This advantage of Mathcad software enables faster analysis of the dynamic behaviour of IM compared to similar software.

4. DESIGNING ROTOR RESISTANCE STARTER OF HIGH POWER IM

When it comes to high-power machines, rotor resistance starters (Fig. 3) are usually used for starting instead of appropriate high-power converters as a more economical solution. Sizing these rotor resistance starters typically requires a detailed iterative mathematical analysis and consideration of a large number of parameters that affect the limitation of the starting currents of the stator and rotor of the machine (I_s and I_p respectively). Here is described design procedure of the IM rotor resistance starter used during the start-up of the high-power IM by Mathcad. Namely, a 2.1 MW 3-ph wounded rotor (slip-ring) induction machine is analysed with and without rotor resistance starter applied during startup. Detailed IM parameters are given in Table 2.

Table 2. *IM 3 AKVh 1407-8 KONCAR parameters*

U_n [kV]	3.46	R_s [Ω]	0.030	L_s [H]	0.879
I_n [kA]	0.24	R_r [Ω]	0.016	L_r [H]	0.797
P_n [MW]	2.1	n_n [min^{-1}]	743	L_m [H]	0.796

The number of starter sections k and corresponding starter resistance values r_k are calculated by Mathcad using a predefined loop given by (5), where R_0 is overall rotor resistance with starter and s_1 is machine slip at the end first resistance starter level, that is the ratio of I_{p_max}/I_{p_min} during startup.

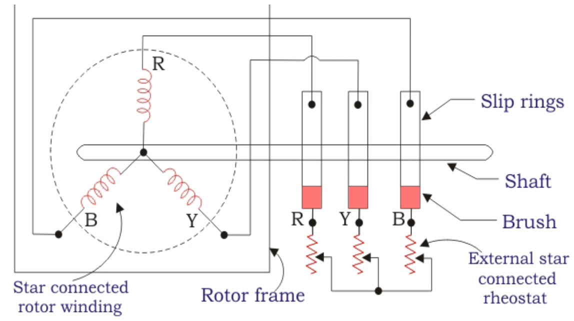

Figure 3. *IM rotor resistance starter operation*

$$r_k := \left\| \begin{array}{l} \text{if } k \le 8 \\ \quad \left\| \left(R_0 \cdot s_1^{(k-1)} \cdot (1 - s_1)\right) \right. \\ \text{if } Z < k \le 9 \\ \quad \left\| 0 \right. \end{array} \right| \quad . \tag{5}$$

The short ***if*** loop defined by (5) is based on relation describing machine slip and rotor resistance R_r (6) allowing automatic calculation of the appropriate rotor resistances depending on the desired number of rotor resistance levels Z.

$$s_1 = \sqrt[Z]{\frac{R_r}{R_0}} \quad . \tag{6}$$

Two sets of rotor resistance starters are analysed, one with 6 and other with 8 resistance levels. Resulting resistance values for both cases are shown in Table 3.

Table 3. *6-level rotor resistance starter values*

r_1 [s]	r_2 [s]	r_3 [s]	r_4 [s]	r_5 [s]	r_6 [s]
0.463	0.234	0.119	0.06	0.03	0.015

8-level rotor resistance starter values

r_1 [s]	r_2 [s]	r_3 [s]	r_4 [s]	r_5 [s]	r_6 [s]	r_7 [s]	r_8 [s]
0.95	0.56	0.33	0.19	0.11	0.06	0.028	0.011

In Fig. 4, the starting currents of the stator and rotor are shown for 6 (left) and 8 (right) added rotor resistance values. The initial stator and rotor currents exceed 1200A and 3600A, respectively, and must be limited during the machine's acceleration. The torque/speed characteristics at the bottom of Fig. 4 are compared with the constant load torque characteristic.

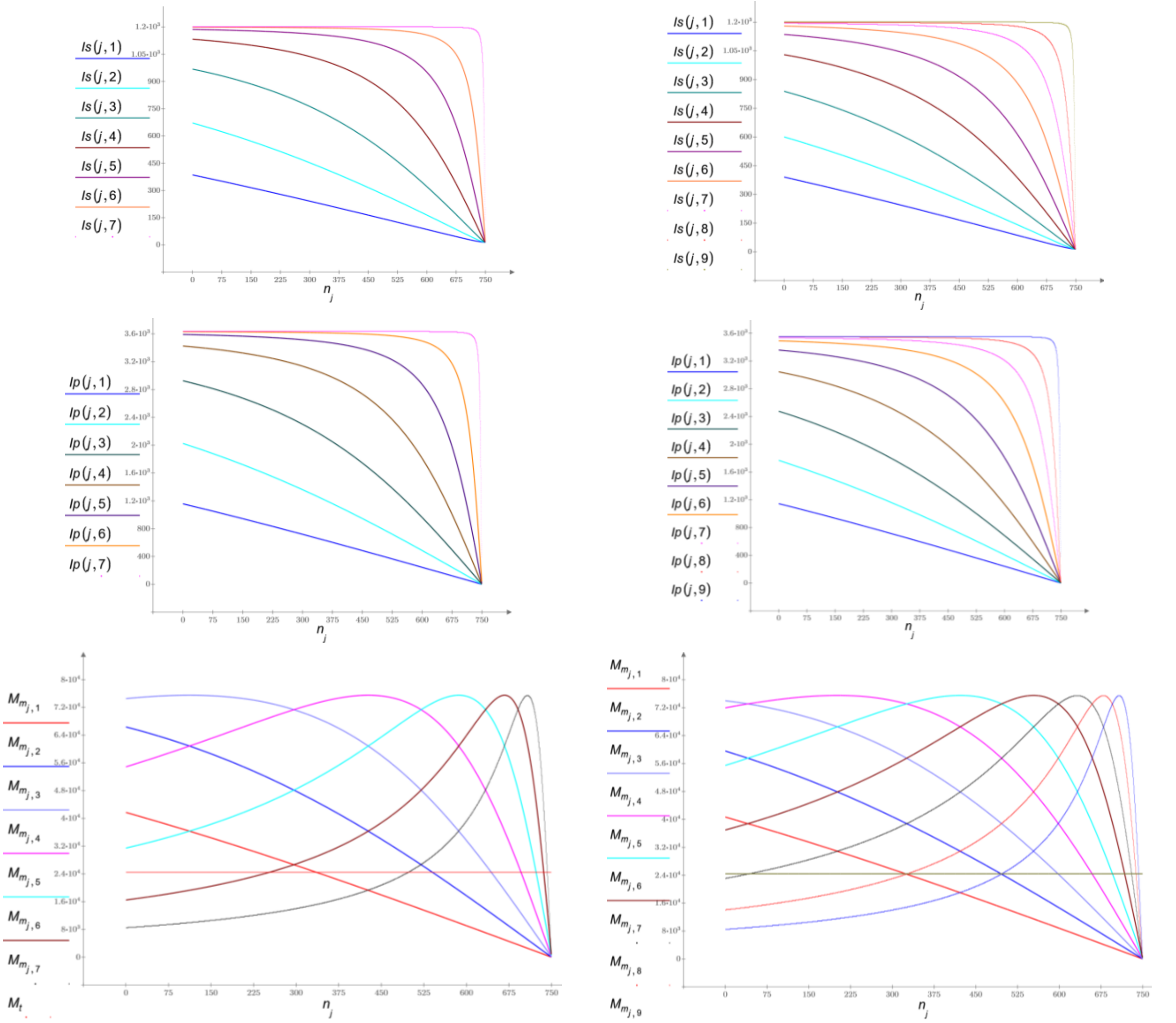

Figure 4. *IM stator (Is) and rotor (Ip) currents, and corresponding torque vs speed characteristics for different values of added rotor resistances: 6 values (left), 8 values (right)*

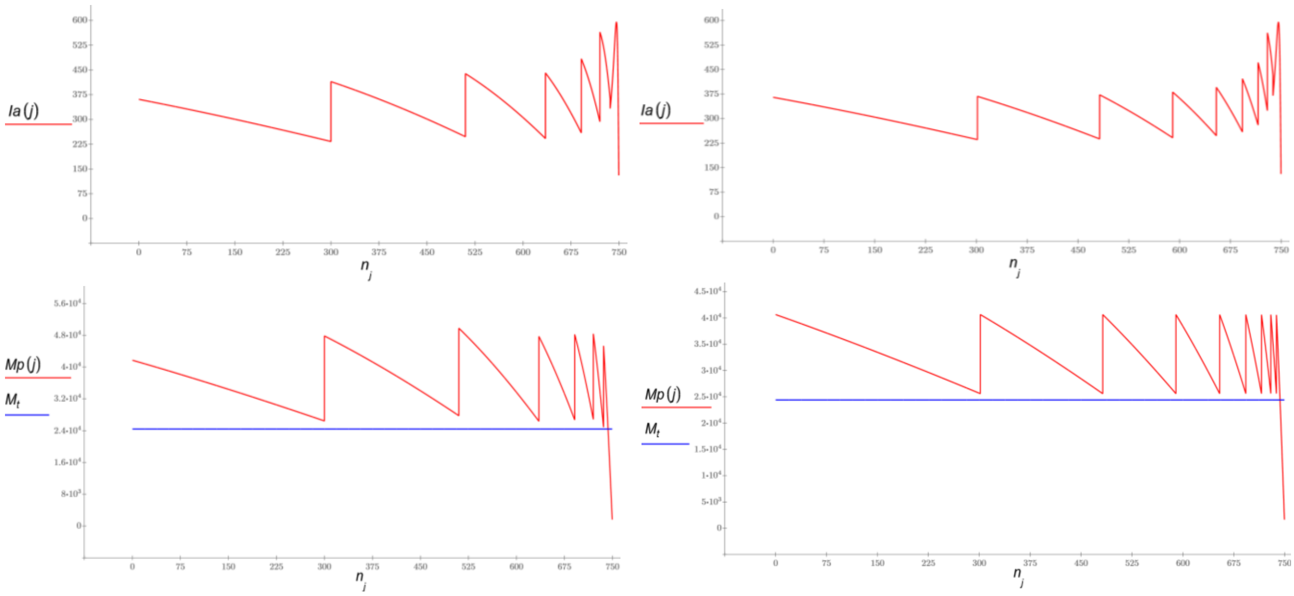

Figure 5. *Resulting IM stator current in a phase (Ia) and torque (Mt - load and Mp – starting machine torque) with 6 level (left) and 8 level (right) resistance starter*

By adding appropriate resistances to the rotor circuit, the maximum starting currents in the stator and rotor can be effectively controlled. This control is achieved by adjusting the switching times of individual resistors in the rotor circuit. Since changes in stator currents correlate with machine speed and slip, the correct resistance values and their switching times can be determined (Table 4).

Defining the switching times for the rotor starter levels results in the stator's starting currents for both cases with 6 and 8 resistor levels, shown in Fig. 5. The stator currents are significantly reduced, ranging from 230A to 600A. Higher starting stator currents correspond to higher speeds and shorter activity periods of the respective resistor levels. The specific switching times for each of the 6 or 8 levels are provided in Table 4.

Table 4. *6-level rotor resistance starter times*

t_1 [s]	t_2 [s]	t_3 [s]	t_4 [s]	t_5 [s]	t_6 [s]
13.054	6.209	4.113	1.879	0.944	0.838

8-level rotor resistance starter times

t_1 [s]	t_2 [s]	t_3 [s]	t_4 [s]	t_5 [s]	t_6 [s]	t_7 [s]	t_8 [s]
16.3	9.73	5.82	3.48	2.08	1.24	0.744	0.445

In the upper part of Fig. 5, the resulting starting current of one stator phase is shown, while in the lower part, the resulting torque-speed characteristic of the machine with the load characteristic is displayed. It should be noted that the resulting torque characteristic during startup does not take values lower than the load torque to ensure a successful startup. Since the activation times of individual starter steps are different, by knowing the current and the resulting resistance values, Mathcad enables a simple calculation of the voltage change at the ends of the starter as well as the thermal losses on individual steps needed for the proper sizing of the starter power.

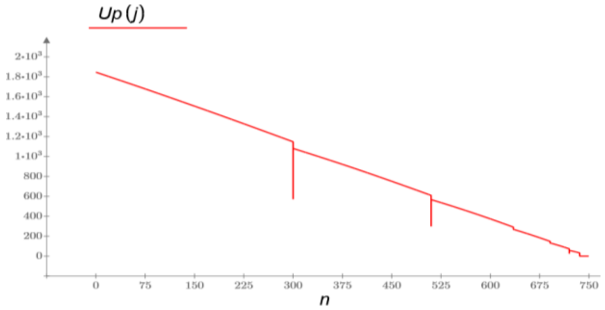

Figure 6. *Resulting voltage across resistance starter during the startup*

Fig. 6 shows that maximal voltage across rotor starter (*Up*) correspond to low speeds and decreases as machine speeds up. This voltage profile together with corresponding starter currents and times form Table 4. allows an engineer to determine energy dissipation and thermal analysis of starter resistance during its designing procedure.

5. THERMAL STRESS ANALYSIS OF IM

International Electrotechnical Commission standard for rotating electrical machines IEC 60034-1 (corresponding Serbian version SRPS IEC 60050-411) [8]) defines different electric drive classification in terms of their operation regime (duty type) and corresponding heating during the defined operation.

Heating of an electric machines within the drive depends on overall losses and electric drive duty type. A well-known conclusion from Montsinger's thermal degradation model [9] indicates that operating just 8°C above the allowed insulation temperature of the windings halves the working life of an electric machine. Therefore, it is necessary to ensure that the maximum allowable temperature of the machine's windings does not exceed the permissible temperature specified by the insulation class of the machine windings. Having said that, it's very important to monitor or estimate machine temperature during different machine operating regimes. This kind of machine thermal analysis and corresponding thermal modelling and simulation is mandatory during first stages of the machine design. Moreover, during the machine exploitation additional thermal analysis should be performed if machine duty type is changed or higher number of startups per hour is expected.

Starting from thermal equilibrium relation (7) it is possible to deliver relations defining thermal heating (8) and cooling of an electrical machine (9).

$$Q \cdot dt = A \cdot \theta \cdot dt + C \cdot d\theta \,, \tag{7}$$

$$\theta = \frac{Q}{A}\left(1 - e^{-\frac{A}{C}t}\right) + \theta_0 e^{-\frac{A}{C}t} \,, \tag{8}$$

$$\theta = \theta_n e^{-\frac{t}{T_0}} \,, \tag{9}$$

where, Q represents machine power losses responsible for heat, θ machine temperature, A specific heat dissipation or emissivity, C specific heat capacity of the material of the machine body.

By defining this set of equations in Mathcad and entering the basic parameters of the machine along with the necessary data related to the insulation class and heating/cooling constants (Table 5), it is possible to obtain all the necessary information related to the thermal stress of the machine during changes in the duty cycle. Specifically, when changing the machine's load or the intermittence of the drive, the machine's (windings) heating profile will differ over time. It is necessary to check the thermal stress on the windings depending on the insulation class (F=100°C).

Table 5. *3ph IM 30kW, DT: S3 parameters*

P_n [kW]	30	C [kWs/kg°C]	0.48
η [%]	90	A [kW/C]	0.0284
P_n [kW]	30	*Th. cl. (F)*	100°
Tz [min]	45	Th [min]	60

In this particular task of thermal stress analysis, the focus was on machine load increase by 10% with an intermittence of 70% of S3 duty type drive. The result of comparing the thermal stress during continuous operation and the described change at an unusually low ambient temperature of θ_a=-15°C is shown in Fig. 7.

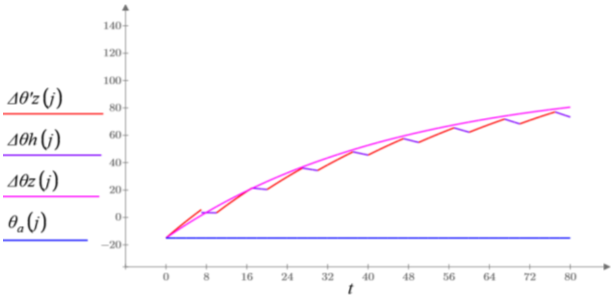

Figure 7. *Machine heating diagram in case of continuous duty and intermittent duty (ε=70%) with 10% overload (Δθ_z heating temp., Δθ_h cooling temp., Δθ'_z overall temperature)*.

Fig. 7 shows that 10% machine overload with ε=70% will not jeopardise machine windings in terms of overheating since maximal temperature doesn't reach temperature defined by insolation class F. Moreover, the resulting machine temperature with 10% overload and ε=70% (S3) doesn't exceeds the temperature in comparison with resulting machine temperature during the continuous duty (S1) which proves that changing machine operating regime in this way is safe form thermal aspect.

Simple changes to input parameters, such as intermittent duty, load, or changes in the machine's loss values, lead to the automatic recalculation of all other defined equations and graphs in the Mathcad file. Fig. 8 shows the case of a change in the percentage of losses in the machine, i.e., the efficiency level, resulting in faster heating of the machine at the same load and duty cycle.

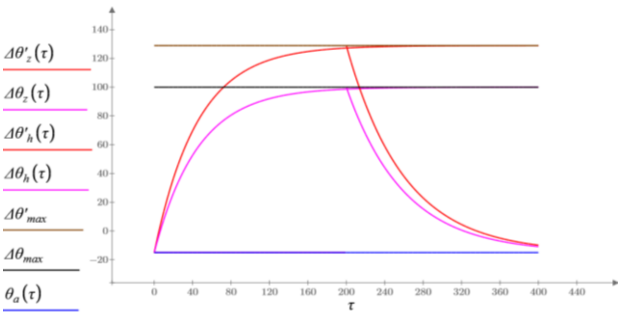

Figure 8. *Machine heating diagram in case of increased machine losses*

It can be noted form Fig. 8 that increased losses or reduced efficiency cause the machine to reach significantly higher temperatures. This consequently necessitates either a reduction in the machine's load or a change in the duty cycle.

6. CONCLUSION

The presented paper provides a brief overview of Mathcad software's capabilities in determining and visualizing the static and dynamic characteristics of induction machines. It showcases the specific characteristics of an IM during the startup period and the procedure for selecting the appropriate resistance levels for the rotor resistance starter for high power IM. Moreover, Mathcad possibilities are presented in terms of thermal aspect analysis of the machine in case of changed duty cycle and machine efficiency followed by appropriate discussion.

ACKNOWLEDGEMENTS

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Modelling and Analysis of an Aquifer System to Enhance Teaching in Control Systems

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Abstract: *This paper aims to demonstrate how analysing a practical example, such as an aquifer system, can enhance understanding of the Control Systems course teaching materials. The aquifer system was chosen because it is a multivariable system with multiple inputs and outputs, and thus has numerous variables that can be monitored over time. This makes it suitable for both time and frequency domain analysis using various MATLAB tools. Since the system is nonlinear, it was necessary to linearize it. A Taylor series expansion approach was used for this purpose. The linearized model was represented in both state-space form and as a block diagram. The state-space model was suitable for testing the controllability and observability of the system, while the block diagram model was used to assess stability and analyse the system's behaviour during transient and steady states.*

Keywords: *aquifer; nonlinear system; multivariable system; state-space model; block diagram model;*

NOMENCLATURE

q_{ik}[m³/s] The flow rate of liquid into the k-th tank;

q_{ok}[m³/s] The flow rate of liquid out of the k-th tank;

q_k[m³/s] The flow rate between tanks;

q_{21}[m³/s] The flow rate between Tank 1 and Tank 2;

d_k[m] Diameter of flow area between tanks;

d_{21} [m] Diameter of flow area between Tank 1 and Tank 2;

a_k[m²] Cross-section of flow area between tanks; $a_k = d_k^2\pi/4$;

a_{21}[m²] Cross-section of flow area between Tank 1 and Tank 2; $a_{21} = d_{21}^2\pi/4$;

D_k [m] Diameter of the k-th rank;

S_k[m²] The cross-sectional area of k-th tank; $S_k = D_k^2\pi/4$;

h_k[m] Height of liquid in the k-th tank;

H_1[m] The reference value of the liquid in the first tank;

h_{ks} [m] Stationary value of the height of liquid in the k-th tank;

g[m/s²] Ground acceleration;

1. INTRODUCTION

In recent years, there has been a lack of motivation among students to listen to classes in certain subjects. In student surveys that are carried out during the year, and are carried out for the purpose of self-evaluation, poorer grades are observed on the question of whether the knowledge acquired in this subject will be useful for their future professional work. Even in subjects where practical application is obvious, students are disinterested and do not see the purpose of learning certain teaching contents.

When talking about control systems, the first thing that comes to mind is physical systems in industrial processes. However, physical systems are also encountered in everyday life. For example, controlling the temperature and speed of a vehicle, as well as regulating temperature in apartments, refrigerators, and stoves. There are also numerous real systems in nature that are not physical but still represent control systems. One example is the human body. The regulation of body temperature and maintaining blood pH are examples of such systems. Also, one of the earliest models of physiological control systems is the pupil light reflex. This reflex involves the iris responding to changes in light intensity on the retina. As ambient light levels increase or decrease, the iris muscles adjust the pupil size to maintain a consistent amount of light reaching the retina. Furthermore, the natural process of groundwater storage and utilization is an example of a control system. These systems are highly complex, but like physical systems, they can be modelled and simplified for analysis and synthesis purposes [1, 2].

This paper aims to showcase how to apply some of the teaching materials from the Control Systems subject using the aquifer system as an example. We chose this example because the aquifer system is a multivariable system with multiple inputs and outputs, along with many variables that can be monitored over time. This makes it suitable for analysis in the state-space and is also interesting for applying MATLAB tools.

An aquifer represents a geological environment completely or partially saturated with free underground water, capable of accumulating and releasing free underground water that feeds springs, freely flows into rivers, lakes, and seas, and is captured by various water-receiving facilities (wells, water-receiving ditches, etc.) [3]. Aquifer systems are used to supply drinking water, for industrial purposes, or in agriculture for irrigation [1, 4, 5, 6, 7]. Such a system can be modelled with three interconnected reservoirs with corresponding liquid levels, called heads [1]. Groundwater naturally flows through aquifer material, which can be permeable or fractured rocks, or unconsolidated materials such as gravel, sand, or silt, altering water levels in reservoirs as it makes its way to the sea or river. The aquifer is made up of three main layers from top to bottom: the groundwater, the saturated zone, and the impermeable layer.

The deepest layer, the impermeable layer, prevents further downward movement of water, causing it to gather and move horizontally. This process plays a crucial role in the water cycle and the geological cycle.

In reality, single aquifers are rare in hydraulic systems. An aquifer is usually part of a larger system comprising multiple aquifers. This system consists of a series of aquifers separated by less permeable confining layers. The flow dynamics in such a system can be quite complex, depending on how well the individual aquifers are connected hydraulically [5].

In the first part, a description of the system, its modelling, and linearization will be provided. Subsequently, the model will be presented in both state-space form and as a block diagram. The results will highlight significant features of the system achieved through these modeling approaches. The state-space model will be used to test controllability and observability, while the block diagram model will be applied to assess stability and analyse and to improve the system's behaviour during transient and steady state.

2. THE SYSTEM MODEL

In Fig.1 a variant of the model of aquifer system consisting of three interconnected horizontally placed natural storage tanks is presented [1]. Natural water flow is towards the sea or river with the flows q_1, q_2, and q_3. The water level of the k-th tank is h_k, k=1, 2, 3. Engineered flow is from the Tank 2 to the Tank 1. If the water level in Tank 1, denoted as h_1, drops below the reference value H_1, it will be refilled with water from Tank 2. Conversely, if h_1 is higher than H_1, water will be pumped back to Tank 2, reducing the leakage towards the sea. The water flow between Tanks 1 and 2 is indicated as q_{21} and is dependent on the difference in water levels between H_1 and h_1.

The water in an aquifer system can be naturally replenished through processes such as rain, snow, irrigation return flow, and seawater intrusion, or artificially replenished through methods like filling tanks from wells [6, 7]. The artificial replenishment is illustrated using flows q_{ik}, k=1, 2, 3 in Fig. 1. Underground water can be utilized for industrial, domestic, and irrigation purposes. These are represented by flows q_{ok}, where k= 2, 3.

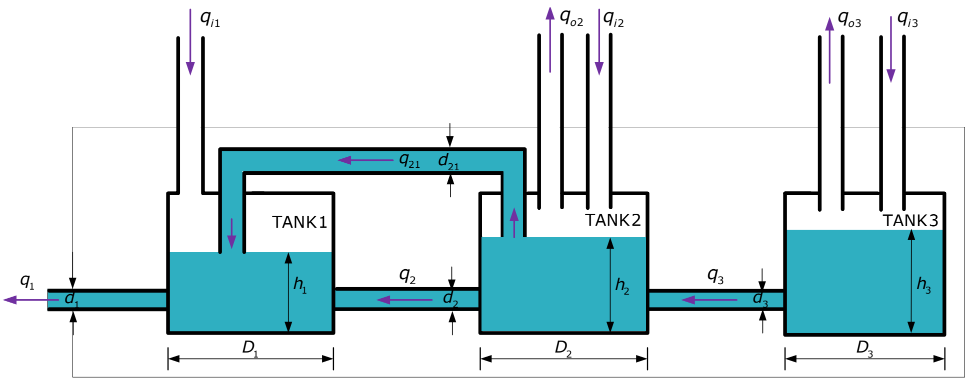

Figure 1. *Model of the aquifer system [1]*

2.1. Mathematical modelling of the system

The nonlinear mathematical model of the aquifer system can be derived using the mass balance equation. The equations that describe the dynamics of each aquifer are as follows:

$$S_1 \frac{dh_1}{dt} = q_{i1} + q_2 - q_1 + q_{21}, \tag{1}$$

$$S_2 \frac{dh_2}{dt} = q_{i2} - q_{o2} + q_3 - q_2 - q_{21}, \tag{2}$$

$$S_3 \frac{dh_3}{dt} = q_{i3} - q_{o3} - q_3. \tag{3}$$

Relations (1) -(3) can be written as:

$$S_1\frac{dh_1}{dt} = q_{i1} + \alpha_2\sqrt{h_2 - h_1} - \alpha_1\sqrt{h_1} + \alpha_{21}\sqrt{H_1 - h_1}, \quad (4)$$

$$S_2\frac{dh_2}{dt} = q_{i2} - q_{o2} + \alpha_3\sqrt{h_3 - h_2} - \alpha_2\sqrt{h_2 - h_1} - \alpha_{21}\sqrt{H_1 - h_1}, \quad (5)$$

$$S_3\frac{dh_3}{dt} = q_{i3} - q_{o3} - \alpha_3\sqrt{h_3 - h_2}, \quad (6)$$

where

$$\begin{aligned}\alpha_1 &= a_1\sqrt{2g},\ \alpha_2 = a_2\sqrt{2g},\\ \alpha_3 &= a_3\sqrt{2g},\ \alpha_{21} = a_{21}\sqrt{2g}.\end{aligned} \quad (7)$$

2.2. The model linearization

After linearizing the model using a Taylor series expansion around the stationary state, the linearized model is obtained in the following form:

$$S_1\frac{dh_1}{dt} = q_{i1} + B_2(h_2 - h_1) - B_1h_1 + B_{21}(H_1 - h_1), \quad (8)$$

$$S_2\frac{dh_2}{dt} = q_{i2} - q_{o2} + B_3(h_3 - h_2) - B_2(h_2 - h_1) - B_{21}(H_1 - h_1), \quad (9)$$

$$S_3\frac{dh_3}{dt} = q_{i3} - q_{o3} - B_3(h_3 - h_2), \quad (10)$$

where

$$\begin{aligned}B_1 &= \frac{a_1\sqrt{2g}}{2\sqrt{h_{1s}}},\ B_2 = \frac{a_2\sqrt{2g}}{2\sqrt{h_{2s} - h_{1s}}},\\ B_3 &= \frac{a_3\sqrt{2g}}{2\sqrt{h_{3s} - h_{2s}}},\ B_{21} = \frac{a_{21}\sqrt{2g}}{2\sqrt{H_1 - h_{1s}}}.\end{aligned} \quad (11)$$

2.3. The state-space model of the system

According to (8)-(10), by selecting the liquid levels in the tanks as state variables

$$x_1 = h_1,\ x_2 = h_2,\ x_3 = h_3, \quad (12)$$

and by defining the input and output vectors as

$$\boldsymbol{u} = \begin{bmatrix} q_{i1} + B_{21}H_1 \\ q_{i2} - q_{o2} - B_{21}H_1 \\ q_{i3} - q_{o3}\end{bmatrix},\ \boldsymbol{y} = \begin{bmatrix} h_1 \\ h_2 \\ h_3\end{bmatrix}, \quad (13)$$

the state-space model of the system (14) can be formed,

$$\begin{aligned}\dot{\boldsymbol{x}} &= \boldsymbol{Ax} + \boldsymbol{Bu},\\ \boldsymbol{y} &= \boldsymbol{Cx},\end{aligned} \quad (14)$$

where the state, input and output matrices respectively are:

$$\boldsymbol{A} = \begin{bmatrix} -\frac{B_1 + B_2 + B_{21}}{S_1} & \frac{B_2}{S_1} & 0 \\ \frac{B_2 + B_{21}}{S_2} & -\frac{B_3 + B_2}{S_2} & \frac{B_3}{S_3} \\ 0 & \frac{B_3}{S_3} & -\frac{B_3}{S_3}\end{bmatrix},$$
$$\boldsymbol{B} = \begin{bmatrix} \frac{1}{S_1} & 0 & 0 \\ 0 & \frac{1}{S_2} & 0 \\ 0 & 0 & \frac{1}{S_3}\end{bmatrix},\ \boldsymbol{C} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1\end{bmatrix}. \quad (15)$$

Simulink state-space model of the aquifer system given with (13), (14), and (15), is shown in Fig.2.

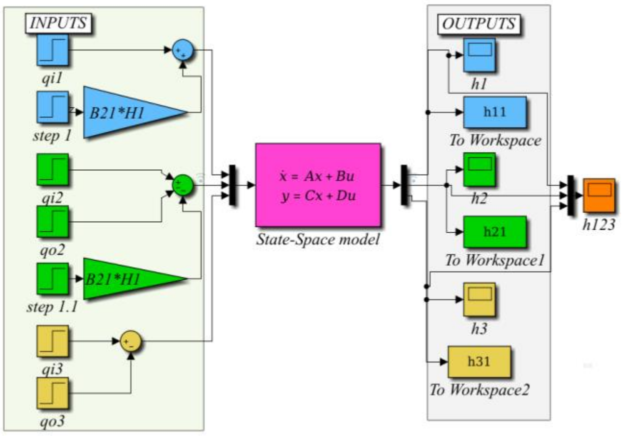

Figure 2. *The state-space model of the aquifer system.*

2.4. The transfer function model of the system

The transfer system model can be obtained by transforming equations (8), (9), and (10) into the Laplace domain:

$$\begin{aligned}h_1(T_1s + 1) &= (q_{i1} + B_{21}H_1)k_{11} + k_{12}h_2,\\ h_2(T_2s + 1) &= (q_{i2} - q_{o2} - B_{21}H_1)k_{21} + k_{22}h_1 + k_{23}h_3,\\ h_3(T_3s + 1) &= (q_{i3} - q_{o3})k_{31} + h_2,\end{aligned} \quad (16)$$

where

$$T_1 = \frac{S_1}{B_1 + B_2 + B_{21}},\ T_2 = \frac{S_2}{B_2 + B_3},\ T_3 = \frac{S_3}{B_3}, \quad (17)$$

$$\begin{aligned}k_{11} &= \frac{1}{B_1 + B_2 + B_{21}},\ k_{12} = \frac{B_2}{B_1 + B_2 + B_{21}},\\ k_{21} &= \frac{1}{B_2 + B_3},\ k_{22} = \frac{B_2 + B_{21}}{B_2 + B_3},\\ k_{23} &= \frac{B_3}{B_2 + B_3},\ k_{31} = \frac{1}{B_3}.\end{aligned} \quad (18)$$

The block diagram, created using the transfer function model of the system (16), is illustrated in Fig.3.

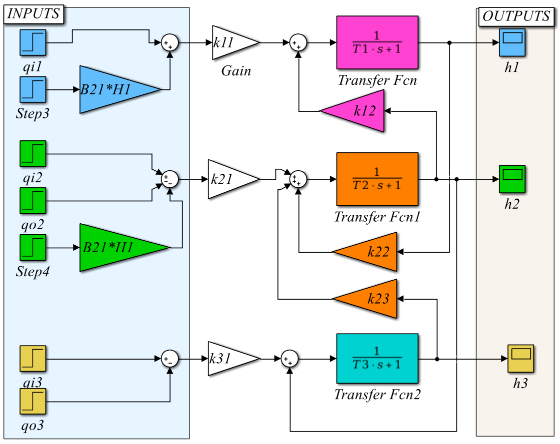

Figure 3. *The block diagram of the aquifer system in open loop.*

3. RESULTS

Table 1 shows the adopted parameters of the aquifer system. It was chosen $d_1=d_2=d_3=d_{21}=d$ and $D_1=D_2=D_3=D$ which implies $a_1=a_2=a_3=a_{21}=a$, and $S_1=S_2=S_3=S$.

Table 1. *Adopted parameters of the aquifer system*

Symbol	Value	Unit
h_{1s}	20	m
H_1	30	m
h_{2s}	30	m
h_{3s}	50	m
a	0.1963	m^2
S	314.1593	m^2

Table 2. *Adopted values of flows of the aquifer system*

Symbol	Value	Unit
q_{i1}	$15.768\cdot10^6$	m^3/year
q_{i2}	$189.216\cdot10^6$	m^3/year
q_{i3}	$94.608\cdot10^6$	m^3/year
q_{o2}	$47.304\cdot10^6$	m^3/year
q_{o3}	$69.379\cdot10^6$	m^3/year

Based on the state-space model (Fig. 2) and the corresponding block diagram (Fig. 3), the outputs of the aquifer system, which are the liquid heights in Tanks 1, 2, and 3, for the given inputs defined within Table 2, are shown in Fig. 4.

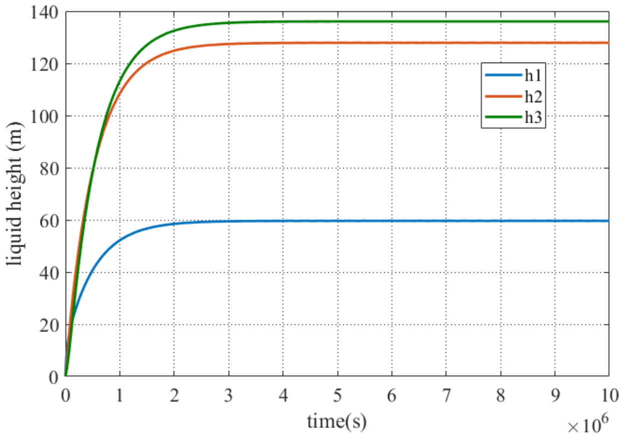

Figure 4. *The outputs of the aquifer system.*

It can be seen that the stationary state is reached after $5\cdot10^6$s which is equivalent to 57.87 days.

3.1. Results obtained on the basis of state-space models

The Kalman test is a method for determining the controllability of a system. According to this test, a linear multivariable time-invariant system is completely controllable if and only if the rank of the controllability matrix

$$\boldsymbol{Q}_c = \begin{bmatrix} \boldsymbol{A} & \boldsymbol{AB} & \ldots & \boldsymbol{AB}^{n-1} \end{bmatrix} \tag{19}$$

is equal to n, where n is the number of state variables in the system.

$$\operatorname{rank} \boldsymbol{Q}_c = n\,. \tag{20}$$

After performing the Kalman test using the MATLAB package (n=3), it was found that the observed system is completely controllable. This means that it is possible to determine the values of the input vector $\boldsymbol{u}(t)$ that will transfer the system from an initial state $\boldsymbol{x}(0)$ to a desired state $\boldsymbol{x}(t)$, i.e. initial liquid levels to the desired liquid levels, within a finite time interval.

The Kalman test to determine observability is applied based on the following condition:

$$\boldsymbol{Q}_o = \begin{bmatrix} \boldsymbol{C}^T & \boldsymbol{A}^T\boldsymbol{C}^T & \ldots & (\boldsymbol{A}^T)^{n-1}\boldsymbol{C}^T \end{bmatrix}^T, \tag{21}$$

$$\operatorname{rank} \boldsymbol{Q}_o = n\,. \tag{22}$$

Given that the matrix $\boldsymbol{C}$ in our case is $\boldsymbol{C}=\boldsymbol{I}$ (15), observability – which indicates that each state $\boldsymbol{x}(t)$ can be entirely determined by measuring the output vector $\boldsymbol{y}(t)$ within a finite time interval – does not need to be checked.

3.2. Results obtained based on the block diagram

Based on the block diagram in Fig. 3, transfer functions can be determined for the inputs and outputs of interest. The derived transfer functions are as follows:

From input 1 to output 1

$$G_{11}(s) = \frac{0.0001273\, s^2 + 5.382\cdot 10^{-9} s + 2.76\cdot 10^{-14}}{s^3 + 8.967\cdot 10^{-5}\, s^2 + 1.607\cdot 10^{-9}\, s + 2.684\cdot 10^{-15}};$$

From input 1 to output 2

$$G_{12}(s) = \frac{4.459\cdot 10^{-9}\, s + 5.52\cdot 10^{-14}}{s^3 + 8.967\cdot 10^{-5}\, s^2 + 1.607\cdot 10^{-9}\, s + 2.684\cdot 10^{-15}};$$

From input 1 to output 3

$$G_{13}(s) = \frac{5.52\cdot 10^{-14}}{s^3 + 8.967\cdot 10^{-5}\, s^2 + 1.607\cdot 10^{-9}\, s + 2.684\cdot 10^{-15}};$$

From input 2 to output 1

$$G_{21}(s) = \frac{2.229\cdot 10^{-9}\, s + 2.76\cdot 10^{-14}}{s^3 + 8.967\cdot 10^{-5}\, s^2 + 1.607\cdot 10^{-9}\, s + 2.684\cdot 10^{-15}};$$

From input 2 to output 2

$$G_{22}(s) = \frac{0.0001273\, s^2 + 7.611\cdot 10^{-9}\, s + 7.472\cdot 10^{-14}}{s^3 + 8.967\cdot 10^{-5}\, s^2 + 1.607\cdot 10^{-9}\, s + 2.684\cdot 10^{-15}};$$

From input 2 to output 3

$$G_{23}(s) = \frac{1.576\cdot 10^{-9}\, s + 7.472\cdot 10^{-14}}{s^3 + 8.967\cdot 10^{-5}\, s^2 + 1.607\cdot 10^{-9}\, s + 2.684\cdot 10^{-15}};$$

From input 3 to output 1

$$G_{31}(s) = \frac{2.76\cdot 10^{-14}}{s^3 + 8.967\cdot 10^{-5}\, s^2 + 1.607\cdot 10^{-9}\, s + 2.684\cdot 10^{-15}};$$

From input 3 to output 2

$$G_{32}(s) = \frac{1.576\cdot 10^{-9}\, s + 7.472\cdot 10^{-14}}{s^3 + 8.967\cdot 10^{-5}\, s^2 + 1.607\cdot 10^{-9}\, s + 2.684\cdot 10^{-15}};$$

From input 3 to output 3

$$G_{33}(s) = \frac{0.0001273\, s^2 + 9.841\cdot 10^{-9}\, s + 1.023\cdot 10^{-13}}{s^3 + 8.967\cdot 10^{-5}\, s^2 + 1.607\cdot 10^{-9}\, s + 2.684\cdot 10^{-15}};$$

With MATLAB's sisotool, it is possible to obtain various diagrams to analyse the behaviour of the observed system in both transient and steady states. For example, Fig. 5 presents the Bode Plots, step response, root locus, and Nyquist Diagram for the transfer function $G_{13}(s)$ in closed loop system, shown in Fig.6.

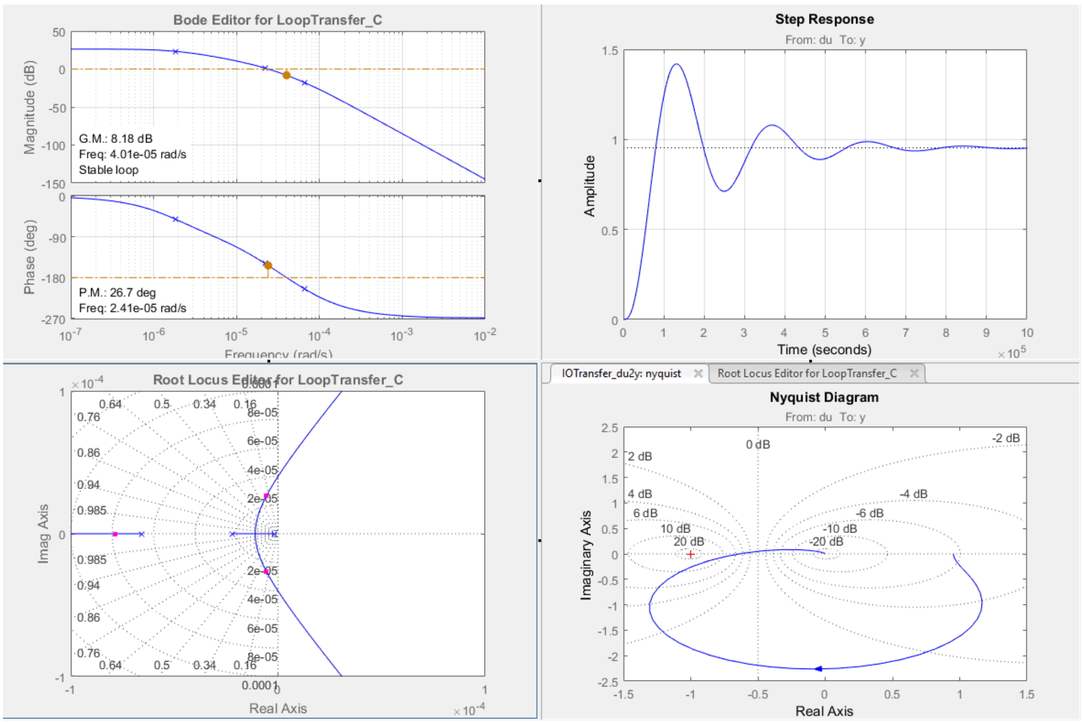

Figure 5. *Sisotool plots for the transfer function $G_{13}(s)$ in closed loop*

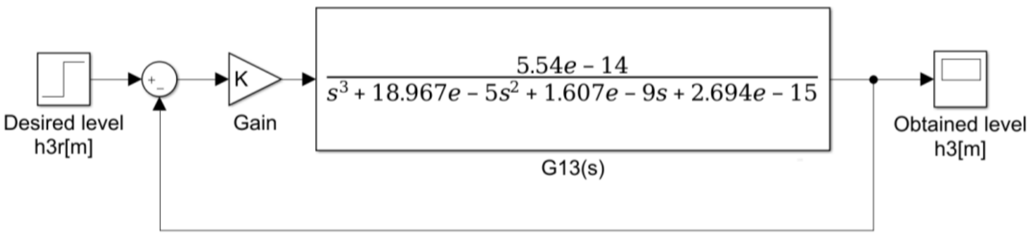

Figure 6. *Block diagram of the closed loop system $G_{13}(s)$*

Based on the obtained Bode Plots (for K=1), it can be concluded that the observed system with the transfer function $G_{13}(s)$ is stable in close loop and has a certain margin of stability. Using the Root Locus and Nyquist Diagram, the range of the gain K for which the closed-loop system remains stable can be determined. The analysis indicates that the system is stable for $0<K<2.7$, marginally stable at $K=2.7$ and unstable for $K>2.7$. Additionally, the step response diagrams (for $K=1$), reveals that the transient dynamics of the transfer function $G_{13}(s)$ are unfavourable, characterized by a steady state error of $e(\propto)=0.046$ (which is due to the lack of integrations in the transfer function $G_{13}(s)$), a rise time of $T_r=8\cdot10^4$s, a significant overshoot $P\%=48.8\%$, and large settling time $T_s=6.43\cdot10^5$s.

To enhance the quality of the transient response and steady-state behavior, a PID controller was designed. This was possible under the assumption that the flow q_{i1} (the output of the PID controller) could be controlled. By limiting it to a range of 0 to 2 m^3/s (Fig. 7), the response shown in Fig. 8 was obtained using an auto-tuning procedure. The auto-tuning procedure resulted in improved response dynamics and steady-state behavior, as depicted in Fig. 8. A zero steady-state error has been achieved $e(\propto)=0$, with a rise time of $T_r=1.377\cdot10^5$s, a overshoot of $P\%=23.6\%$, and a settling time of $T_s=5.297\cdot10^5$s.

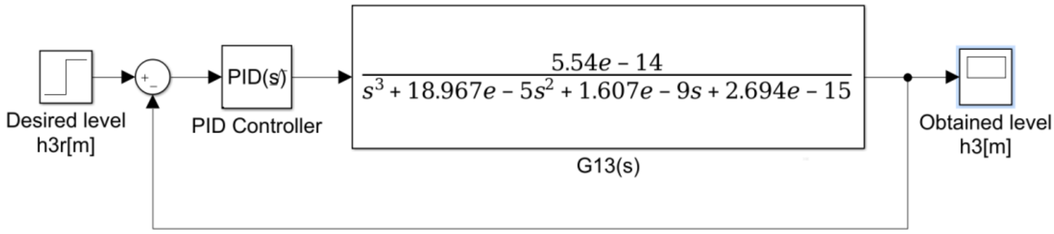

Figure 7. *Block diagram of the closed loop system $G_{13}(s)$ with PID controller*

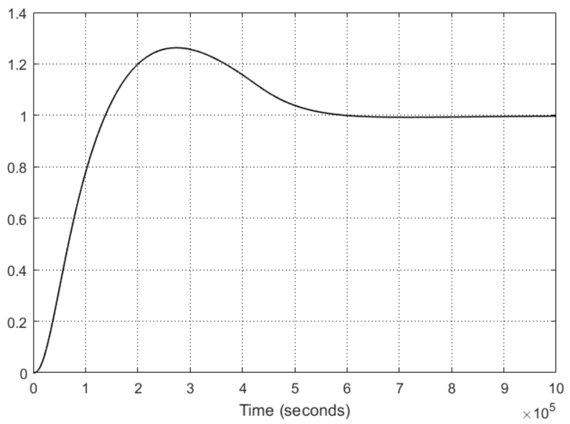

Figure 8. *Step function of the closed loop system $G_{13}(s)$ with PID controller*

4. CONCLUSION

This paper presents the application of teaching content from the control systems course using an example of an aquifer system. The system is multivariable, making it suitable for analysing the relationships between different variables within it. Both models presented, the state-space model and the block diagram model, are essential. The state-space model was used to analyse the controllability and observability of the system, while the block diagram model was utilized for analysing time and frequency responses. Based on the results shown, students can connect much of the teaching content covered in the control systems course with a real-world system. Given that this study models the system with three tanks, the analyses provided in this paper can be extended to similar systems with more tanks for various applications.

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Project-Based Learning: Synthesis of Theory and Practice Through Interdisciplinary Projects

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Abstract: *Project-based learning (PBL) in the field of mechatronics is an effective way to develop practical skills and prepare students for real industrial jobs. This article presents an example of the application of the PBL concept at the Faculty of Technical Sciences Čačak in cooperation with industrial partner Vorwerk. By introducing real industrial projects and technical requirements, students are more involved and motivated. The results highlight PBL as a method that connects academia and industry.Prepares students with essential skills for professional success in the rapidly evolving field of mechatronics. PBL also brings together different departments around a common goal.*

Keywords: *Project-based learning; project-based skills; interdisciplinary, mechatronics.*

1. INTRODUCTION

Project-Based Learning is an educational approach in which students acquire knowledge and skills by working on real industrial projects. This method allows students to actively engage in the learning process, developing critical thinking, problem-solving, and teamwork skills. In the field of Mechatronics, PBL holds particular significance as it enables students to synthesize theoretical knowledge from various domains and apply it in solving complex technical problems. [1]

PBL is based on several key principles: active learning, teamwork, and the application of theoretical knowledge in practice. Active learning involves student engagement through discussions, research, and hands-on activities. Teamwork allows students to develop communication and collaborative skills, while applying theoretical knowledge in real-world situations helps students to better understand and retain the teaching material. [2, 3]

PBL builds on constructivist learning theory, which states that students construct their own knowledge by engaging in the learning process. Additionally, experiential learning theories and interdisciplinary theories play a crucial role in PBL, enabling knowledge from various fields and to solve real-world problems. [4] In PBL, the role of the teacher shifts from traditional lecturer to that of mentor. Teachers help students define project goals, guide them through the problem-solving process, and provide feedback and support throughout the project. [5, 6, 7]

2. METODOLOGY

The projects of the Mechatronics Undergraduate program are of a technical nature based on real industry requirements. Students work in teams of two to four which allows them to develop teamwork and collaboration skills. The projects involve the integration of knowledge from various areas such as introduction to mechatronics, technology re-engineering, CAD/CAM technology, computer systems control, sensors, electronics and work organization.

One of the key elements of the PBL in program is interdisciplinarity. Projects require students to integrate knowledge from different topics and apply it to solve complex techniques. For example, students can use CAD/CAM knowledge to design and produce components, while applying computer and electronic control systems to develop management and control systems.

The projects are carried out over several semesters, allowing students to gradually develop and improve their work. During each semester, students work on aspects of the project with mentoring and support from their mentors/professors. This approach allows students to develop a deep understanding of the material and learn practical skills directly in industry.

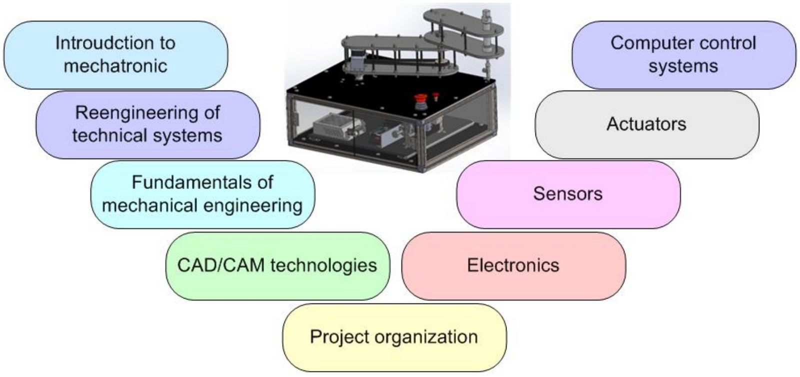

Figure 1. *Interdisciplinarity in PBL*

One of the main benefits of PBL is that students develop practical skills. Working on real-world projects allows students to apply their theoretical knowledge in practice, thus developing essential skills for success in a professional environment. For example, students can use their knowledge to design and test electronic components, while their knowledge of work organization will help to effectively manage projects.

PBL increases the motivation of students by allowing them to work on projects corresponding to their interests and their future career. Students are more motivated when they see that their work has concrete applications growing in front of their eyes. This encourages them to be more involved in the process and give their best.

Working on projects based on real industry demands prepares students for professional challenges. Students gain experience and skills directly for the industry, helping them find employment more easily and adapt quickly to the working environment. In addition, collaboration with industry allows students to create a network of contacts and better understand market needs.

PBL promotes the development of teamwork and communication skills among students. Working in teams of two to four members allow students to develop skills in collaboration, sharing and conflict resolution. Students also learn to communicate effectively their ideas and results, which is a crucial skill in a professional setting.

One of the main challenges of PBL is organization and logistics. Planning and implementing projects require significant resources and time from students and teachers. Teachers must coordinate various subjects and align the project with the curricula, which can be challenging.

Figure 2. *PBL process monitoring*

Evaluation and grading of student projects is a challenge. It is necessary to objectively evaluate the work of each team member. Teachers should develop clear assessment criteria and feedback that will help students improve their knowledge.

Establishing coordination between the different subjects is another challenge. Teachers must align their curricula and methods to allow students to integrate knowledge from various fields and apply it in projects. This requires good communication and collaboration between the teachers.

3. CASE STUDY

One of the successful projects of the Mechatronics program on Faculty of technical science in Čačak involved the use of a planar delta robot for sorting products. A team of students in the course Introduction to Mechatronics first perform research of the current state of the art of technical request. They analyzed in depth the characteristics, costs and design of existing solutions on the market.

Then, through the Fundamentals of mechanical engineering course, they defined the project task with relevant requirements. Based on the task of the project, the team brainstormed and defined several alternative solutions. These solutions were evaluated according to the criteria defined by the courses, resulting in the optimal solution.

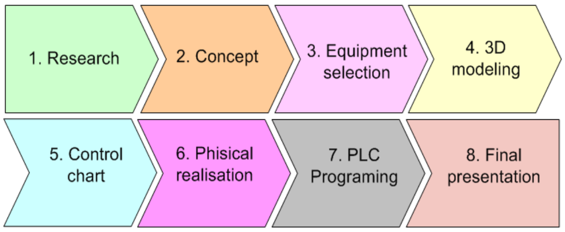

Figure 3. *Phases during the Project*

After finding the optimal solution, the student team developed a detailed 3D model and documentation using CAD/CAM technology. They applied their knowledge of Control Computer Systems and Electronics to develop software and hardware systems.

After detailed hardware development, parts list was created for purchasing of the necessary components. Students are involved in purchasing process. When all the components arrive, they assemble them into a working machine.

The project was successfully realized and presented to industrial partners.

In successful projects, students are actively involved in all stages of the development of the project, with professors as mentors. Students define project objectives, design and test solutions, while teachers provide support, feedback and guide students throughout the process.

Industrial partners often provide feedback on student projects, which helps students improve their skills and better understand market needs. Industry feedback can also contribute to program improvement, allowing teachers to adjust content and teaching methods based on market demands.

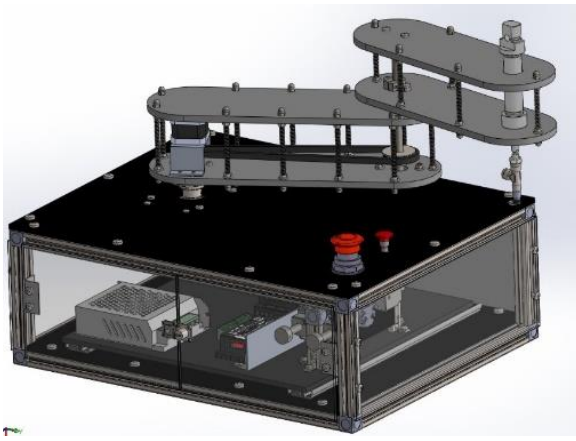

Figure 4. *Detailed 3D model of the Project*

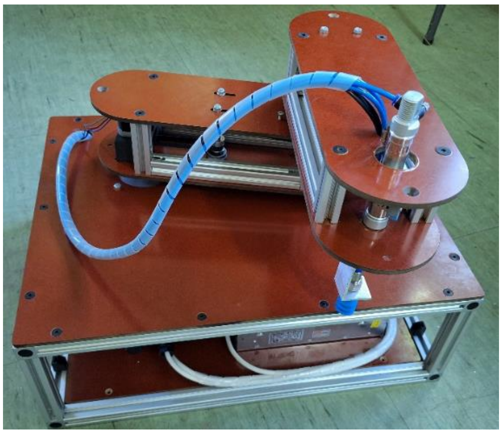

Figure 5. *Physical realization of the Project*

4. CONCLUSION

Project-based learning on the Mechatronics Undergraduate program represents an efficient way to develop practical skills and prepare students for professional challenges. Through practical projects, students cultivate their criticism, their problem-solving abilities, their work and their communication skills. Despite the challenges of organization and evaluation, the benefits of project-oriented learning are clear and significantly improve the quality of education.

Future prospects involve further improving the methodology and strengthening collaboration with industry, which will enable them to acquire even more relevant knowledge and skills.

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PLM Education: The State of the Art and Future Trends

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Abstract: *New industrial initiatives and innovations are being brought forward at an increasingly rapid rate, radically transforming job profiles and imposing the need for new paradigms in engineering education. Over the last few decades, PLM has evolved into the key business paradigm for supporting companies' efforts to achieve long-term sustainable competitiveness by balancing innovation and efficiency growth on the one hand and cost optimization on the other. New labor market demands, shaped by rapid PLM evolution, require a shift in current engineering education to adapt to new realities and better prepare engineers for future challenges. This paper aims to provide a comprehensive review of the state of the art in PLM education, highlight issues facing PLM education, and discuss possible future trends and developments. The paper aims to increase awareness of the importance of PLM education development and encourage active debate about potential actions as responses to current issues.*

Keywords: *PLM concept, PLM education, engineering education*

1. INTRODUCTION

Over the last two decades, deep technological changes have occurred, influencing businesses and increasing the risk of changes in the labor market, necessitating a thorough discussion of what engineering education should be like in the future.

Analyses and forecasting of future work activity mainly point to the impact of digitization, new industrial initiatives, and technology-based business paradigms. Actually, current students should be prepared for professions that are still in their infancy. This implies that as new challenges arise in a changing environment, the demand for new skills and qualifications will increase. In order to meet modern industry qualifications and skills, education systems must evolve, adapt to new realities, and better prepare engineers for the future.

Passow [1] provided a list of engineering competencies required of for modern industry, which includes the ability to apply knowledge from mathematics, science, and engineering, design and perform experiments, analyze and interpret data, identify, formulate, and solve engineering problems, and apply methods, skills, and modern engineering tools needed for engineering practice.

Interdisciplinary, new education standards and technologies, the digital classroom and online technologies, the relationship between engineering education and high-tech business and industry, models of digital competencies and ways to acquire them, the training of highly qualified staff, professional education in the school-university-enterprise system, and many other important aspects of modern engineering education are up for discussion right now [2].

Manufacturing enterprises in every industry are working in complex, fast-changing times, they are being challenged by an ever-shorter product life cycle, rising globalization, technological advances, and increasingly demanding customers in terms of product customizability and functionality. This is resulting in more and more complex products, systems, and processes, while the amount and complexity of the product information structure and flows are increasing.

In response to these challenges, a PLM approach has been developed, enabling integrated management of product-related information across its lifecycle, from conception to disposal. The PLM system is a set of consistent tools for integrating information about products and related processes throughout the entire product life cycle, enabling organizations to access and share information through business processes and improving operational efficiency. Furthermore, PLM is becoming increasingly important in today's corporate world due to its ability to support the company's efforts to attain long-term competitiveness by balancing innovation, enhancing operational efficiency and flexibility on the one hand, and cost reduction on the other. Moreover, the successful implementation of the

PLM approach becomes of key importance for the growth and development of organizations today.

Operational and strategic excellence acquired via PLM implementation in many companies has initiated the strengthening of the PLM initiative in various sectors, while the IT market records a drastic growth in PLM technology investments. According to the reports of the CIMdata company [3], the global leader in the field of PLM consulting, the PLM software market is the fastest-growing IT market today, with a total investment value of $66,6 billion in 2022 and an estimated growth rate of 10.1% over the following five years.

Despite this, companies are still struggling with the difficult implementation and attainment of PLM maturity, as a result of which the implemented PLM technologies usually fail to generate the expected business value. Johansson et al. [4] estimate that 70% of PLM implementation projects fail to achieve the expected goals, Singh et al. [5] also report an alarmingly low success rate for launched PLM initiatives.

Despite continuous conceptual and technological advancements, it appears that the PLM concept has not yet attained the anticipated maturity in industrial systems practice. Some of the key reasons for that are complexity and insufficient complexity and insufficient understanding of PLM as a business paradigm and technological concept, unstructured information flows, neglecting the business system's readiness for the introduction of PLM technologies, non-standardized and insufficiently formally defined processes, and inconsistency between the specific organization's needs and the functional aspects of the implemented PLM system [6, 7, 8].

However, most PLM implementation and institutionalization challenges are connected to the human factor. As Singh et al. [5] highlight, the success of PLM implementation hinges on the end users' acceptance and their learning curve. Furthermore, the adoption of PLM necessitates fundamental changes in the context of work practices and organizational culture. Furthermore, employees assume the role of change agents in PLM transformation processes, as well as key organizational levers in the launch and execution of PLM initiative. Despite this, various empirical studies report that the role and influence of employees in PLM initiatives are often underestimated.

Companies need employees to have a basic understanding of PLM concepts and be able to work efficiently and autonomously in a PLM environment. Future engineers not only need to have a comprehensive understanding and in-depth knowledge of the complex product life cycle but also the ability to collaborate and communicate effectively in interdisciplinary teams. Gandhi [9] indicate the need for establishing PLM education pertinent to industry demands. Greaves [10] emphasizes the necessity of establishing educational processes about PLM strategy, processes, and tools from the early stages of university education.

New labor market demands, shaped by rapid PLM evolution, require a shift in current engineering education to adapt to new realities and better prepare engineers for PLM. According to Burchardt [11] there is no systematic introduction of students to the field of PLM knowledge, and numerous empirical studies have supported this claim, indicating that PLM topics are not acknowledged as being part of contemporary educational paradigms.

This paper aims to provide a comprehensive review concerning the state of the art in PLM education; it discusses the topical issues of PLM education and possible future trends and developments. The paper attempts to increase awareness of the importance of PLM education development and encourage active debate about potential actions as responses to current issues.

The rest of the paper is organized as follows: The second section discusses the theoretical basics of the PLM concept; the third section provides an overview of previous research in the field of PLM education with the intention of defining the state of the art in PLM education; and the fourth section discusses future trends in the conceptual and technological development of PLM and their implications for future directions of PLM education.

The final section offers some conclusions and insights on additional considerations that future PLM education will have to take into account.

2. PRODUCT LIFECYCLE MANAGEMENT CONCEPT

PLM has emerged and developed under the influence of technological advances, new industry initiatives, and business paradigms. It is an IT-driven business model based on establishing the synergy between people and systems for processing information and synchronizing various processes throughout the entire product life cycle in order to optimize current and future products and related services.

Despite the prevailing narrative, PLM is much more than a technology solution, information system, or IT-based concept of integrated management of product information throughout the lifecycle. In attempts to conceptualize and formally describe PLM, terms such as "strategic business approach," "business model," "business paradigm," and "approach to management and optimization of business processes" have frequently been used, indicating the much broader context of PLM and the multi-layered nature of this phenomenon.

According to CIMdata [12], PLM is a business approach that applies a consistent set of business solutions to support the collaborative creation, management, sharing, and use of product information across a company.

As a technology solution, PLM facilitates the flow of information through the various phases of the product life cycle, acting as an integration core that connects automation islands. The essential PLM's function, according to Corallo et al. [13] is to provide a unique, time-limited source of product information, ensuring its consistency, traceability, and long-term archiving. The PLM system encompasses integrated information systems that unite various industrial software, including tools for creating, analyzing, simulating, and documenting product definition information, tools for collaborative product definition management, and digital manufacturing systems.

PLM unifies the domains of requirements management, product planning, production planning and realization, distribution and sale, customer service, delaying, and reusing products and their parts, thus creating a business environment for the integrated management of product information within organizational boundaries and through the inter-organizational value chain [13].

2.1 The necessity of PLM

The PLM concept has emerged as a response to the challenges posed by globalization, rapid technological progress, and the ever-shortening life cycle of products. It provides a paradigmatic model of how to maintain business efficiency and effectiveness in the face of current business challenges, which includes.

- Globalization's intensifying process has altered business conditions.
- Product complexity growth.
- Smart, connected systems are transforming the idea of a "product as an independent entity".
- Change the production strategy from "make-to-stock" to "mass customization."
- The trend toward outsourcing is leading to increasingly complex inter-organizational supply chains.
- Tendencies of production system digitization.
- Services that encompass the entire life cycle of the product are provided.
- Concurrent engineering, as well as related concepts.

PLM has evolved from specialized IT tools for automating specific business functions to digitally connected platforms capable of managing digital threads, and as Wang et al. [14] state, they continuously integrate new technologies related to the collection and processing of product information, the management of customer preferences and behavior, and the optimization of business workflows and processes.

The PLM implementation brings improvements in various aspects, both at the operational and strategic levels, generating growth in product profitability, growth in market share, greater user satisfaction, promotion of innovation, and so on.

The implementation of PLM generates business values through its capabilities to:

- Accelerate the exchange of information between processes within the product life cycle.
- Eliminate organizational barriers and foster cooperation throughout the inter-organizational value chain.
- Facilitate product knowledge management;
- Support the production of customized products;
- Increase workplace productivity;
- Reduce product life cycle costs;
- Reduce the time to market;
- Enhance the economic efficiency and flexibility of supply chains.
- Facilitate handling the product complexities;
- Support multidisciplinary interactions during product development and realization.

3. PLM EDUCATION – THE STATE OF ART

Emphasizing the relevance of the PLM concept for modern business systems growth and development, Greaves [10] stresses the necessity of establishing educational processes for PLM strategy, processes, and tools in the early stages of university education. He also stresses the need for establishing relevant pedagogical approaches in PLM professionals' education that shift learning concepts from studying the process to mastering PLM practice and understanding PLM strategy instead of becoming familiar with available PLM tools.

Burchardt [11] notes that students are not systematically introduced to the field of PLM knowledge; in addition, PLM education is not acknowledged as a part of contemporary educational paradigms, as is confirmed by numerous empirical studies. Current studies primarily focus on finding solutions to operational application problems, while the issue of developing comprehensive PLM educational paradigms receives insufficient attention.

It is believed that systematic PLM education is essential to successful PLM implementation in any industry. Moreover, Gandhi [9] indicates that PLM education can help improve product development competencies, skills to apply advanced product design tools, product base management competencies, industrial application to improve customer satisfaction, and maintenance and management of PLM processes.

Accordingly, there is an imperative to revise the existing engineering education curricula in order to ensure that students acquire the relevant multidisciplinary competencies required to work in a PLM environment, maximize understanding of PLM concepts, and gain practical "real-world" knowledge.

Over the past decade, different researchers have discussed the theme of PLM education in many contexts and subject areas. Most of them have focused on defining PLM-oriented curriculums, identifying teaching strategies used to increase PLM literacy, and discovering challenges and constraints that occur during PLM education development and delivery, as well as what strategies are used to overcome these obstacles. Furthermore, some studies have aimed to provide a model, an example, and suggestions for establishing and fostering meaningful partnerships to build authentic and relevant PLM experiences.

We reviewed and analyzed the research articles in the field of PLM education from 2014 to 2023. The following were some popular topics covered in these papers:

- Recognizing PLM education challenges
- Discussions on the contribution of PLM education to engineers' professional development
- Identifying appropriate PLM education approaches and designing new educational strategies and frameworks
- Development of a PLM-oriented academic course
- Creation of PLM educational resources

The table provides a summary of studies in the field of PLM education, along with their respective study goals.

Table1. *Overview of research in the field of PLM education*

Research aim	Focus on	Reference
Creation of the scenario around a product in its eco-system using simple technologies, in the way that all relevant organizational aspects, processes, and IT tools are present as they are in the real world.	Educational approach	[15]
Establishing the appropriate educational approach in engineering management, industrial engineering, and systems engineering programs on the PLM concept.	Educational approach	[16]
Design of a new course focuses on acquiring skills in customizing PLM systems to meet business requirements, incorporating fundamental aspects of PLM business models and engineering relationships.	PLM-oriented academic course	[17]
Consideration of the impact of the incorporation of PLM training in coursework and education of best practices, processes, and solutions at educational institutions as well as organizations on leveraging their intellectual assets and turning them into deliverable assets.	Contribution of PLM education to engineers' professional development	[9]
Describing the process of identifying and assessing the benefits of PLM applications that facilitate collaborative practices in project development and assessing their appropriateness within a higher education context.	Contribution of PLM education to engineers' professional development	[18]
Considering how foregrounding pedagogy will help realize the transformational potential of PLM through the skills and knowledge of the upcoming generation.	Contribution of PLM education to engineers' professional development	[19]
Analysis of existing approaches to solving the challenge of building a PLM professional education at the university in an industry context to educate industry employees, and improve engineering education at the university by using industry best practices.	PLM education challenges	[11]
Establishing the educational framework for the Bachelor, Master, and PhD study programs in industrial engineering and management, ensuring sustainable management of the product throughout its entire life cycle in a digital factory.	Educational framework	[20]
Establishing a new framework for global PLM strategy and a new curriculum for cultivating the “Global-PLM Producer” educational programs for undergraduate and adult education.	PLM education strategy	[21]
Considering the challenges in building the PLM competence of management students and outlining new opportunities.	PLM education challenges	[22]
Developing the PLM education materials that fall into the categories of fundamental concepts, digital product development, non-graphical concepts, and graphical concepts, and exploring methods of sharing these materials with students via PLM software workshops.	PLM learning materials	[23]

3.1 The concept of PLM-oriented education

According to Van Til [16], the establishment of PLM education is based on several strategies, including 1) incorporating PLM techniques and technologies into current courses; 2) establishing training programs for industry-relevant PLM software; and 3) developing a PLM dual education program with industry. On the other side, Burchardt [11] outlines three significant aspects of PLM education: 1) knowledge as an invariant core with an outer layer of empirical knowledge about specific systems with a tendency for constant development; 2) know-how, which refers to the development of the ability to transfer knowledge into the employee's working practice; and 3) modeling an employee's individual character through personality development training and mentoring.

The articles devoted to PLM education mostly focus on defining a set of competencies and learning outcomes for PLM-oriented educational programs. There is a consensus that PLM education should focus on cultivating professionals with multidisciplinary competencies rather than individual specialization in particular fields. The priority is to expand the scope of PLM education beyond its traditional engineering focus to include other business domains where the PLM approach has a significant impact. Additionally, educational processes must go beyond simply processing PLM theoretical assumptions and principles. Namely, the consistent application and control of the PLM approach requires extensive analysis and understanding of information flows, business activities, specific methods, and concepts used in different phases of the product life cycle.

Burchardt [11] stresses the need for structured programs in PLM professional education. These programs should focus on developing a basic understanding of PLM topics to support specialized PLM processes, building the competencies required to successfully implement PLM concepts, and improving practical skills to establish the basic PLM functional aspects (configuration management, variant management, change management, and workflow management). Sahu & Panda [22] are adding the following to this list: development of technical and commercial awareness; acquiring interpersonal skills to empower staff in the PLM implementation processes, working with software tools for product conceptualization, creatng of digital models, designing and simulating product environments; and developing skills for leveraging virtual space's potential for collaboration. While Van Til [16] argues that improving educational frameworks for the acquisition of PLM competencies in the digital factory environment necessitates the incorporation of thematic units and modules from the following areas: 1) theoretical and system approach for PLM in a digital factory environment; 2) technological preparation and support for production in a digital factory environment; 3) design of production systems (processes) in a digital factory environment; and 4) planning and controlling production and information support in a digital factory environment.

Tamaki et al. [21] define a strategy for the development of so-called "global-PLM producer" education. The strategy defines the educational goals for the development of the comprehensive competence necessary to cultivate the global-PLM producer through the competence matrix.

This matrix delineates specific competencies for each phase of the product life cycle, including: 1) product strategy; 2) business model; 3) global market sensing and new product plan; 4) production architecture strategy; 5) supply chains management, manufacturing and quality control; 6) global marketing channels, sales and maintenance services. These stages are linked to four levels of business administration, which determine specific competencies for managing the internal and external organizational environment, including: 1) global business environment; 2) business creation; 3) customer creation; 4) product development and operational management.

Product lifecycle phase

PLM level

	Product strategy	Business model	Global market sensing	Product architecture strategy	SCM, manufacturing and QC	Global marketing channel, sale and maintenance
LEVEL 1 Global business environment	Product line-up strategy Platform strategy Product line strategy Variation management					
LEVEL 2 Business creation		Analysis of business environment New business concept Global business model Competitive strategy				
LEVEL 3 Customer creation			Marketing research Market segment positioning Customer behavior analysis New product planning			Global logistic strategy Local market cultivation Local market promotion Local service promotion
LEVEL 4 Product development and Operational management				Technological benchmark Product specification Concept development System architecture design Integrated PLM business process model	Global framework building of production and SCM strategy Mass production planning Manufacturing process planning	

Figure 1. *„Global-PLM producer" competence matrix [21]*

As an important aspect of the PLM educational paradigm, many authors point to the imperative of establishing synergy between the academic sector and industry. This involves various modes of interaction between students, teachers, and industry experts, blurring the boundaries of conventional education and encouraging the realization of PLM's transformational potential through the skills and knowledge of future generations of engineers.

Burchardt [11] asserts that industrial systems play a significant role in the PLM educational paradigm, whose role is reflected in the critical analysis of curricula, the active involvement of experts in educational processes, and the provision of financial support to educational programs. Academic institutions play a crucial role in imparting invariant core knowledge, whereas industrial systems concentrate on teaching specific aspects of empirical knowledge, tools, and their applications, thereby integrating practical knowledge into educational processes. Van Til [16] also emphasizes the importance of more intensive interaction between educational institutions and industry and research centers.

Conlon [19] advocates for alternative approaches that align with foregrounding pedagogy in education, prioritizing student work in a practical PLM environment over the transmission of curriculum content. For instance, they recommend establishing PLM learning communities that provide both academic and theoretical knowledge as well as practical content, encouraging involvement from external stakeholders, while not neglecting the impact of academic and theoretical knowledge on the further development of critical practice.

This mainly refers to the establishment of PLM education partnerships with PLM technologies providers (PTC, WhichPLM, ITC, Infotech, etc.). These partnerships provide universities with resources, enable teachers to stay up to date with the latest technological advancements and current industry practices, while providing students with an in-depth understanding of industrial processes and practices, help in realizing correlations with other relevant areas of knowledge, and also encourage students to develop a critical perspective of existing practice.

With the intention of enabling students to learn and apply concepts in a simulated business environment, PLM software solutions can be used for educational purposes to create a simulation environment that mimics a real business environment.

4. FUTURE TRENDS IN PLM-ORIENTED EDUCATION

A new era in PLM's technological and conceptual evolution is on the horizon.

Today's companies face the challenge of developing more personalized, smarter, and eco-friendly products. According to [24] success necessitates continuous and, more rapid innovation in products and processes. Going forward, companies must undergo a digital transformation of their businesses and evolve their current product lifecycles to enable true end-to-end lifecycle optimization. Also, companies today must respond to the imperative of sustainability in order for society to tackle climate change and pollution problems.

According to CIMdata [25] research, which examines how important certain technologies, processes, or abilities are for making sustainability efforts, PLM is an important part of a systemic response. PLM-enabling solutions must act as a nexus for sustainability information attached to the digital thread as it evolves across the product lifecycle. Moreover, PLM must support a model of production and consumption that involves reusing, repairing, refurbishing and recycling existing materials and products as long as possible.

PLM is a critical component for fulfilling companies' digitalization strategies. The use of emerging technologies like the Internet of Things, cloud computing, big data, and artificial intelligence transforms PLM systems into digital platforms capable of supporting the digital transformation.

On the other hand, the technologies associated with Industry 4.0 provided potential solutions to the challenges that prevented mass adaptation of PLM in the past [26]. Thus, one of the key trends in the development of PLM in the future undoubtedly refers to the realization of an integrated PLM by application of key industry 4.0 technologies.

Ji & Abdoli [26] have identified the most important technology concepts brought forth by Industry 4.0 that can help companies set up better processes for managing all stages of the product lifecycle, including:

- Big data analytics, or data mining using artificial intelligence technologies;
- Data collection via cyber-physical systems or digital twins.

Today's PLM environment makes extensive use of artificial intelligence and machine learning technologies. The machine learning concept enables the automation of the time-consuming process of acquiring and even discovering knowledge that might otherwise be overlooked [27]. These technologies find application in various aspects of PLM. The manufacturing industry widely adopts these concepts for process monitoring and fault detection, and their predictive ability also extends to the field of predictive maintenance.

Tao et al. [28] defined digital twin as an integrated multi-scale and probabilistic simulation of a complex product or system to mirror the life of its corresponding twin. It is a bi-directional relationship between a physical artifact and the set of its virtual models, enabling the efficient execution of product design, manufacturing, servicing, and various other activities throughout the product life cycle [29].

In the context of PLM, digital twin technologies can be used as tools for the simulation, prediction and optimization of a physical production system or product [30] through different phases of its life cycle.

According to Pang et al. [31] some of the application areas of digital twin in the context of PLM include the detailed recording and storage of process data from manufacturing, the direct use of information on manufacturing errors and part defects to identify critical production steps, the ability to customize products to customers' needs, the scheduling of repair processes based on knowledge of the product's entire operating history throughout the product's life cycle, etc.

Today`s PLM systems need to be adapted to become more comprehensive product innovation platforms. As a set of "realistic product and production process models, DT links enormous amounts of data to fast simulation, which allows the early and efficient assessment of the consequences of the design decisions on products and production lines." [32] „These capabilities allow the enterprise to focus on innovating to create value, leveraging higher-level or more advanced product innovation platform capabilities to assess product and business scenarios to optimize the business." [33]

The foundation of digital twin creation is coordinated digital threads, which demand the storage, maintenance and integration of digital data about products and resources across all stages of the product life cycle, which relies on the use of technical concepts like MBE, MBSE, etc. for product and production environment modeling and validation.

MBE is an approach that uses mathematical multi-dimensional models as an integral part of the technical product definition and uses a single platform to support the requirements of analysis, design, implementation, and verification of a product throughout its lifecycle, beginning in the conceptual design phase and continuing throughout development and later lifecycle phases [32].

The MBSE approach allows groups of users to collaborate on a single system, where they can share data, simulate and visualize a highly detailed model of a future physical product, and exchange information in the form of a model instead of a document.

Considering the current trends in PLM conceptual and technological evolution, engineering education must incorporate some specific topics to prepare future engineers with the competencies to work in a PLM environment. This includes:

- The concept of Life Cycle assessment (LCA) and the potential of integrating LCA tools with PLM technologies for facilitating the incorporation of sustainability principles into product and process engineering;
- The possibilities of applying PLM-enable technologies to help engineers make critical decisions that will affect product sustainability, such as:
  - Designing with sustainable part and assembly reuse in mind
  - Designing for sustainable manufacture
  - Designing with a sustainable supply chain in mind
  - Considering how the product will be used and taking early steps to design the product to improve lifecycle sustainability.
- The concept of PLM-enabled digital transformation;
- Digital twin-enabling technologies and artificial intelligence, and the way they transform how the company operates and how it manages and leverages product information from concept until a product is retired.
- Engineering approaches that use multidimensional models as an integrated part of the technical product definition, such as the MBE and MBES approaches.

5. CONCLUSION

The converging impact of technological progress and new business paradigms has led to changes that have challenged every aspect of engineering education. To cope with these run-away changes, the educational system must prepare the workforce with the competencies to work in new industry environments.

PLM is essential to a systemic response to the challenges of developing more personalized, smarter, and eco-friendly products. Thus, PLM-oriented education needs to be at the core of contemporary engineering education paradigms.

Furthermore, as the PLM concept evolves, the body of comprehensive PLM competencies continues to change. The trend of incorporating new technological concepts into PLM has repercussions for how educational systems should prepare future engineers for work in a PLM environment, imposing new topics up for discussion.

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Application of Educational Software Packages for MRP Data Processing

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Abstract: *In the context of modern higher education courses, the use of software packages and tools has become imperative, especially in professional and application-oriented subjects. On the other hand, the contemporary business environment expects young engineers to be innovative in their work, applying current methods, techniques, models, and software tools that contribute to more efficient management. This paper aims to highlight the potential application of various software packages in the domain of Material Requirements Planning (MRP) to enhance teaching in the fields of Industrial Engineering and Engineering Management. The paper focuses on processing MRP data using the software packages WinQSB and POM-QM for Windows. Through comparative analysis based on different criteria, a preference is given to one or the other software program. The results showed that WinQSB was preferred in seven out of ten criteria. However, the choice of which program to use is left to the user.*

Keywords: *engineering management science, educational software; MRP; WinQSB; POM-QM software*

1. INTRODUCTION

Curricula and course content need to be continuously innovated in line with labor market demands and the expected competencies of students. This includes, among other things, the introduction of new educational software packages that enable students to better understand real-world problems and solve them quickly and efficiently (see [1]). These tools provide students with the opportunity to test and understand how theories work in practice, thereby gaining valuable experience for their future work in the industry [1]. Additionally, interest in a particular course unit is significantly increased.

The importance of using software packages is highlighted by authors Ku et al. [2] in four papers that cover topics forming the modules of the Engineering Management Science course. The first paper addresses the use of software packages in delivering critical path networks; the second on the application of software packages in linear programming: distribution method and simplex method; the third on the utilization of software packages in delivering quality control and financial analysis: net present value and break-even analysis; the last one on the use of software packages in delivering simulation [2].

The pressure to introduce new educational software comes from many sources, including employers who require graduates with both generic and specific skills, students who expect to use technologies in their learning [3], and higher education institutions that aim to offer attractive study programs and course content. For this process to be successful, the higher education institution must continuously invest in training its teaching staff to enable them to effectively use new technologies in teaching.

For successful production planning and management, managers use various principles and techniques, and certainly, one of the key ones is Material Requirements Planning (MRP), which is studied in the courses of Industrial Engineering and Engineering Management. This fact is confirmed by authors stating that Material Requirements Planning (MRP) is a traditional topic in operations management and industrial engineering education [4].

In the teaching process, students first manually calculate MRP and then use one of the software packages. The course content usually does not specify which software is used.

This paper aims to highlight the possibility of applying different software packages in the domain of Material Requirements Planning (MRP) to enhance teaching.

In the second part of the paper, the theoretical foundations of the MRP concept will be presented, and software packages for MRP data processing will be highlighted. In this chapter, preference will be given to the software packages POM-QM for Windows and WinQSB, which are most suitable for educational purposes.

Through an illustrative example, in the third chapter, the use of the selected programs will be explained in detail, and their comparative analysis will be conducted.

The conclusion will be presented at the end of the paper.

2. MATERIAL REQUIREMENTS PLANNING

Material Requirements Planning (MRP) is a powerful tool that helps manufacturing organizations manage their materials, inventory, and production schedules.

MRP is a computer-based set of planning techniques that examines future needs for finished products in terms of the master production schedule. It uses this information, along with the bill of materials, inventory status data, and lead time information, to generate requirements for all subassemblies, components, and raw materials that constitute the finished product [5]. If properly implemented and used, it can help production managers plan capacity requirements, schedule production time [6] and calculate production start dates so that parts are available at inventory locations precisely when they are needed [7].

MRP is usually depicted as the opposite of the just-in-time concept. However, if production is order-based and input data is accurately determined, MRP can actually achieve the just-in-time principle by producing parts precisely when they are needed.

MRP emerged in the late 1960s but was popularized only in the mid-1970s [7]. There are five stages of MRP system evolution (Material Requirements Planning (MRP); Closed- loop MRP; Manufacturing Resource Planning (MRP II); Enterprise Resource Planning (ERP) and Enterprise Resource Planning Extended (ERP II) [6], that were based on the application of ICT equipment and adequate software solutions [8]. In all mentioned phases (modules), MRP occupies a central place.

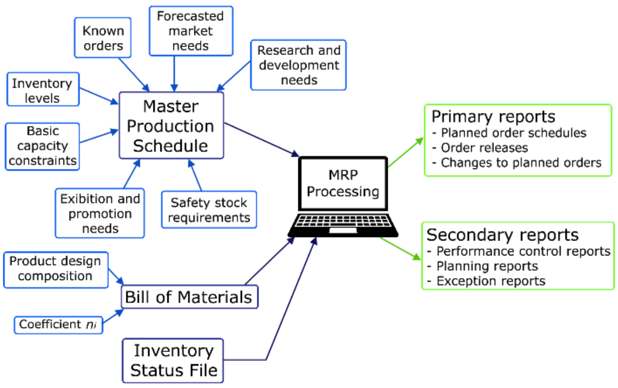


Figure 1. *MRP concept*

The MRP concept consists of several elements:

1. MRP inputs: Master Production Schedule (MPS); Bill of Materials (BOM) and Inventory Status File (ISF).
2. MRP software for calculating required orders.
3. MRP outputs: primary and secondary reports.

In Fig. 1, a schematic representation of the MRP concept is provided with input and output elements. Various authors (see [8] and [9]) present similar illustrations. In Fig. 1 the coefficient n_i is the quantity of the *i*-th subassembly (production phase) incorporated into the first parent level.

When using the MRP system, it is assumed that the input elements are deterministic, which is not always the case in real business environments. Therefore, it is crucial to accurately determine these inputs before processing MRP data. To achieve this, students apply knowledge gained from various academic subjects.

The primary sources of uncertainty relate to the requested quantities (forecasting errors and calculation errors of planned quantities for individual parts that make up the complex product) and the estimation of lead times for individual production phases (material procurement, part manufacturing, assembly, and packing). Many authors emphasize the need to establish planned lead times. As Sadeghi et al. points out, the delivery time for each component is uncertain, leading to three states for each component: planned delivery time equals actual delivery time; planned delivery time is longer than actual delivery time; and planned delivery time is shorter than actual delivery time [5]. It is necessary to design times so that they are equal or approximately equal to the actual times. When designing, it is important to take into account all losses in the production cycle.

In their paper [10], the authors developed a mathematical model used for the optimization of planned lead times and periodicity for MRP systems under uncertain lead time. In [11] in the MRP planning system, each production activity (or production resource or supply chain stage) is assigned a planned lead time, and in [12] the production start dates for each station are calculated for each part backward scheduling using planned lead times.

2.1. Software packages for processing MRP data

The first computer programs that attempted to perform MRP calculations were produced in the late 1950s and early 1960s in the United States, at a time when business computing was in its infancy [5]. In today's world of digitalization, MRP modules can be part of a unified complex ERP system or part of software packages that solve problems in the broad area known as Decision Sciences, which students should use in the educational process.

Below are some software programs and tools that support MRP:

- MRP_Excel for Windows - free Manufacturing Resource Planning tool in an Excel workbook.
- Odoo - free online version for one app only, paid online version for all apps with free trial. Needed

app: Manufacturing, contains MRP, MES, PLM, Quality, Shop Floor and Maintenance.

- Officebooks - free for up to 5 users and up to 25 records.
- Axolt ERP - paid version with free trial for 14 days.
- Metasfresh ERP - open source ERP solution, self-hosted version is free.
- Quantitative Systems for Business (WinQBS) - free online version.
- Production and Operations Management (POM-QM) for Windows - free online version.

Considering the availability, costs of software usage, and the complexity of its implementation, it is best to use WinQSB and POM-QM software in the educational system. They can be used with any Production and Operations Management, Management Science, Quantitative Methods, or Operations Research textbook [13, 14, 15].

The suitability of the software for use depends on the modules being used and the subjective feeling of the software user. According to Amariei et al. [3], the use of WinQSB software in practice has a real contribution to the developed activities' efficiency, ensuring a high economy of time by eliminating routine activities tied to the classic way of solving the problem.

In [4] the evaluation results of three generations of students showed that WinQSB's MRP module is far more suitable software than POM-QM for Windows' MRP module and that the selected software was very useful in acquiring advanced MRP skills for students.

On the contrary, in the work [2], the authors emphasize that the more suitable software for solving the Critical Path method is POM-QM for Windows.

Various applications of different modules of both software can be found in the papers. In the work [3], the authors presented a way to solve certain types of problems using the WinQSB program. They used two modules, PERT/CPM and Facility Locations. In [16], the authors used the Queuing System Simulation module, in [17] they used submodules of Network Modeling to solve transportation problems, in paper [13] the PERT/CPM module was used, in [18] the Linear Programming module, and in [19] the Markov Process module of the WinQSB software.

The application of POM-QM software can be found in the work [20], where the authors defined a procedure for planning and scheduling consisting of formulating an equivalent linear programming problem and sequentially applying the software.

WinQSB includes 19 application modules: Linear programming (LP), Linear goal programming (GP) and integer linear goal programming (IGP), Quadratic programming (QP) and integer quadratic programming (IQP), Network modeling (NET), Nonlinear programming (NLP), Dynamic programming (DP), PERT/CPM, Queuing analysis (QA), Queuing system simulation (QSS), Inventory theory and systems (ITS), Forecasting (FC), Decision analysis (DA), Markov process (MKP), Quality control charts (QCC), Acceptance sampling analysis (ASA), Job scheduling (JOB), Aggregate planning (AP), Facility location and layout (FLL) and Material requirements planning (MRP) [15]. Some of the submenus of the main menu change its main available options, depending on the type of problem selected [13]. MRP module has the following capabilities [15]:

- Perform full MRP function with input including item master, bill of material (BOM), inventory records, and master production schedule (MPS)
- Explode the MPS requirements to obtain net requirements, planned orders and projected inventory for parts and materials
- Show indented, single-level, and where-used BOM
- Show graphic product structure
- Show MRP report in part item, ABC class, source type, or material type
- Show capacity analysis
- Show cost analysis.

POM-QM for Windows [14] is free software and it is a user-friendly Windows software [20]. It includes 29 modules or calculation methods. They are divided into three groups, Fig. 2. The modules in the first group typically are included in all POM and QM books, whereas the modules in the second group usually appear only in POM books, and the modules in the third group appear only in QM texts [14].

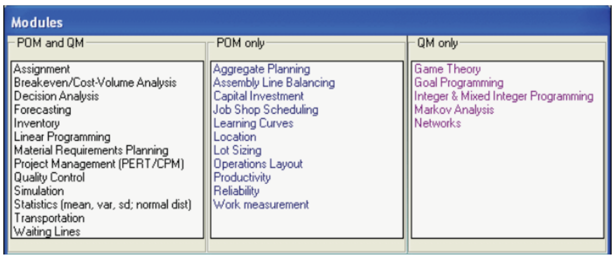


Figure 2. *POM-QM for Windows modules [14]*

3. ILLUSTRATIVE EXAMPLE

Design composition (decomposition scheme) is used to define and shape complex structures of products and is a basis for industrial product manufacturing. Within the framework of design composition a designer defines functional levels starting from elements that represent the first level, arriving at the final level, i.e., packed product, over sub-assemblies and assemblies [21]. The elements, sub-assemblies, assemblies, and packaged products are collectively called the production phase (PF).

Fig. 3 shows a design composition of a complex product (labelled as X) used as an example in several professional subjects in the field of Production Planning and Control in the basic vocational studies of Production Management.

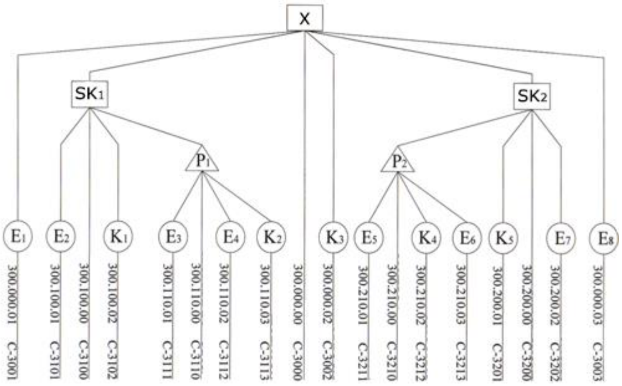


Figure 3. *Product design composition*

The product consists of four functional levels consisting of thirteen parts (E_i, K_j), two sub-assemblies (P_k), and two assemblies (SK_l), totaling 18 production phases (PF). Table 1 shows the values of coefficients n_i, i.e., the number of PFs incorporated into the first superior level, as well as the projected lead times PF (T_i). It is necessary to deliver 10,000 units of product X within 6 weeks. There are no stocks of individual production phases.

Table 1. *Coefficients n_i and lead times per PFs*

PF	n_i	T_i (week)
X	1	1
SK1	3	1
SK2	1	2
P1	2	1
P2	1	2
E1	0,2	3
E2	2	2
E3	3	1
E4	2	2
E5	0,025	2
E6	6	2
E7	1	1
E8	0,02	1
K_i, $i = \overline{1{,}5}$	1; 1; 3; 2; 4	1

Taking into account the defined input data, it is necessary to process them in one of the above-mentioned software packages and tools. In this work, POM-QM and WinQSB will be used. Detailed explanations on how to input data, descriptions of the main menu of the program, and obtaining solutions to the problem can be found for POM-QM for Windows in [14] and for WinQSB software in [15] and [13].

3.1. POM-QM for Windows

In the first step after launching the program, it is necessary to select the module in which you will be working. In this case, Material Requirement Planning is chosen. The next step involves creating a new problem where a window opens, and it is necessary to enter data in the initial menu (Fig. 4): Problem name; Total number of PFs that make up the complex product (Number of BOM lines – 18 pieces); Deadline for the completion of the complex product's production (Number of last period – 6 weeks).

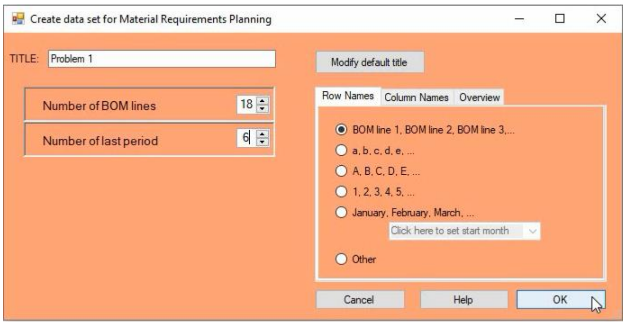
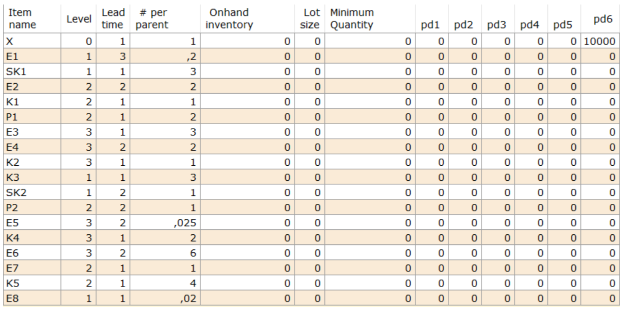


Figure 4. *Initial menu of POM-QM software*

After that, a table opens, Fig. 5, in which it is necessary to enter input data while considering the schedule of entering PFs. Subordinate PFs need to be entered after the parent PFs so that it is known that they are part of those PFs. For example, after SK1, it is necessary to enter P1, E2, and K1, see Fig. 3. In addition to the name/code of the PF, it is necessary to enter the level at which the part is located, lead time in weeks, coefficients n_i (# per parent), and others.



Item name	Level	Lead time	# per parent	Onhand inventory	Lot size	Minimum Quantity	pd1	pd2	pd3	pd4	pd5	pd6
X	0	1	1	0	0	0	0	0	0	0	0	10000
E1	1	3	,2	0	0	0	0	0	0	0	0	0
SK1	1	1	3	0	0	0	0	0	0	0	0	0
E2	2	2	2	0	0	0	0	0	0	0	0	0
K1	2	1	1	0	0	0	0	0	0	0	0	0
P1	2	1	2	0	0	0	0	0	0	0	0	0
E3	3	1	3	0	0	0	0	0	0	0	0	0
E4	3	2	2	0	0	0	0	0	0	0	0	0
K2	3	1	1	0	0	0	0	0	0	0	0	0
K3	1	1	3	0	0	0	0	0	0	0	0	0
SK2	1	2	1	0	0	0	0	0	0	0	0	0
P2	2	2	1	0	0	0	0	0	0	0	0	0
E5	3	2	,025	0	0	0	0	0	0	0	0	0
K4	3	1	2	0	0	0	0	0	0	0	0	0
E6	3	2	6	0	0	0	0	0	0	0	0	0
E7	2	1	1	0	0	0	0	0	0	0	0	0
K5	2	1	4	0	0	0	0	0	0	0	0	0
E8	1	1	,02	0	0	0	0	0	0	0	0	0

Figure 5. *Input data*

To the right of the table where the data is entered, a product tree is automatically generated (Fig. 6). It displays the levels, coefficient n_i, and lead time.

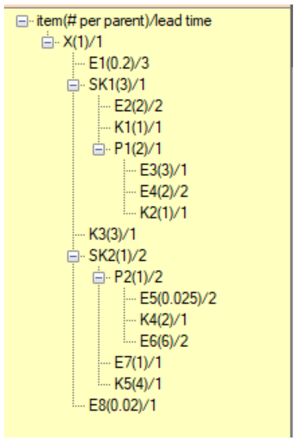


Figure 6. *Product tree*

To obtain a solution, it is necessary to select the Solutions option. Part of the solution is shown in Fig. 7 due to limited space in the document.

X (0)							
Gross REQ.							10000
ON HAND							
SchdREC.							
NET REQ							10000
PlanREC							10000
ORD REL.						10000	
E1 (1)							
Gross REQ.						2000	
ON HAND							
SchdREC.							
NET REQ						2000	
PlanREC						2000	
ORD REL.			2000				
SK1 (1)							
Gross REQ.						30000	
ON HAND							
SchdREC.							

Figure 7. *Part of the solution in POM-QM*

3.2. WinQSB software

After selecting the MRP module in WinQSB software, it is necessary to create a new problem, after which the initial menu opens, Fig 8.

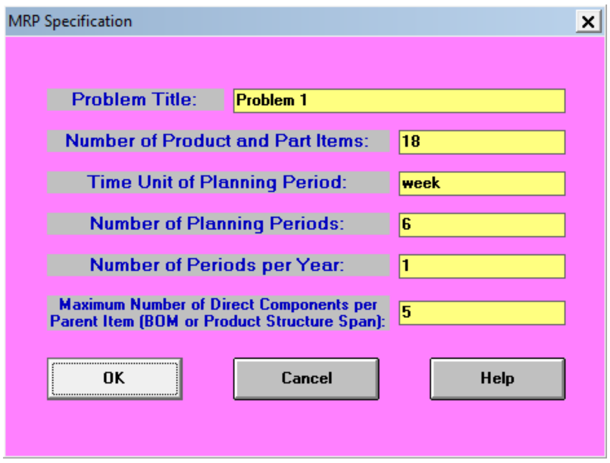


Figure 8. *Initial menu of WinQSB software*

In the initial menu, you need to enter the following information:

- Problem name.
- Total number of PFs (Product and Part Items) that make up the complex product (Number of Product and Part Items – 18 pieces).
- Time unit in which delivery times and lead times are expressed (Time Unit of Planning Period). The default unit is Month.
- Production completion deadline for the complex product (Number planning period – 6 weeks).
- Number of cycles per year (Number of Periods per Year).
- Maximum number of PFs that are installed in one assembly/subassembly/final assembly at the level of the complex product (Maximum Number of Direct Components per Parent Item – 5 pieces, see Fig. 3. Number of PFs for final assembly X is five).

After entering the required data, the Item Master table (Fig. 9) opens in the initial menu, where you need to enter several input data (part number/code, lead time, etc.).

No	Item ID	ABC Class	Source Code	Material Type	Unit Measure	Lead Time
1	X				Each	1
2	SK1				Each	1
3	SK2				Each	2
4	P1				Each	1
5	P2				Each	2
6	E1				Each	3
7	E2				Each	2
8	E3				Each	1
9	E4				Each	2
10	E5				Each	2
11	E6				Each	2
12	E7				Each	1
13	E8				Each	1
14	K1				Each	1
15	K2				Each	1
16	K3				Each	1
17	K4				Each	1
18	K5				Each	1

Figure 9. *Part of the Item Master table*

To enter all input data, you need to select the View option and fill in the following tables:

- BOM (Bill of Material), as shown in Fig. 10. The data should be entered based on Fig. 3 and Tab. 1.
- MPS (Master Production Schedule). This table contains data on desired quantities of parts/products and the time required to complete production, as shown in Fig. 11.
- Inventory – contains information about parts inventory levels.
- Capacity – provides information on the maximum number of parts that can be produced within a specific period.

Item ID	Component ID/Usage	Component ID/Usage	Component ID/Usage	Component ID/Usage	Component ID/Usage
X	E1/.2	SK1/3	K3/3	SK2	E8/.02
SK1	E2/2	K1	P1/2		
SK2	P2	E7	K5/4		
P1	E3/3	E4/2	K2		
P2	E5/.025	K4/2	E6/6		
E1					
E2					
E3					
E4					
E5					
E6					
E7					
E8					
K1					
K2					
K3					
K4					
K5					

Figure 10. *BOM table*

Item ID	Overdue Requirement	week 1 Requirement	week 2 Requirement	week 3 Requirement	week 4 Requirement	week 5 Requirement	week 6 Requirement
X							10000
SK1							
SK2							
P1							
P2							
E1							
E2							
E3							
E4							
E5							
E6							
E7							
E8							
K1							
K2							
K3							
K4							
K5							

Figure 11. *MPS Table*

After entering the input data, to solve the problem, you need to select the Solve > Explore Material

Requirements option and in the menu, as shown in Fig. 12, specify which report to display, as indicated in Fig. 13. Due to limited space, in Fig. 13, only a portion of the output report or results is displayed.

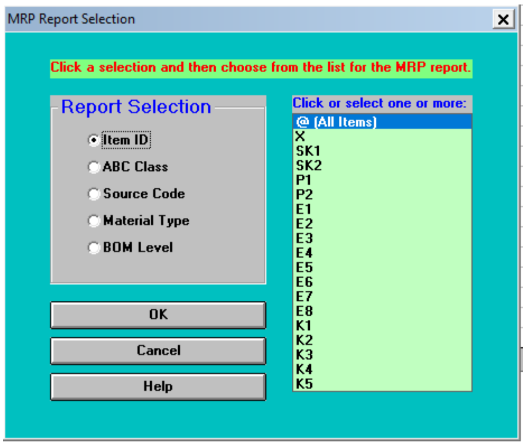


Figure 12. *MRP report selection*

06-03-2024	Overdue	week 1	week 2	week 3	week 4	week 5	week 6	Total
Item: X		LT = 1	SS = 0	LS =	UM = Each	ABC =	Source =	Type =
Gross Requirement	0	0	0	0	0	0	10.000	10.000
Scheduled Receipt	0	0	0	0	0	0	0	0
Projected On Hand	0	0	0	0	0	0	0	
Projected Net Requirement	0	0	0	0	0	0	10.000	10.000
Planned Order Receipt	0	0	0	0	0	0	10.000	10.000
Planned Order Release	0	0	0	0	0	10.000	0	10.000
Item: SK1		LT = 1	SS = 0	LS =	UM = Each	ABC =	Source =	Type =
Gross Requirement	0	0	0	0	0	30.000	0	30.000
Scheduled Receipt	0	0	0	0	0	0	0	0
Projected On Hand	0	0	0	0	0	0	0	
Projected Net Requirement	0	0	0	0	0	30.000	0	30.000
Planned Order Receipt	0	0	0	0	0	30.000	0	30.000
Planned Order Release	0	0	0	0	30.000	0	0	30.000
Item: SK2		LT = 2	SS = 0	LS =	UM = Each	ABC =	Source =	Type =
Gross Requirement	0	0	0	0	0	10.000	0	10.000
Scheduled Receipt	0	0	0	0	0	0	0	0
Projected On Hand	0	0	0	0	0	0	0	
Projected Net Requirement	0	0	0	0	0	10.000	0	10.000
Planned Order Receipt	0	0	0	0	0	10.000	0	10.000
Planned Order Release	0	0	0	10.000	0	0	0	10.000
Item: P1		LT = 1	SS = 0	LS =	UM = Each	ABC =	Source =	Type =
Gross Requirement	0	0	0	0	60.000	0	0	60.000
Scheduled Receipt	0	0	0	0	0	0	0	0
Projected On Hand	0	0	0	0	0	0	0	
Projected Net Requirement	0	0	0	0	60.000	0	0	60.000
Planned Order Receipt	0	0	0	0	60.000	0	0	60.000
Planned Order Release	0	0	0	60.000	0	0	0	60.000

Figure 13. *Part of MRP Report in WinQSB*

WinQSB provides several other reports in addition to the MRP report, including:

- Action (Order) List - which shows the week in which a specific part needs to be produced (Fig. 14).

06-03-2024	Item ID	Overdue	week 1	week 2	week 3	week 4	week 5	week 6	Total
1	X	0	0	0	0	0	10.000	0	10.000
2	SK1	0	0	0	0	30.000	0	0	30.000
3	SK2	0	0	0	10.000	0	0	0	10.000
4	P1	0	0	0	60.000	0	0	0	60.000
5	P2	0	10.000	0	0	0	0	0	10.000
6	E1	0	0	2.000	0	0	0	0	2.000
7	E2	0	0	60.000	0	0	0	0	60.000
8	E3	0	0	180.000	0	0	0	0	180.000
9	E4	0	120.000	0	0	0	0	0	120.000
10	E5	250	0	0	0	0	0	0	250
11	E6	60.000	0	0	0	0	0	0	60.000
12	E7	0	0	10.000	0	0	0	0	10.000
13	E8	0	0	0	0	200	0	0	200
14	K1	0	0	0	30.000	0	0	0	30.000
15	K2	0	0	60.000	0	0	0	0	60.000
16	K3	0	0	0	0	30.000	0	0	30.000
17	K4	20.000	0	0	0	0	0	0	20.000
18	K5	0	0	40.000	0	0	0	0	40.000

Figure 14. *Show Action (Order) List*

- BOM (Bill of Materials) - selecting a part generates a report showing the quantity of sub-components that are part of its assembly. Fig. 15 displays the sub-levels for product X.

06-03-2024	Item ID	Component ID	Component ID	Component ID	Usage
1	X				1
2		E1			0,20
3		SK1			3
4			E2		2
5			K1		1
6			P1		2
7				E3	3
8				E4	2
9				K2	1
10		K3			3
11		SK2			1
12			P2		1
13				E5	0,03
14				K4	2
15				E6	6
16			E7		1
17			K5		4
18		E8			0,02

Figure 15. *Show BOM*

- Product Structure in Graph – by selecting product X (Fig. 16), a graphical representation of the product's constructional composition shown in Fig. 17 is obtained.

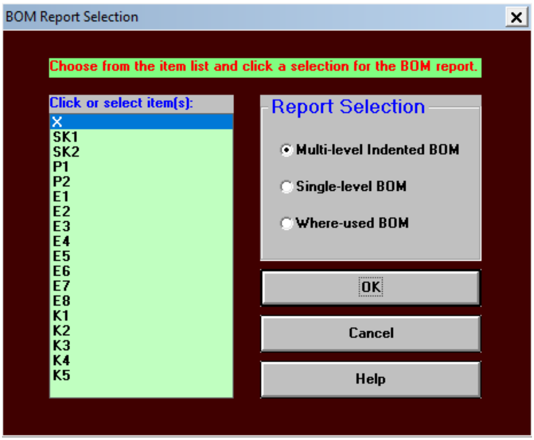


Figure 16. *Show Product Structure in Graph*

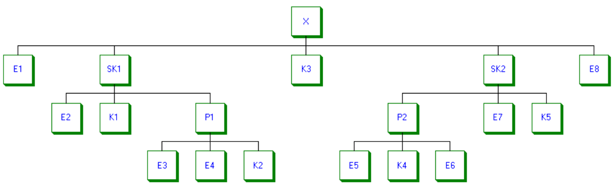


Figure 17. *Product design composition for X*

The software allows for the display of the constructional composition and other PFs. Fig. 18 and Fig. 19 show the constructional compositions of assembly SK1 and sub-assembly P1.

- Capacity Analysis.
- Cost Analysis.

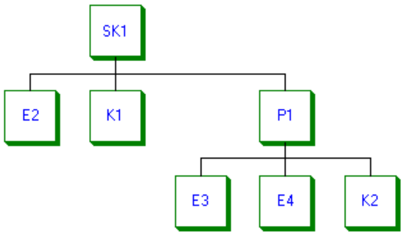


Figure 18. *Product design composition for SK1*

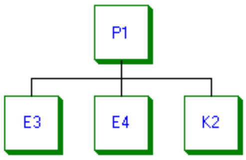


Figure 19. *Product design composition for P1*

3.3. Discussion

Both programs provide the capability to track multiple products. These tools are free and available to all users.

POM-QM is compatible with newer versions of Windows, and installing this program is easy. WinQSB is compatible with Windows Vista, but it can also be installed on newer versions. For this reason, installing WinQSB on newer versions is more complicated.

The difference between POM-QM and WinQSB is that in POM-QM, all modules are located in one place and visible under the MODULE option (see Fig. 2), whereas in WinQSB, there are main modules with submodules defined as Problem Types within the main module (see Fig. 20). For example, to solve a transportation problem in WinQSB, this option is found within the Network Modeling (NET) module, Fig. 21.

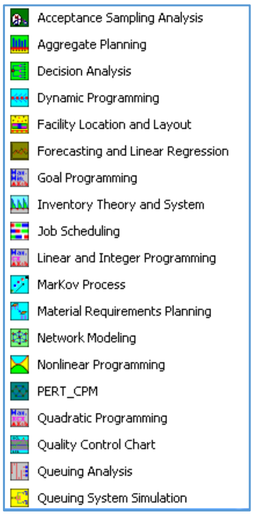


Figure 20. *WinQSB software moduls*

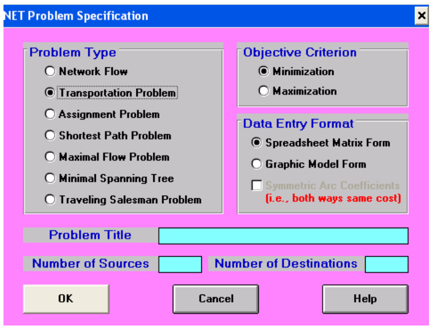


Figure 21. *Problem Type of the NET module*

Considering the processing of MRP data, their advantages, and disadvantages, a comparative analysis of both programs across ten features is presented in Tab. 2. It is clear from the table that WinQSB software is preferred in seven out of ten criteria compared to POM-QM for Windows.

Table 2. *Comparative analysis of POM-QM and WinQSB in terms of different features*

Characteristic	POM-QM	WinQSB	Preference (software)
Interface layout	Nicer look, user-friendly	Rough look, less user-friendly	POM-QM
Number of parts	The number of parts is limited in range from 2 to 90 parts	The number of parts is not limited	WinQSB
Period of production	The period of production is limited (2-48 weeks)	The period of production is not limited	WinQSB
Modification of the production period	It's not possible to change production period	It's possible to change production period	WinQSB
Data entry	All data is entered in one table	Data is entered in multiple tables	POM-QM
Input sensitivity	When entering data, it is necessary to enter parts in certain order	When entering data, the order of parts is not important	WinQSB
Scrap	It does not take into account the scrap	It's possible to enter the amount of scraps in the table	WinQSB
Period od part production (time unit)	In weeks	Depends on the input data	WinQSB
Presentation of the product structure	In the form of a list	Graph. Possibility of displaying product tree for a certain parts	WinQSB
Visibility of modules and programs	All modules in one place	Modules and submodules (problem type)	POM-QM

4. CONCLUSION

The application of educational software packages in subjects related to Industrial Engineering and Engineering Management is mandatory, regardless of the specific software package used. This approach enhances the quality of the teaching process and increases student interest in specific learning units.

For processing MRP data, using the example of a complex product, WinQSB and POM-QM software were utilized. A comparative analysis of the software across various features concluded that WinQSB is more suitable for use in seven out of ten criteria. However, the decision of which software to use should be left to the user.

It should be noted that the results will not be applicable in a real business environment if the input variables are not well defined. The study particularly emphasizes the importance of determining lead time, thus opening up a new topic for the application of different methods and software programs to calculate the projected lead time that will approximate the actual lead time.

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Technical Drawing in Engineering Education: Tool for Engineers' Communication, Design and Ability Development

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Abstract: *Technical drawing is a core of many engineering and design courses. The goals of this research are to assess whether engineering students who studied technical drawing at the university, using traditional tools for drawing and computer tools, improve their intellectual abilities, especially the effectiveness of perceptive and cognitive processors. The pilot research consists of two studies: (1) a correlation study of students' abilities and pre-university experience with technical drawing courses; and (2) a quasi-experimental study of the effects of technical drawing courses on students' abilities. The sample consists of 46 first-year undergraduate students in engineering departments (study 1) and 12 students selected from the first group after completing the course and passing an exam. The correlations between students' ability to visualize spatial relationships and achievement in presenting a three-dimensional model in three projections are confirmed. The second study confirmed that the students' perceptual processing abilities improved during the technical drawing course. In conclusion, the importance of learning technical drawing for some abilities development is emphasized, some research topics are opened, and some educational implications are suggested.*

Keywords: *Technical drawing; Mechanical engineers' abilities development; Perceptual abilities; Spatial abilities; Engineers' education.*

1. INTRODUCTION

The technical drawing or engineering drawing is an effective way of engineers' communication, cooperation and collaboration, conceptualization and coordination. It is an essential tool for communicating ideas and concepts in engineering and industrial production, for understanding the design process, and transformation an idea into the product (real thing). Technical drawing is an international language, a professional language without borders. The standards of technical drawing, as an international convention (standardized principles, signals and symbols) enable a uniform application in a wide range of engineering.

Technical drawing is a step that mechanical engineers absolutely have to master in order to present their product in the developmental and design phase. Therefore, technical drawing courses are necessary for engineering students for their professional education and career development, as well as for effective professional communication.

Technical drawing is a major part of engineering university education. As a *method of communication* by graphic means, technical drawing is widely used in different professions (engineers, designers, architects, graphic designers, photographers, artists, cartographers, chess players, video-game designers) to transfer information about various objects (machinery, products, structures, buildings, traffic), or to share technical information [1]. The other very important functions of technical drawing are the *visualization of the idea and the design and construction of the objects*. Visualization as a process of engineers' creative activities and as a universal visual language enables the transfer of ideas and information about the approach to construct something, or specificities of functioning between engineers in different cultures.

Technical drawing is a core part of many design courses. Although teachers and engineers use two terms – technical drawing (TD) and engineering drawing (ED), the basic concepts and standard conventions and rules for TD and ED are common [2]. The visual and spatial intellectual abilities and skills are the basis for TD/ED as a form of graphical communication. The conception of teaching and learning skills of technical or engineering drawing is the same.

Recognizing that visualization of the problem is a very important tool required in the technology and engineering professions, researchers [3] emphasized that visualization of problems has a formative impact on the success of technical /engineering education and will be used as a predictor of success in several engineering and technology disciplines [1, 2, 3, 4, 5]. These abilities are necessary for technical problem-solving success.

On the other hand, the researchers confirmed that TD courses affected spatial ability [6, 7, 8]. Results indicated that the TD course caused a significant increase from the pre-test to the posttest, with a significant positive relationship between spatial visualization abilities and spatial orientation abilities [2]. In the experimental research of the impact of engineering three-dimensional modelling (3D modelling) with SketchUp computer programme on the development of students' spatial thinking and visualization, in the context of previous experience with 3D modelling and students' achievement in the course Technics and Technology (secondary level of edu-cation), the researcher confirmed "that introducing spatial modelling with SketchUp in early technics and technology education enables more effective development and improvement of children's spatial visualization ability skills" [8]. Review of research on spatial ability improvement in the context of TD teaching emphasized that "several researchers have suggested that spatial ability can be enhanced and taught by some instructional designs" [3]. Drawing and spatial abilities share mutual training [9].

This paper investigates the mutual connections and formative impact between abilities, achievement in technical drawing courses at the university educational level, and educational settings.

1.1. Technical drawing and intellectual abilities and skills

Abilities are important and formative for academic and professional achievement, and some educational activities are formative for ability development. Researchers confirmed that it is possible to improve skills and abilities through educational activities [2, 4, 10, 11, 12, 13]. In the field of technical and engineering education, as a field of visuo-spatial engagement, spatial ability, and perception skills are very important and formative factors of efficiency.

According to Gardner [14], spatial intelligence, or spatial-visual intelligence, is the ability to think abstractly and in multiple dimensions. Based on spatial reasoning and conceptualization, it means keeping their cognitive maps in multiple directions and dimensions in their head. Humans with higher spatial-visual intelligence are thought to have a heightened awareness of individual physical spaces or environments. Some occupations of humans with higher spatial intelligence may include architects, mechanical engineers, artists, video-game designers, etc. [14, 15]. It is manifested as "the performance on tasks that require: the mental rotation of objects, the ability to understand how objects appear at different angles, and how objects relate to each other in space" [1]. Spatial ability is the mental manipulation of objects and their parts in 2D and 3D space, consisting of two major components: spatial relations and spatial visualization [16].

In the review of the research and literature about the importance of the spatial ability to vocations and other cognitive areas or academic disciplines, some conclusions are the following [2]:

- There is an association between spatial ability and performance or interactions and success in technical drawing and several occupations that require spatial understanding.
- The spatial ability could be increased with training, instruction, and practice.
- Spatial skills increase with vocational subjects.

Researchers identified some factors of TD effectiveness as spatial visualization, spatial relations, spatial orientation, spatial cognition, spatial intelligence, spatial ability, and visualization [3].

Spatial skills "promote a holistic understanding of engineering graphic tools, techniques, and processes" [4]. The spatial ability of two groups of engineering students is compared: the students studying TD at the pre-university and university levels and the students of philology not oriented towards engineering. The main results are showing that first-year engineering students present better visual discrimination and spatial memory than philology students. Therefore, improvement of spatial skills is possible through science, mathematics, and drawing classes [4]. Measuring spatial skills of the students before and after spatial ability enhancing courses, with three tests (mental rotation, mental cutting, and spatial visualization test), the researchers show similar results with the prior research [4], that the students' performance in the post-test measurement was improved, but differently in various sample groups and test types: first-year students improved significantly, but only on two of the three used tests [17].

The research on the participant's performance on a range of spatial cognition tasks considered important to designers, two groups of university students are compared [1]: a skilled group and an unskilled group, based on whether or not they had prior TD experience. The skilled group did consistently better on spatial ability tasks, with differences in performance shown to be statistically significant. Those tasks requiring advanced spatial skills associated with coordinate systems were found to be difficult. Other tasks requiring spatial reasoning to identify 3D properties from 2D produced better results than expected.

Based on a review of the results of other studies that showed "spatial ability can be improved through direct training with tasks similar to those integrated into the tests used to measure the ability," the experimental research with the aim "to analyze whether the indirect training in Technical drawing improved the spatial visualization ability of architecture students" was realized with the students in the course Fundamentals of Architecture participated [6]. At the beginning and at the end of the courses, two tests were implemented: a Spatial Visualization task and an Abstract Reasoning task. Their results were compared with the control group of students enrolled in a Mathematics degree (without training in Technical Drawing). Although the difference was expected, improvements occurred in both groups; therefore, the conclusion was that this improvement was not due to indirect training.

The study of positive effects of three different types of teaching visual models (a 3D printed solid object, a 3D computer-generated drawing, and a 2D drawing) confirmed some differences [3]. The main results are the following: the 3D printed solid model and the 3D computer-generated image both provided statistically significant higher scores than the 2D drawing. While not statistically significant, the students who received treatment via the 3D-printed solid model outperformed their peers who received treatment from the other two models in the drawing. This could indicate that students could better comprehend visual data obtained from 3D solid models than from 3D computer-generated models or 2D drawings.

1.2. Technical drawing trainings and courses

Technical or engineering drawing skills are the formative skills for more activities of engineers in different engineering fields [18], because those skills are necessary for project documentation preparation, to sharing of different information using graphic languages (diagrams, schemes, and facilities, with a 2D drawing being the most frequently used), to deemed fundamental to graphic expression in professional practice. In many engineering professions, prospective and active engineers learn the rules of engineering communication through TD based on conventions and standards.

ED/TD courses can provide the context and tools for improving professional abilities and developing professional skills. The following reasons are emphasized [16]:

- It is a teachable area because it has a practical base in real-life situations organized according to occupational standards and drawing conventions;
- “The concrete experiences with geometrical objects and representing them in two-dimensional space are proved helpful in improving students' performance in spatial visualization” [16].

Development technical documentation is important part of TD courses. For communication to be unambiguous, it is necessary to follow valid standards when creating technical documentation. Standards in TD refer to the use of appropriate types of lines, the layout of projections, dimensioning rules, the definition of sections, the marking of surface quali-ty. For the correct interpretation of the drawing, the 3D model must be displayed accurately in the plane of the drawing with all visible and invisible edges. This is necessary in order to create a clear idea of the appearance of the 3D model presented in the drawing when reading the drawing. This means that engineers of all profiles should be able to present a 3D model in the plane of the paper and a 3D model in space based on 2D drawings.

The goal of the Technical Drawing Course for students-mechanical engineers is to make students technically literate, that is, to know all the rules and standards used to define machine parts on drawings. Also, they need to acquire the knowledge necessary for the successful presentation of machine parts and assemblies on TD and to be able to represent a 3D body based on a TD. Also, after the course, students can sketch a machine part or assembly, based on which a technical drawing can be made later. By studying the Auto CAD software, students are trained to draw with a computer, which speeds up the drawing process significantly. The mixed method of TD courses (teaching and learning manual technical drawing supported with digital tools) is the most present teaching methodology in this field today [19].

The knowledge the student acquires when he/she passes this course enables him/her to independently draw machine parts and assemblies on the appropriate drawings, with the necessary cross-sections, so that they are defined in terms of shape, dimensions, and machining. Students are trained to make drawings by hand and by computer.

2. RESEARCH METHODOLOGY

The goal of this paper is to highlight the connection between learning technical drawing and abilities development in a new educational context – a mixed teaching process with traditional tools of teaching and learning ED/TD and CAD. The tasks are to assess whether engineering students, who studied TD at the university level, improve their intellectual abilities, especially the effectiveness of the two very important cognitive processors: perceptive processors and cognitive processors. For these goals, the efficiency of the cognitive processors, defined in the framework of the cybernetic model of intellectual function [20], was investigated and used as a correlated phenomenon with the objectives of TD courses. The relationship between achievement in TD at the university level as a predictor or as an effect of TD courses will be explored in future research.

2.1. Variables

- Intellectual abilities: Based on the theoretical framework and model of intellectual functioning of the applied instrument/test and according to the authors of the instrument KOG3 [20], intelligence is: an adaptation ability, learning ability (learning speed, complexity of the operations which a person can learn) and abstract thinking (the ability to manipulate with the idea and symbols, using rules of education of the relation and correlates, reasoning, and deduction). According to this cybernetic model, intellectual ability is constituted by perceptive abilities (synthesis of perceptive analysis, perceptive structuring, and perceptive identify-cation), verbal comprehension, and visual spatialization (as an indicator of the factor of education and of the general intellectual factor).
- Initial skills of technical drawing: skills of technical drawing before attending the course of TD at higher educational institutions;
- Educational variables:
  - ✓ Type of pre-university education: mechanical vocational education, technical vocational education in the other fields (except for mechanical and mechatronics), nontechnical vocational education, general secondary education (grammar school);
  - ✓ Attending courses in TD and similar courses in secondary schools: with courses in the field of TD and without the courses in the field of TD (prior education in the field of TD and technics);
  - ✓ Results in Technical drawing exam after the course of technical drawing.

2.2. Method and techniques

Method: A quasi-experimental research used for the analysis of connections between learning technical drawing and the intellectual abilities of university engineering students. The research is realized in three phases:

(1) Collecting initial data about students' pre-university education, testing them by the test of intellectual ability and testing their initial knowledge and skills in the field of TD;

(2) Realization of the course: technical drawing and monitoring the process of students' learning technical drawing knowledge and skills during the TD course.

(3) Evaluation of the effects of TD courses: final measurements of intellectual ability and results on the exam.

Two connected exploratory pilot studies are realized and presented in the paper:

I The first study explores the correlations between students' abilities, pre-university educational variables, initial technical drawing skills, and results on the exams and pre-exam activities.

II The second study explores, based on initial research, the effects of a TD course on the students' abilities; the second study is in the case study format.

Techniques and instruments for data collection include:

1. Questionnaire of students' education and socio-demographic characteristics;
2. The cybernetic battery of intelligence tests KOG3 [20].
3. An initial test of technical drawing was constructed for this research.
4. The exam on the Technical Drawing Course.

The cybernetic battery of intelligence tests KOG3 [20] enables the evaluation of the efficiency of the functioning of the most important cognitive processors defined by the cybernetic model of intellectual functions. The battery consists of three tests of cognitive functioning, which assess the efficiency of the perceptual processor (IT-1 – image comparison test); the serial processor (AL-4 – verbal comprehension assessment test); and parallel processor (S-1 – test for measuring the ability to visualize spatial relationships) [21]. KOG3 battery was applied to the group of participants.

An initial test of TD was constructed for this research. The test of knowledge and skills in TD is a composite measure and consists of three groups of tasks with six examples each (Fig. 1, 2, 3 – next page). The maximum score is 18 points.

The first task is to match the displayed 3D models with the corresponding projections. This task is the most common task in TD, which is to define appropriate projections for a given 3D model. The students needed to combine one of the six offered 3D models with the corresponding projections.

The second task is to match the shown two projections with the missing third projection. Students should construct the third projection respecting the spatial relationships shown in the first two projections. Also, the height, length, and width of the 3D model must be the same in all projections. The six pairs of projections are given. The task is to match each pair of projections with the corresponding third projection.

In the third task, 3D models with different holes are given. It is necessary to find a suitable section for each 3D model. Respecting all the rules of technical drawing, it is needed to connect the displayed 3D models with the corresponding sections. The test of knowledge and skills in TD is a composite measure and consists of three groups of tasks (Fig. 1, 2, 3 / next page).

There is no correlation between the three groups of tasks. This result confirmed that the three groups of tasks measure different components of technical drawing skills. But all the task groups impact the general score (sum) and the correlations with the general score are very high (Table 1 - next page).

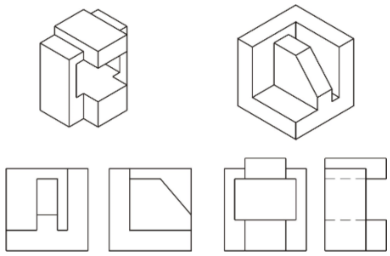

Figure 1. *Example of tasks 1*

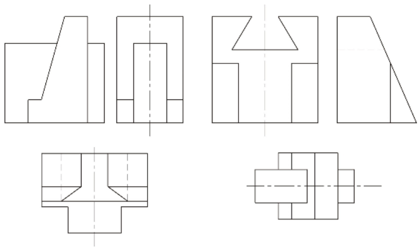

Figure 2. *Example of tasks 2*

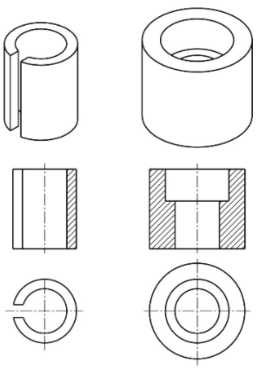

Figure 3. *Example of tasks 3*

Table 1. *Correlation matrix of the results on the technical drawing tasks*

	Tas7k 2	Task 3	Tasks sum
Task 1	0.24	0.07	0.50**
Task 2		0.26	0.89**
Task 3			0.58**
	N=46	** p< 0.01	* p< 0.05

The exam on the TD course consists of two parts. In the first part of the exam, it is necessary to present displayed 3D model in three projections, that is, to make a TD of the 3D model. The TD must be done by the standards. Also, the TD must be fully dimensionally defined. Surface roughness for each machined surface must be defined, as well as tolerances. In the second part of the exam, the task is to make a TD for a given 3D model, but in this part of the exam, AutoCAD is used. In this part of the exam, students' ability to present 3D models in projections is checked, as well as their knowledge of the rules of TD and capability to use AutoCAD for 2D drawings.

Techniques of data processing are based on the properties of small samples; descriptive statistics, correlation analysis, and analysis of variance are used.

2.3. Sample and procedures

The sample in the first study consists of 46 students, 20–21 years old, all undergraduate students in the first year of their studies in the engineering departments at the Faculty of Technical Sciences in Čačak at the University of Kragujevac in Serbia.

The sample in the second study (case study) involves 12 students in two departments (mechatronics and mechanical engineering), who passed the course Technical Drawing and participated in the initial and final testing.

Data collecting: March 2022 (Study 1) and March 2023 (second part of Study 2).

3. RESULTS AND DISCUSSION

This exploratory research was organized into two connected pilot studies.

3.1. Study 1

The first pilot study was realized as an initial investigation: collecting initial data about students' pre-university education, testing them by the test of intellectual ability, and testing their initial knowledge and skills of TD. Analysis of the main results in the first study confirmed the correlations between students' ability of space relationship visualization and achievement in the presentation 3D model task in three projections (table 2). Following this result, there is a correlation between the ability of space relationship visualization and the composite sum of three groups of tasks (r=0.34, p<0.05).

Table 2. *Correlation (r) of the KOG3 subtests and initial test (tasks) of technical drawing skills*

	Tasks 01	Tasks 02	Tasks 03	Tasks
Perceptual processing KOG3-IT-1	0.04	-0.05	-0.12	-0.07
Serial processing KOG3-AI-4	0.06	-0.11	-0.03	-0.07
Parallel processing KOG3-S-1	0.33*	0.27	-0.14	0.34*
Abilities KOG3 (Sum z score)	0.13	0.03	-0.01	0.08
Intellectual ability KOG3 IQ	0.20	0.05	0.00	0.09
	N=46	** p< 0.01	* p< 0.05	

Although "the research relative to engineering is centered on spatial skills, the mechanisms through which engineers may present a better spatial ability are not completely understood" [4]. Spatial skills are the focus of various research studies, but, the perceptual ability is the focus of this study, and increasing perceptual abilities based on perceptual processing is confirmed.

There are no differences in the measured abilities and results in the initial TD tasks between the students with different pre-university education (students from different vocational secondary schools and grammar schools).

3.2. Study 2

The second study focused on the measurement effects of the TD course on the students' cognitive abilities: the abilities of perceptual processing (visual-perceptual ability), serial processing (verbal comparison ability), and parallel processing (spatial ability or ability of space visualization).

Based on the results of the first study, 12 students were selected for this study, organized as research of a small educational group or case study. One year after the initial testing of students' cognitive abilities and six months after the course finishes and students pass the exam, the testing of students' cognitive abilities by the KOG3 battery is applied. Based on the ANOVA procedures for analyzing two measures on the same small sample, some differences were found (Table 3).

Students' abilities for perceptive processing are improved between two measurements, and composite intellectual ability (represented as IQ) is higher after a course and a passed exam than before attending TD courses. This result is highly significant.

Table 3. *Comparison* of the results of pre-course and post-course testing

	Measurements			
Cognitive functioning KOG3	Pre-test Mean	Post-test Mean	F	Sig
Perceptual processing KOG3-IT-1 Max result 39	18.83	25.08	9.868	0.01**
Serial processing KOG3-Al-4 Max result 40	28.85	32.08	3.361	0.08
Parallel processing KOG3-S-1 Max result 30	23.17	24.17	0,181	0.67
N	12	12	F–Fischer coef.	
		** $p< 0.01$		* $p< 0.05$

So far, the researchers have analyzed connections between TD skills and the effectiveness of cognitive parallel processor (spatial ability in the KOG3) more often than the other connections. However, the results obtained in this study highlight the connections between TD skills and the effectiveness of perceptual processors.

Some research emphasizes that drawing and spatial ability have mutual connections: "drawing is dependent on spatial ability and spatial ability may be enhanced through learning to draw" [22]. Although the improvement in the ability to visualize spatial relationships in this research was expected, this cognitive function is stable between two measurements, and it is the same before and after the TD course. All of the selected students attended the TD course during pre-university vocational education in their middle and late adolescent period, and the effects of learning TD are formative for an earlier adolescent age [22]. The relationship between different forms of drawing and spatial and visual-perceptual ability, based on complex information processing, is very complex [9]. Consideration of the control condition of the effect of TD courses on the improvement the spatial and perceptual abilities [6]. Some explanation is the following: "Concrete experiences with geometrical objects and representing them in 2D space are proved helpful in improving students' performance in spatial visualization" [16].

The correlations between intellectual abilities improvement and results on the pre-exams and final exam are also analyzed. There are no correlations between the changes in intellectual abilities and students' results on the TD pre-exam and exam tests. The obtain result is significant for the course evaluation showing that the outcomes of the course and students' results on the exam (and pre-exam activities) are independent of the student's abilities. This result indicates that the realization of the TD course and the effectiveness of teaching differentiation and individualization as key to the additional value of education and the role of education to compensate for differences between students.

3.3. Teaching implications

What is the reason to improve intellectual skills during the TD course at the university and higher education level and based on TD activities?

The current tendency in education policy emphasizes the importance of middle and late adolescent's educational intervention for the improvement of their capacities. "It is a time for core programmes for abilities development" [22]. The first-year mechanical engineering students at the university are people in late adolescence. If there is an opportunity to develop abilities within the teaching process, it should be used because of the long-term effects and to increase efficiency.

What are the suggestions for TD teaching useful for broader transfer from the development of TD skills of students-mechanical engineers and to the development of their connected intellectual abilities? Although this research has limitations (a small sample, cognitive processing test standardized for a limited population), the comparison with the other research confirmed some educational implications.

Based on the researchers' evidence that "drawing and spatial abilities share common training" [9], on the constructivist theoretical approach, and on the review of the teaching and learning methods of TD courses and their effects [23, 24, 25, 26, 27], some suggestions to TD teaching formative for developing both technical drawing skills and perceptual and spatial abilities are the following:

- Using self-assessment of technical drawing skills and knowledge is a useful activity at the beginning of the TD course. This test provides students "with a tool for self-assessing their knowledge of the basic TD rules and principal standards and to give teachers some feedback on the different TD topics" [26]. The transfer from technical drawing skills development to the intellectual abilities connected with them is broader in this case.
- Using questionnaires of different students' opinions of technical topics related to technical drawing skills and competences and to possibilities to improve these skills. It is a tool for improving students' self-awareness in the field of TD.
- Using different teaching methods to increase students' motivation to learn TD [26].
- Using interactive self-learning tools for teaching TD, especially for teaching manufacturing dimensioning [26].
- Using 3D visualization tool-based training programmes for practicing mental rotation processes [28].
- Using student-centered education methods: include a continuous reflection process; appropriate different teaching and learning styles for the participants; recognize the diverse educational needs of the students; adapt their learning needs to their lives and professional experiences; allow the students to be involved in designing courses and control their own learning; improve students responsibility for learning; and involve cooperation between teachers and students [27].

4. CONCLUSIONS

The correlations between students' ability to visualize spatial relationships and presenting a 3D model in three projections are confirmed in this study. The students' perceptual processing abilities improve during the course of technical drawing, and composite intellectual ability (represented as IQ) is higher after a course and a passed exam than before attending TD courses. TD skills are correlated with some intellectual abilities and TD course is formative for some intellectual abilities.

Technical drawing courses consist of exercises in perceptual space recognition, too. In this research TD course have effects like the perceptual ability courses, because it consists of the acquisition of visual perception and spatial visualization skills, skills to interpret the 2D representation of 3D objects, manipulation, form development, and orthographic projections.

Enchasing students' abilities for perceptive processing and composite intellectual ability (represented as IQ) after a course is a highly significant research result. This result highlights the connections between technical drawing skills and the effectiveness of perceptual processors.

Technical drawing is a graphic language without boundaries. The main conclusion of this research is the importance of learning TD for the development of some perceptual spatial abilities. These abilities are one of the prerequisites for professional activity in the field of mechanical engineering. And the opportunity to improve these abilities is an important part of the education of mechanical engineering students for the most successful professional communication through technical drawings.

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Creating the Flipped Classroom in the Course Engineering Graphics

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Abstract: *With the advancement of technology, the possibilities of learning are changing and so are the approaches. There is a high demand in the market for engineers with an advanced level of knowledge in the field of 3D modeling. The students of vocational studies at the Faculty of Technical Sciences in Čačak have different prior knowledge in this field, and therefore the subject Engineering Graphics, in which 3D modeling is studied, is adapted to an intermediate level of knowledge. The paper shows the preparation of a new approach to teaching, the flipped classroom, because this strategy has proven to be successful in encouraging greater student activation and deeper knowledge.*

Keywords: *Technical drawing; 3D modeling; flipped classroom; Education in engineering*

1. INTRODUCTION

At European universities, students acquire basic knowledge of technical drawing and 3D modeling in the first year, as part of engineering curriculums. At the Faculty of Technical Sciences in Čačak, in the vocational studies of mechanical engineering, during the first semester, students have the subject Technical drawing. With the rapid development of computers and information technologies, there has been a revolution in the field of creating and using technical documentation. According to the mentioned changes, during the second semester, the subject Engineering Graphics has been introduced. During the 15-week Technical Drawing course, students acquire the knowledge and skills necessary for making technical drawings and reading already made technical drawings, while during the Engineering Graphics course, students learn the basics of modeling in the SolidWorks software package.

The lectures in Engineering Graphics were held in the amphitheater where the teacher presents the modeling process on the computer while the students can only follow the process on the screen via projection. Some students passively followed and some took notes during the lectures. After two hours of the lectures, it was noticed that some of the students who passively follow, stop following the class and start to get bored because of the large amount of information [1]. Also, a significant number of students attended classes without prior knowledge, which is why it took a long time to explain the basics of 3D modeling. Due to slow progress, students who had prior knowledge quickly lost interest in the subject.

In addition, the lectures lacked interaction because students could not work simultaneously on the computer to encounter possible problems in the modeling process. The observed problem was solved by providing a computer classroom for the lecture period. However, this solved only a part of the observed problem because, in addition to the students for whom it is a compulsory subject, students from the Graphics department and Information technologies for whom it is an optional subject, also follow the classes in the Engineering Graphics. The computer classrooms are mostly equipped with 20 computers, which is small considering that around 60 students attend classes during the lecture period. In this way, one third of the students actively followed the teaching and in parallel with the teacher on their computer applied, step by step, the modeling process. Two thirds of the students still passively followed the classes.

After several years of traditional teaching and observed problems, innovation in teaching is being considered in order to improve students' results. In addition to teaching materials in text format, e-education programs increasingly use multimedia materials. Different media have different informational attributes and make different demands on students regarding information processing. For example, our perception of a film whose action is based on a novel is different compared to the perception while reading the novel [2].

The rest of this paper is structured as follows: Section 'Related work' goes through some advantages faced by other researchers. Section 3 describes in details course outline. In Section 4, a conclusion and the future work are presented.

2. RELATED WORK

Following the literature in the field of engineering education, the inverted (or flipped) classroom approach emarges as a promising strategy. The flipped classroom is a new pedagogical method, which uses asynchronous video lectures and practice problems as homework, and active group activities for solving problems in the classroom [3, 4]. The Flipped Classroom consists of interactive group learning activities inside the classroom and direct one-on-one computer-based instruction outside the classroom.

Through the flipped classroom, not only knowledge can be well acquired, but also some other abilities can be developed, such as the ability to access information, a sense of teamwork, communicative abilities, and the ability to reason and (connect knowledge) summarize [5].

Research shows that students learn best when they are taught in accordance with their particular learning style, which can be dependent, collaborative, or independent [6]. The time when students really need a physically present professor is when they have a problem (get stuck) and need his individual help. The students do not need the presence of a professor while following the course content [7].

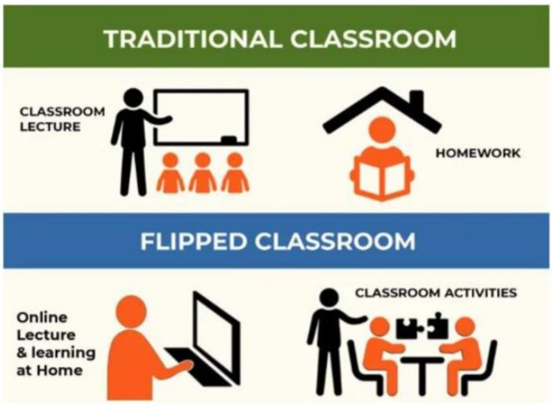

Figure 1. *Traditional Versus Flipped Classroom taken from [8].*

3. COURSE OUTLINE

After the decision to apply this method, video tutorials were recorded to accompany the course. The video tutorials are available for free on YouTube and could be found on the channel called "Engineering Graphics". In addition, teaching materials have been written in text format. The changes in the organization of the teaching process are planned in order to ensure the improvement of students' results.

Given that the course lasts 15 weeks, the idea is to divide the course into three parts. Each part lasts 4 weeks and at the end of each part the students take a test.

In the first part, it is planned to learn the modeling of prismatic and rotational parts, in the second part the generation of technical drawings, and in the third part the modeling of complex parts and assemblies.

The first part of the course should be the most intensive, because students will, at the same time, become familiar with working in the program, sketching procedures, basic modeling techniques of prismatic and rotational parts, and the most commonly used commands.

In the second part of the course, students are introduced to the basic techniques of generating technical drawings and the most commonly used commands. In order to successfully master this part of the course, students, in addition to knowing how to work in technical drawing software, must have a good knowledge of the principles of technical drawing.

In the third part of the course, students are introduced to the modeling techniques of complex parts and assemblies and the most commonly used commands used in this part of the course.

In order to motivate students to look at the teaching materials before coming to class, entrance tests will be prepared for each teaching week.

3.1 First part of the course

At the beginning of the course, it is necessary for students to familiarize themselves with opening a new document in SolidWorks, with the sketching environment as well as with document parameter settings. After that, through several prepared video examples, students will learn the basic commands for sketching the profile of model forms (Fig. 2).

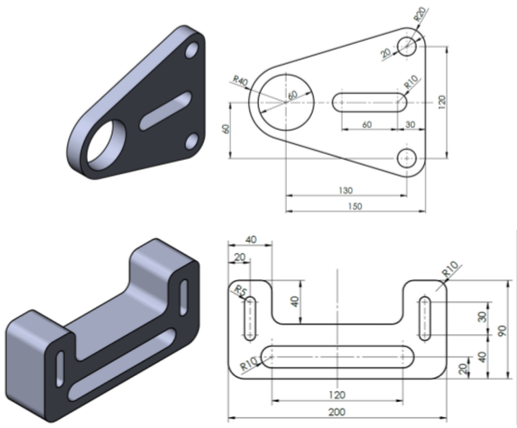

Figure *2*. *Example of the profile of model forms*

Then, through several prepared video examples, students will master the basic commands for creating model forms of prismatic parts (Fig. 3). The commands needed for the first exercise are: Extruded Cut and Extruded Boss/Base.

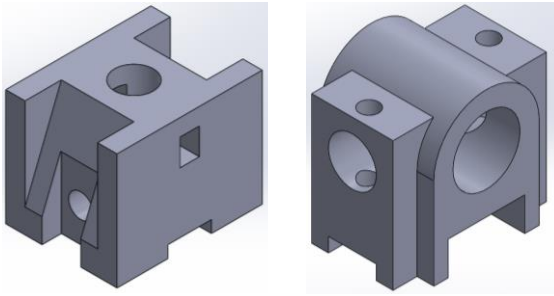

Figure 3. *Example of the prismatic form*

In the next step, students are expected to master the basic commands for creating model forms of rotational parts (Fig. 4). By creating these models students will learn the following commands: Revolved Boss/Base, Revolved Cut, Chamfer, Hole Wizard and Cosmetic thread.

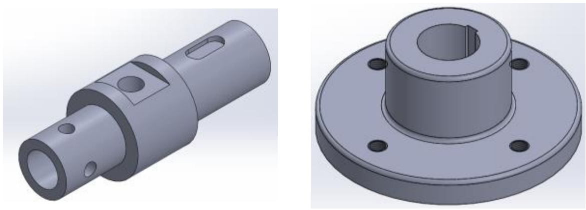

Figure 4. *Example of rotational parts*

Based on the knowledge they have acquired in the previous exercises, in the first test, students need to create appropriate model forms of prismatic or rotational parts based on the presented technical drawing of the 3D model in SolidWorks (Fig. 5).

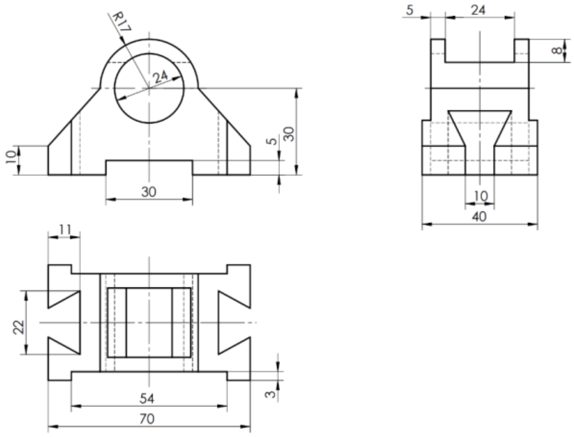

Figure 5. *Example of the first test: Based on the technical drawing create 3D model*

3.2 Second part of the course

In the second part of the course, students will first learn through prepared video examples that can be find in „Engineering Graphic" YouTube channel how to create orthogonal projections of 3D models in SolidWorks (Fig. 6).

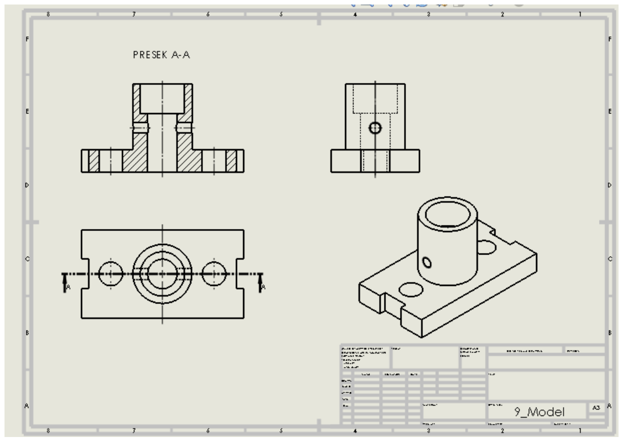

Figure 6. *Example of the orthogonal projections*

In order for the technical drawing to be complete, through several examples, the drawing must be dimensioned. Also the marking of surface roughness quality and tolerances is done in Solid Works (Fig. 7).

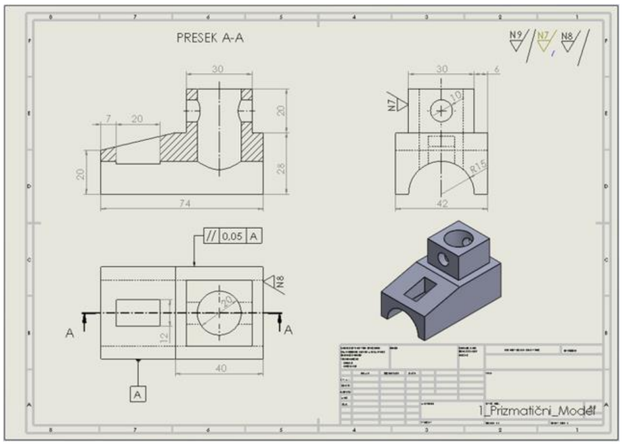

Figure 7. *Example of the finished technical drawing*

In the second test, based on the knowledge they have acquired in this part of the course, students are required to create a model and create a workshop drawing for the model shown in isometry. Figure 8 shows an example of the test task.

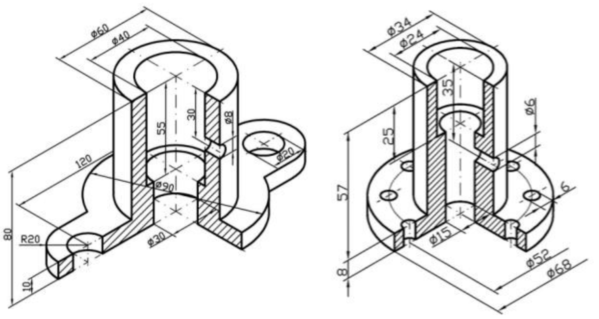

Figure 8. *Example of the second test: Based on isometric model create technical drawing*

3.3 Third part of the course

The third part of the course will be the most demanding for students, because in this part they need to learn how to model complex geometric parts such as springs, bolts, nuts, gears, etc (Fig. 9).

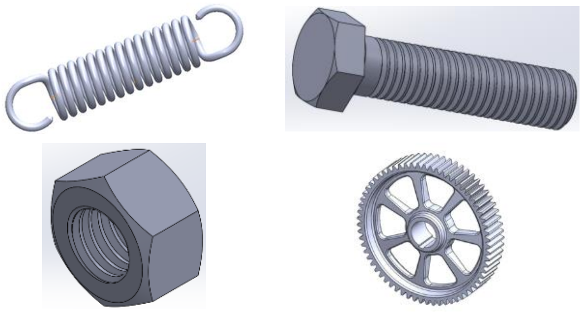

Figure 9. *Example of machine elements*

After that, students will learn, through appropriate examples from the above mentioned „Engineering graphics" youtube cannal, how to make assemblies (Fig. 10).

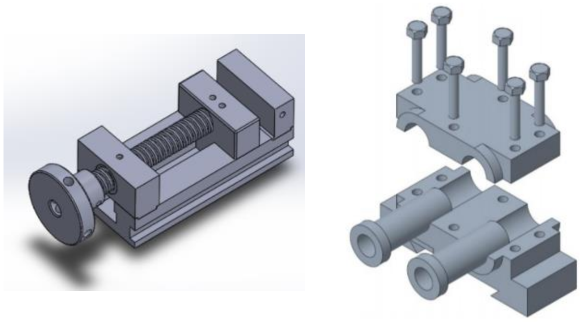

Figure 10. *Example of Assemblies adapted from [9]*

At the end of the third part of the course, students will take a last test. The test consists of two tasks. The first task is to model a suitable machine element, and the second task is to create a suitable assembly based on the given components of the assembly (Fig. 11).

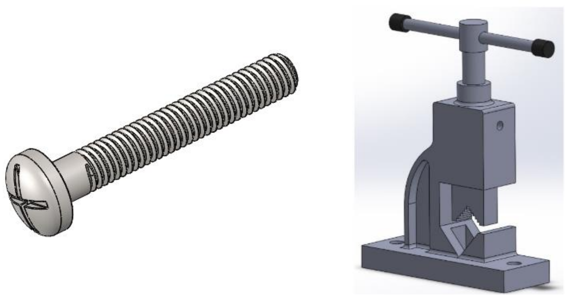

Figure 11. *Example of the third test: Task 1 – Create appropriate machine element; Task 2 – Create assembly based on the given components*

4. CONCLUSIONS

The changes are necessary in the teaching of engineering studies in the respective subjects in order to improve the results of students who need to respond to the increasing demands of the market. At the Faculty of Technical Sciences in Čačak, one of the very important subjects is the Engineering Graphics. It represents the universal language of communication of technical persons. According to conducted survey [10], which shows students' willingnes to upgrade their knowledge level, a new student-centered approach to teaching Engineering Graphics is planned.

The new approach to teaching through the flipped classroom will allow students to prepare before coming to class through video tutorials and teaching materials in text format that will cover all lectures and are made for absolute beginners with step-by-step explanations.

The future work will focus on the implementation of proposed flipped classroom. After implementation and, at the end of the course, the survey will be conducted in order to analyzed students attitude toward proposed method.

ACKNOWLEDGEMENT

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Digital Analysis of Traffic in the Port of Split during the COVID-19 Pandemic: A Numerical Study for Technical Education

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Abstract: *The COVID-19 pandemic had a profound impact on maritime transport globally, significantly affecting the Port of Split, which saw substantial declines in both passenger and cargo traffic. This study examines data from the Split Port Authority before, during, and after the pandemic, highlighting a dramatic decrease in passenger traffic by over 50% in 2020 compared to 2019. Although there were signs of recovery in 2021 and 2022, the full extent of the pandemic's impact remains to be fully understood. The port's strategic location and infrastructure investments underscore its importance, yet the pandemic underscored vulnerabilities in its operations and the broader economic repercussions. Despite challenges, the return to pre-pandemic levels of activity is progressing, supported by increased vaccination and eased mobility restrictions. The findings suggest that while the port is on a path to recovery, continued efforts are necessary to ensure resilience against future disruptions.*

Keywords: *COVID-19, maritime transport, Port of Split, numerical study, technical education*

1. INTRODUCTION

The outbreak of COVID-19 in China in December 2019 and its global spread in early 2020 led to the most deadly and disruptive pandemic in recent history. The global response to COVID-19, despite its deficiencies, is an example of the rapid and coordinated reaction of humanity to a threat to human lives and overall health [1]. Over ninety percent of total trade is carried by sea, making ports one of the most important factors in the global economy. Since the start of the pandemic, the shipping industry has taken actions to provide the continuity of operations and thus the security of supply [2]. Governments worldwide have applied rules to prevent the spread of the disease, but those rules negatively impacted traffic and transportation, and therefore the entire economy. This event, called “anthropause”, was responsible for reductions in transport and energy consumption, but it also left a positive mark on the natural environment due to the reduction in pollution [3].

This study observes a significant decline in passenger traffic, including cruising traffic, and cargo traffic in the Port of Split. The Port of Split measures significant reductions in income, negative effects on transportation and traffic, and maritime services in general.

2. THE PORT OF SPLIT AND DIGITAL ANALYSIS METHODOLOGY

The Port of Split is in the central part of the eastern coast of the Adriatic Sea at traffic corridors between Rijeka and Dubrovnik, including Split, Ancona and Pescara. Since its establishment, the Port of Split has been continuously investing in port infrastructure, with the aim of providing excellent conditions and services in passenger traffic, as well as increasing the competitiveness of its cargo, port and freight traffic. The natural position and size of the Port of Split enable its rapid development as an open port for international public transport. Therefore, this port has been recognized through decades as a port of special international economic interest for the Republic of Croatia. Thanks to its strategic position in the Mediterranean region (between Venice and the Aegean port), the Port of Split is one of the most important ports of call for cruises in the Adriatic Sea, and its long history and numerous sights attract thousands of tourists each year [4]. Growth and development of an integrated and sustainable transportation system is extremely dependent of ports and port industry. In order to achieve economic and any other progress in specific area, whether it is on local, regional or national level, the first and fundamental precondition is well - developed transport and traffic. Transport is the totality of various transport services, postal-telegraph-telephone services, which as independent economic activity has a useful effect in the movement of material goods, transport of people, transmission of news and exchange of thoughts. There are several seaports under the jurisdiction of the Port of Split and each of them has a different purpose and facilities. Depending on the kinds of traffic carried out within the port, it is divided into six basins:

1. "City Port"

Port of Split is one of the main touristic port for island destinations and other destinations along the coast. It also maintains daily ferry connections with Italy and Europe.

2. "Vranjic – Solin"

The purpose of this basin is docking of cargo ships in international and domestic traffic, ships in disarray and other purposes (general cargo terminal, terminal for bulk commodities and containerized cargo).

3. "Kaštela A"

Kaštela basin A is intended for cargo ships in international and domestic traffic that perform loading or unloading of cargo for the needs of the concessionaire or other needs.

4. "Kaštela B"

Kaštela basin B is intended for cargo ships in international and domestic traffic that perform loading or unloading of cargo for the needs of the concessionaire or other needs. This basin is intended for cargo ships, liquid cargo ships, ships in disarray, ships carrying out rodent control or other needs.

5. "Kaštela D - Resnik"

The basic function of Resnik basin is connecting air and sea traffic whereby passengers and goods transfer from Split – Kaštela Airport to costal and island destinations bypassing traffic jams in the port of Split.

6. "Komiža"

Komiža is dislocated basin on the island Vis having the main purpose of provision of fishing services.

Considering that over 90% of the global trade is carried by sea, ports and port industry are the centers of economic and industrial activities, essential for the functioning of the transportation process and transportation services. In the Republic of Croatia, port authorities are public non-profit institutions in 100% ownership, in charge of the management of Croatian ports. This paper presents COVID-19 impact on passenger and cargo traffic in the Port of Split.

The term "Digital Analysis" in the title refers to the use of digital tools and software to analyze the traffic data for the Port of Split. This involves using numerical methods and computer-based models to process large sets of data efficiently. In this study, data from the Split Port Authority was digitized and analyzed using statistical software such as R and Python. These tools were used to perform various statistical analyses, create visual representations of the data, and identify trends and patterns in traffic flows during the COVID-19 pandemic. The digital aspect ensures precision and the ability to handle large datasets that would be impractical to analyze manually.

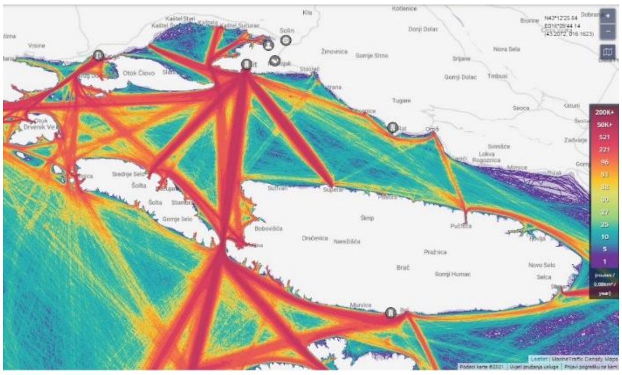

Figure 1. *Main access seaways to the Port of Split (Source: Made by authors using data provided from University of Split, Marine traffic).*

Fig. 1 shows main access seaways to the Port of Split and intensity of traffic flows throughout year 2019, before pandemic started.

3. DYNAMICS OF PASSENGER TRAFFIC IN THE PORT OF SPLIT

Maritime passenger ports have the main role in development of traffic, tourism and economic activities, serving a purpose to range of tourist services and meeting passenger needs for transportation [5]. Fig. 2 and Fig. 3 show a dynamic of passenger traffic in the Port of Split in the period 2013-2021.

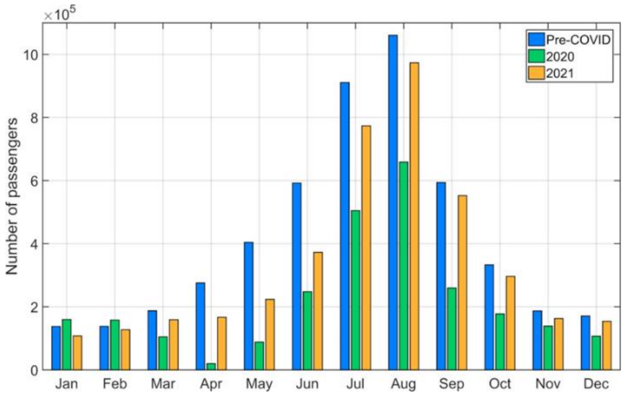

Figure 2. *Passenger traffic in the Port of Split over the months in the pre-COVID period (mean of 2013-2019 in each month), year 2020 and year 2021 (Source: Made by authors using data provided from Split Port Authority 2023).*

A significant decline of the number of passengers is recoded in the year 2020, when the rules of restricted mobilities were on their peak. The decline is evident during summer months due to the absence of the touristic season, with up to 400 thousand passengers less compared to the average values in the pre-COVID period (2013-2019). Year 2021 has brought a recovery in the passenger traffic in the Port of Split, still not reaching the scores from the pre-COVID period, but with significantly higher number of passengers than year 2020, up to 300 thousand in each month.

When comparing the total volume of passenger traffic in 2020 (2 625 106) with the volume in 2019 (5 607 789 passengers) it is evident that there has been a significant decline in passenger traffic in 2020, by more than 50% (Fig. 3). The passenger traffic in the Port of Split has been constantly increasing from 2013 until 2019, when a sharp drop occurred in 2020 due to the pandemic. It can be stated that in year 2020 the amount of passenger traffic was very reduced and the number of passengers in the traffic is the lowest in the last decade of the Port of Split.

This situation, of course, left a mark on a touristic season from which Croatia normally earns billions of euros. Numerous economists have warned that the share of tourism in Croatia's GDP is too large and that there will be consequences. In 2020, Croatia planned to earn almost 12 billion euros from foreign guests, which is 20% of GDP. However, the Central Bureau of Statistics publishes the first estimate. According to data in February 2021, GDP fell 8.4% in 2020. It is a record decline, caused by the COVID-19 and restrictive measures applied to prevent the spread of the disease [6].

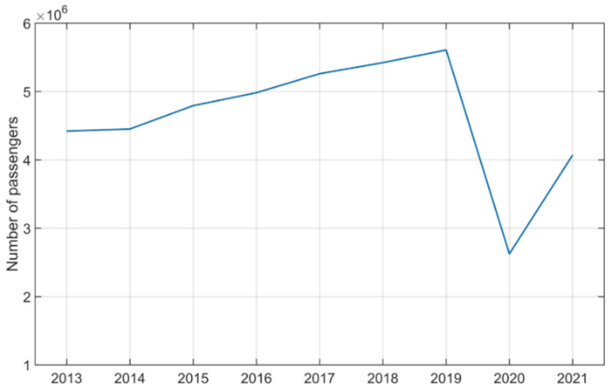

Figure 3. *The total number of passengers in the Port of Split in the period 2013-2021 (Source: Made by authors using data provided from Split Port Authority 2023).*

The port of Split and the city of Split have become an attractive cruising destination in recent years and an increasing number of tourists is being recorded. Cruise ships began arriving in the port of Split in 2002, that year, 82 ships with 20 616 passengers visited Split. Before the pandemic, cruising tourism in the port of Split was at its peak, 2019 is recorded as the best year of cruising tourism in the city of Split. The city was visited by 359 955 cruise tourists while in 2020, the number of tourists barely exceeded 500. This is another indicator of the negative effects of COVID-19 on passenger and cruising traffic. Furthermore, as the shipping industry is already notoriously volatile due to its relationship with world trade and output, the pandemic has further added to its volatile nature which highly affected shipping companies' cash flows, leaving both ship-owners and the industry's stakeholders exposed to potential losses [7].

4. RESULTS

Dynamics of cargo traffic in the port of Split

Activities of the cargo traffic in the port of Split are located in the main cargo north port of Split, northern basins of the city including Vranjic – Solin basin, Kaštela A, B, C and basin Kaštela D. Basins are equipped to accommodate different types of cargo as mentioned in the Introduction. Cargo – handling equipment is one of the essential structural elements in the production of the overall port service. The main cargo – handling equipment in the southern part of Vranjic – Solin basin includes three types of cranes intended for the usage on the different terminals. The other port equipment in the container terminal include container forklifts, reach stacker, container trailers, container truck, terminal tractor for container trailer and other mechanization relates to numerous forklifts, tractors, skid and wheel loaders.

Fig. 4 and Fig. 5 shows the dynamics of cargo traffic in the Port of Split during the period 2013-2021. It is evident that this part of industry has also been significantly affected by the pandemic.

However, the decline in the cargo traffic is not so drastic as for the passenger traffic. During 2019, 2 913 509 tons were manipulated in the northern port of Split while in 2020 the number is somewhat lower, with 2 811 376 tons of cargo (Figure 4). It is evident that cargo traffic has been declining since 2017 until 2020, with each year approximately 100 000 tons less of total cargo. Year 2021 has highest values in the considered decade, reaching more than 3.2 million tons of cargo.

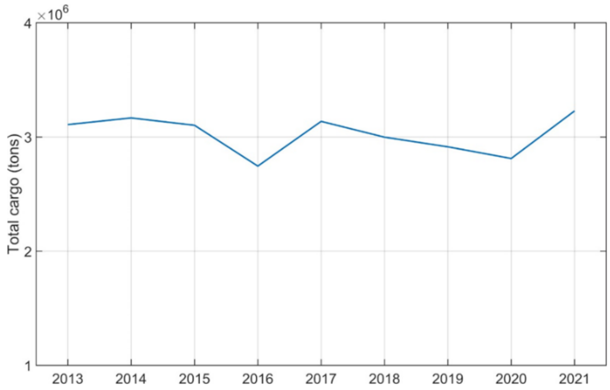

Figure 4. *Dynamics of total cargo traffic (Source: Made by authors using data provided from Split Port Authority 2023).*

Considering the processed data of the Split Port Authority, it can be stated that COVID-19 left negative effects on cargo traffic in the port of Split. There has been a significant decline in traffic, however, by studying the market situation in recent years, it is evident that decline in cargo traffic has been proceeding at the same rate as in 2017, 2018 and 2019, so the cargo traffic has been falling continuously.

5. RETURN OF PASSENGERS AND FREIGHT TRAFFIC IN PORT OF SPLIT

More than 5 million passengers and 750 000 cars pass through the port of Split each year.

The traffic in the port of Split has increased over the years and tends to raise even more [8]. Since the beginning of its appearance, COVID-19 has caused a large decline in cargo and passenger traffic including cruise ships in all ports, especially in the port of Split.

Thanks to the discovery of the vaccine and incentive measures for vaccinating both seafarers and passengers on passenger ships (cruisers), both passenger and cargo traffic are slowly returning to their capacities before the pandemic. This can be confirmed by the increased arrival of passenger ships in the port of Split. Cargo traffic, however, does not have the same dynamics of return due to declining industry activity in Croatia.

The number of passengers in Croatian seaports increased by more than 23,3 % in first quarter of 2022, both on ferries and passenger ships, comparing to the same period in 2021 (Fig. 5) [9]. There was also an increased turnover in goods in all ports of Republic of Croatia by 3,7 % compared to the same period in 2021.

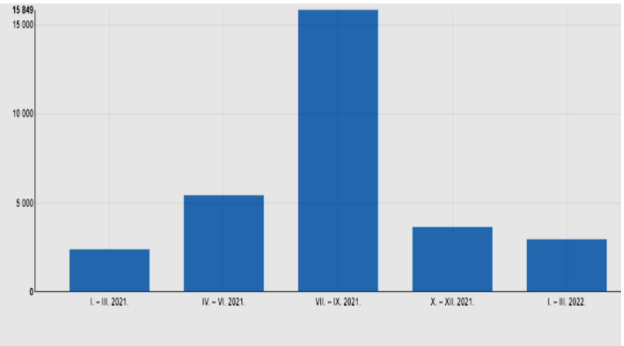

Figure 5. *Passenger traffic by quarters in 2021 and 2022 (Source: Bureau of Statistics, 2022)*

6. CONCLUSION

The findings from this study have significant implications for the education of students at the Faculty of Maritime Studies. By incorporating real-world data and analysis from the Port of Split during the COVID-19 pandemic, students can gain practical insights into the challenges and responses in maritime transport. This study can serve as a case study in courses related to maritime logistics, port management, and crisis response, enhancing the students' understanding of how global disruptions impact local port operations. Furthermore, the use of digital tools and numerical methods demonstrated in this study provides a valuable example of modern analytical techniques, preparing students for the demands of a data-driven industry. Integrating these results into the curriculum will not only enrich the academic experience but also equip future maritime professionals with the skills and knowledge needed to navigate and mitigate similar challenges in their careers.

The economic crisis induced by the COVID-19 pandemic had a serious impact on cargo and passenger traffic in the port of Split in the period from December 2019 to the end of COVID-19 crisis in March 2022.

Future analysis should focus on long-term impacts of the COVID-19 pandemic on port operations and regional economy. Additionally, exploring the effectiveness of different recovery strategies and their implementation across various ports could provide valuable insights. Integrating advanced digital tools and real-time data analytics could further enhance the resilience and efficiency of port operations in the face of future disruptions.

The Port of Split has always been oriented towards passenger and cargo traffic due to its geographical position, hinterland, and a large number of inhibited coastal islands. The COVID-19 pandemic triggered an economic shock just eleven years after the shock of the 2008 global financial crisis [10]. Cruising traffic as part of passenger traffic largely contributes to the economy and society development of the destination. As the ongoing COVID-19 pandemic poses a global threat, it is of utmost importance that governments provide effective solutions of combating vaccine hesitancy and encouraging their citizens to vaccinate [11]. COVID-19 green passports were also a reason of reduced cruising and passenger traffic. The increasing use of vaccine passports [12] to certify immunity from the prevailing coronavirus has created positive and negative aspects that have shaken the workings of markets.

Port of Split measures significant reductions of the passenger traffic including cruising traffic, as well as cargo traffic decline in total tonnage. The latter is expected considering measurements implemented by governments, which included reduced human mobility. As COVID-19 restrictions have been reduced within the European Union and the United States, everything is slowly returning to normal. The port of Split expects a record number of tourists and cruisers again, as in the 2019 season. Since March 2022, COVID-19 green passports are abolished. People are free to move, yet future measures and similar experiences with the pandemic should serve as a lesson to introduce more effective measures in the case of next pandemic [13].

If in the future the next mutations of the virus will not cause major health consequences and if the vaccine found so far protect seafarers and passengers on ships, a resumption of maritime passenger and cargo traffic in all ports, including the port of Split, is expected.

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Didactic Model of a Beeswax Foundation Sheet Forming Machine

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Abstract: *In engineering education, hands-on experience is indispensable for connecting theoretical knowledge with practical applications. This paper discusses a didactic model of a beeswax foundation sheet-forming machine developed at the Faculty of Technical Sciences in Novi Sad. The model replicates the industrial process of forming beeswax foundation sheets, which are vital in modern beekeeping. This setup allows students to observe and interact with the machine's operation, enhancing their understanding of control systems and manufacturing processes. The operational control system enables precise setting of sheet length and motor speed, simulating real-world production scenarios. Most components are visible and easily accessible, allowing students to closely examine and understand their interactions. This educational tool not only provides practical skills but also offers insights into industrial environments, preparing students for future engineering challenges by fostering a deeper understanding of complex systems and machinery. The didactic model incorporates both pneumatic and electrical equipment, demonstrating the operation principles of components widely used in industrial systems. By integrating various technologies into a cohesive system, it ensures that students receive a well-rounded education.*

Keywords: *didactic model; beeswax foundation sheet; process control*

1. INTRODUCTION

In the field of engineering education, the importance of hands-on experience cannot be overstated. While theoretical knowledge forms the foundation of understanding, practical application brings those concepts to life. One crucial aspect of this practical learning experience is the utilization of machine prototypes and didactic models [1-4]. These prototypes provide students with the opportunity to interact with physical representations of complex machines, allowing them to gain firsthand insight into their functionality, design principles, and operational intricacies, all while being in safe and supervised laboratory conditions. This immersive interaction enables students to bridge the gap between abstract concepts and real-world applications. Through these practical experiences, students develop a deeper understanding of engineering concepts such as mechanical design, dynamics, control systems, and manufacturing processes.

Furthermore, they gain valuable insights into the industrial environment and the technologies used across various sectors [5]. In many cases, students are allowed to develop the experimental setups themselves and have to go through all the development stages from selecting the appropriate equipment and placing an order, to assembling the components and connecting them accordingly [6, 7]. This exposure is invaluable in preparing students for future careers in engineering, where they will be required to design, analyze, and optimize complex systems and machinery. For example, [7] shows a didactic set for controlling an asynchronous AC motor using a Programmable Logic Controller (PLC), and a frequency regulator. In [8], the authors present an experimental setup for data transmission performance evaluation intended for telecommunication engineering students. This system is used to generate and analyze data streams and emulate communication channels. An experimental setup that combines pneumatic and electro-pneumatic systems with remote control, providing a useful, internet-accessed didactic tool that simulates a continuous production process is presented in [9].

One such didactic model, developed at the Faculty of Technical Sciences in Novi Sad for the purposes of students' practical learning, is that of a beeswax foundation sheet forming machine. A beeswax foundation sheet is a plate that serves as the foundation for a single honeycomb and is crucial for modern beekeeping [10]. Although occasionally made of plastic, beeswax is often the material of choice due to its natural properties and suitability for bees. The edges of these sheets are fixed to a rectangular wooden frame, which allows the frames in the hive to be easily inspected and moved. The embossed hexagonal cell shapes on the sheet provide bees with a precisely defined surface for building their comb. This guided construction ensures that bees build their combs within the designated frames, preventing the construction of combs outside the given frames, which can make inspection difficult or impossible for beekeepers. By using foundation sheets, bees save time and energy that would otherwise be spent producing wax and constructing combs from scratch. This efficiency not only benefits the bees but also leads to a significant increase in honey production compared to traditional beekeeping methods [11]. The use of foundation sheets, therefore, enhances both the productivity and manageability of modern beekeeping practices, making it easier for beekeepers to maintain healthy and productive hives. The appearance of a beeswax foundation sheet is shown in Figure 1.

Figure 1. *The appearance of a beeswax foundation sheet*

In the past, beeswax foundation sheets were first produced exclusively by hand using appropriate molds until later when mechanisms with rollers powered by hand appeared. Over time, it became apparent that such mechanisms were not cost-effective for producing larger quantities. Specifically, cutting to a defined size was problematic because the resulting dimensions often varied. This was one of the key reasons for introducing automation in the process of forming and cutting the foundation sheets. Nowadays, there are fully automated machines available in the market, and foundation sheets are usually produced in one of two ways: cold or hot rolling of foundation sheets. During cold rolling, the beeswax is first poured into flat sheets, then passed through rollers that imprint the comb pattern onto the sheets. On the other side, during hot rolling, hot beeswax is poured directly onto rotating rollers and cooled to harden the beeswax and obtain the shape of the sheet. Both of these processes result in large rolls of beeswax foundation sheets that require cutting into smaller pieces of the wanted dimensions.

One example of an automated foundation sheet forming machine is shown in [12]. In this specific example, beeswax is heated to 120°C and poured onto aluminum rollers engraved with the honeycomb cell pattern. These aluminum rollers are water-cooled to maintain their temperature and prevent the beeswax from sticking. The formed beeswax strip is then pulled by rubber-coated rollers, which measure the cut foundation sheet. Before passing through the rubber-coated rollers, the first set of knives cuts the honeycomb foundation by width. After the foundation exits the rollers, a second knife cuts the sheets by length. This length-cutting knife is activated by a solenoid, which is triggered by the control device. In the developed didactic model, this is modified in a way that the operation of the second knife is simulated using a double-acting pneumatic cylinder instead of the solenoid.

The paper is organized as follows: Section 2 shows the architecture of the developed didactic model, Subsection 2.1 provides explanations of the setup's operation principle, Subsection 2.2 shows the pneumatic end electrical control circuits, and Subsection 2.3 gives an explanation of the applications of the model and its utility. Finally, in Section 3, the most important conclusions were drawn.

2. BEESWAX FOUNDATION SHEET FORMING MACHINE DIDACTIC MODEL

The didactic model of a foundation sheet forming machine is shown in Figures 2 and 3.

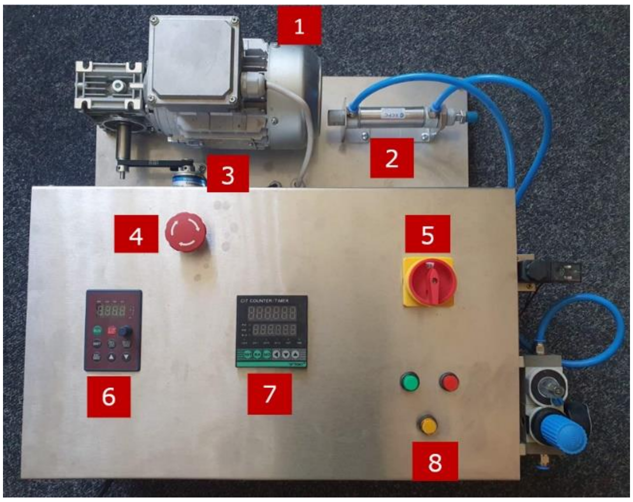

Figure 2. *The didactic model of a foundation sheet forming machine (upside view)*

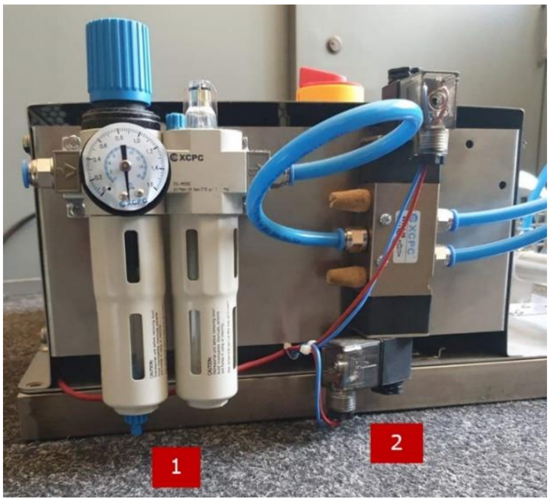

Figure 3. *The didactic model of a foundation sheet forming machine (side view)*

The components of this didactic model are:

- The AC motor *Elvem 6T1-63B4 B14* (Figure 2, position 1),
- Double-acting pneumatic cylinder *XCPC MA 64 32 25X50* (Figure 2, position 2),
- Rotary encoder *Omron* (Figure 2, position 3)
- Safety/emergency switch (Figure 2, position 4),
- On/Off switch (Figure 2, position 5),
- Frequency regulator *Shenzhen Encom Electric Technologies CO EDS800-2S0004* (Figure 2, position 6),
- Control counter *CL7F-RC60* (Figure 2, position 7),
- Start, Stop, and Reset pushbuttons (Figure 2, position 8),
- Service unit *XCPC XOU-MINI-1/4* (Figure 3, position 1),
- Electrically operated bistable directional valve *XCPC 4V320-08* (Figure 3, position 2),
- 24VDC power supply *Mean Well LRS-100-24*, and
- The didactic model housing.

The housing of the didactic model is custom made and its 3D model is shown in Figure 4.

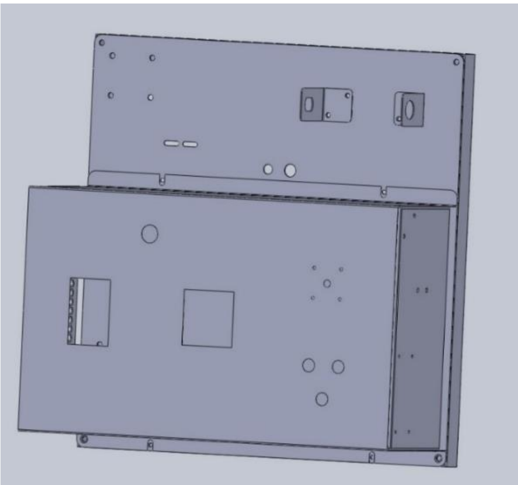

Figure 4. *The housing of the didactic model*

The housing was designed to showcase the functionality of all system components and enable easy access. This is especially convenient because the students can see all components in detail, unlike standard industrial machines available in the industrial environment.

The housing is an assembly of five different parts - the frame made of pipes with dimensions of 50 mm × 30 mm and a wall thickness of 1.5 mm; the supporting plate, made out of sheet metal with a thickness of 1.5 mm; the cover made of 0.8 mm thick sheet metal, with openings provided for the frequency regulator, emergency switch, control counter, On/Off switch, and Start, Stop, and Reset buttons. The sides of the cover are partially closed to allow air to flow through the components and assist in cooling. All necessary openings intended for fixing electrical components, motor, pneumatic cylinder, cover, and openings for fixing the frame are provided. This is shown in Figure 5.

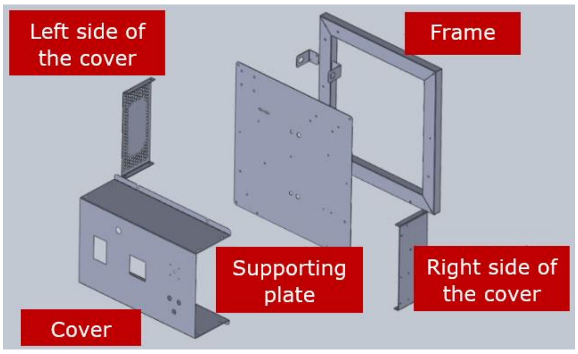

Figure 5. *The expanded view of the housing 3D model*

2.1. Didactic model operation and control

The operation of the didactic model begins by toggling the On/Off switch and pressing the green (Start) pushbutton, which activates the frequency regulator relay. This initial step sets the machine into a ready state for processing. The control counter, serving as the main control unit of the didactic model, allows the user to set the desired length of the foundation sheet to be cut. This setup is crucial for ensuring the accuracy and repeatability of the cutting process. Next, the desired speed of the AC motor is adjusted using the frequency regulator, which is used to fine-tune the motor's speed. The motor shaft mimics the function of rubber-coated rollers that pull the beeswax sheets during the production process, ensuring the sheets are correctly positioned before cutting. By controlling the motor speed, the production rate of the foundation sheets is adjusted as well. The rotary encoder tracks the number of motor rotations, providing essential data on the length of the foundation sheet that has been fed through the rollers. This information is then forwarded to the control counter. Depending on the input received, the counter generates one of two signals. These signals activate the solenoids of the directional valve. One signal extracts the pneumatic cylinder, simulating the cutting action of the knife attached to the end of the cylinder's piston rod. Once the cutting is complete, the other signal retracts the cylinder, completing one operation. To stop the process, the red (Stop) button can be pressed, which deactivates the frequency regulator relay.

Additionally, the entire system can be shut down by toggling the On/Off switch back to the off position or by pressing the emergency switch, which is designed for immediate shut-off of all operations in case of an emergency. Resetting the counter is achieved by pressing the yellow (Reset) button, which prepares the system for a new cycle. The pneumatic cylinder operation requires adequately prepared compressed air, which is provided by the service unit. Finally, the entire didactic model is powered by a 24 VDC power supply, providing the necessary electrical energy for most components to function. An exception to this is the AC motor which requires 220 VAC. This comprehensive setup not only demonstrates the intricate operations involved in the production of beeswax foundation sheets but also provides a robust educational tool for students to learn about complex industrial machinery and control systems.

2.2. The control circuits of the didactic model

The pneumatic control circuit of the didactic model is quite simple as shown in Figure 6.

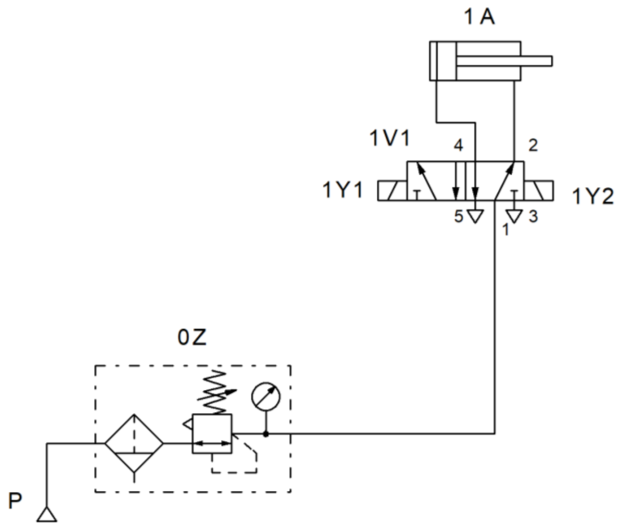

Figure 6. *Pneumatic control circuit of the didactic model*

The components of the circuit are:

- P – compressed air supply,
- 0Z – service unit,
- 1V1 – electrically activated bistable directional valve, and
- 1A – double-acting cylinder.

The electrical control circuit is given in Figure 7.

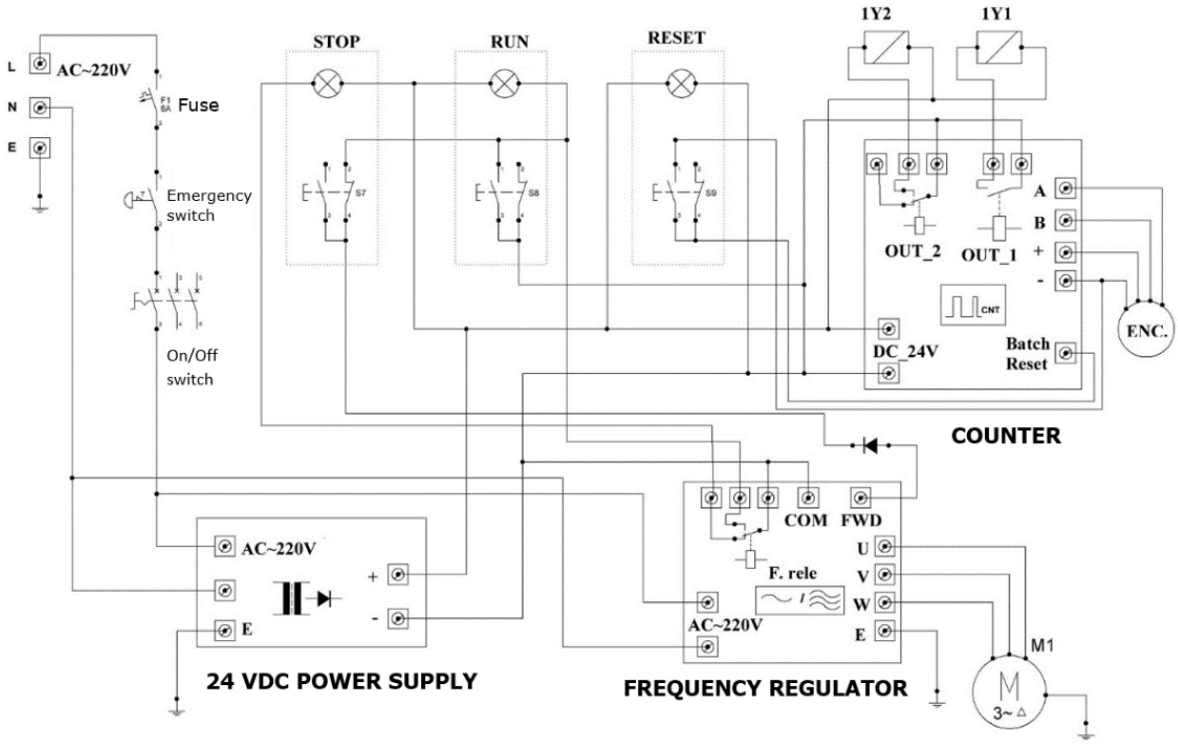

Figure 7. *Electrical control circuit of the didactic model*

2.3. The control circuits of the didactic model

Having integrated electro-pneumatics and AC motor control as well as providing detailed control circuits for students to analyze and compare to the physical representation, this didactic model presents a comprehensive learning tool that could be used in multiple courses that the Faculty of Technical Sciences offers, such as Work Process Automation, Motion Control, Implementation of Automated Systems, Components of Technological

Systems, Material Handling Technologies, etc. The students can observe and participate in controlling the motor speed, pneumatic control, obtaining information from the rotary encoder, reading inputs and generating outputs of a controller, all the skills highly required in industry. Apart from the connection methods, the analysis of the control circuits gives them insight into the things to be careful about, such as planning and connecting fuses to protect the device, as shown in Figure 7.

3. CONCLUSION

As shown in this paper, the complex processes of the industrial setups can be brought to students by simpler didactic models. The ability to adjust the operational parameters, such as sheet length and motor speed, simulates real-world production scenarios, giving students a realistic view of industrial environments. The visibility and accessibility of most components also facilitate a deeper understanding of their interactions and functionalities. This prepares students for the demands of the engineering field, ensuring they are well-equipped to design, analyze, and optimize industrial systems. The beeswax foundation sheet cutting machine didactic model is a prime example of how educational tools that provide some kind of practical experience can effectively prepare students for the challenges of the engineering industry and possibly contribute to advancements in other fields, such as agriculture and beekeeping.

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Selection of Personnel Based on a Two-Stage Multi-Attribute Decision-Making Model

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Abstract: *The problem of personnel selection in the logistics process is one of the most important tasks of human resource management, and its relationship has a critical effect on achieving the organization's business goals. The considered problem can be stated as a two-stage multi-attribute decision problem that includes both quantitative and qualitative criteria. The attribute weights are determined by applying the modified CRiteria Importance Through Intercriteria Correlation (CRITIC) method. The proposed fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is applied to rank the personnel. The proposed model is illustrated by an example using literature data. It is shown that the proposed two-stage MADM model is highly suitable as a decision-making tool for making decisions about personnel selection in the logistics process.*

Keywords: *personnel selection, CRITIC, TOPSIS, logistics process*

1. INTRODUCTION

The development of new technologies, primarily information technologies, has led to the conclusion that it is not possible to base personnel selection on traditional decision-making methods. This issue is particularly prominent in the logistics process, where intuitive, analytical, and experienced workers are employed to ensure the achievement of goals. Therefore, it is inevitable to use scientific approaches in the process of selecting candidates who can meet job expectations in the best possible way.

The application of Multi-Attribute Decision-Making Methods (MADM) enables decision-makers (DMs) to evaluate potential candidates according to numerous attributes. These attributes can be qualitative and quantitative. It is common for DMs to assess the values of qualitative attributes using a measurement scale. The obtained results can help DMs make the right decision in a shorter period. It should be noted that DMs can use one or more MADM methods when solving problems.

Some authors [1] believe that the use of MADM methods increases the innovative and creative capacity of the organization. The selection of candidates based on an exact approach prevents employees from developing negative feelings toward the organization, which leads to increased effectiveness and efficiency of employees.

In the literature, many papers can be found where the considered problem is solved in an exact manner using multi-attribute decision-making methods [2, 3, 4, 5].

The aim of this research is to develop a method that can quickly and efficiently select the best candidate for the logistics process.

It is assumed that not all attributes have equal weights. Generally, the determination of attribute weights can be based on subjective MADM methods. The most commonly used MADM method in this group is the Analytic Hierarchical Process (AHP) [6]. The weights obtained in this way are to some extent influenced by the subjective views of DMs. By applying objective MADM methods such as CRiteria Importance Through Intercriteria Correlation (CRITIC) [7], subjectivity in determining attribute weights can be reduced. This method is widely used in the literature for determining the weight vector [8, 9, 10, 11, 12]. In all analyzed papers, the normalized decision matrix is constructed by applying Weitendorf's linear normalization procedure [13], as in this research. The main difference between the analyzed papers and our research is the domain of application of the CRITIC method.

In the second stage, the selection of candidates is based on the proposed Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [14]. The TOPSIS method is widely used in the literature for ranking various items [15].

Comparing papers that propose a model for ranking items by applying TOPSIS, some differences can be noted, which are further described below. The construction of the normalized decision matrix is based on using: (i) linear normalization procedures [16, 17, 18], and (ii) vector normalization procedures [1, 20, 21]. In our research, Weitendorf's linear normalization [13] was applied, which represents one of the main differences between our research and the papers found in the literature. In all analyzed papers, the positive ideal solution (PIS) and negative ideal solution (NIS) are determined according to the weighted normalized decision matrix. In our research, PIS and NIS are determined according to the veto concept, which represents another main difference between our research and the analyzed papers. The distance from both PIS and NIS is calculated with respect to expressions from traditional TOPSIS in the analyzed papers, as in our research.

The paper is organized as follows. The proposed methodological approach for selecting the best personnel in the logistics process is given in Section 2. Section 3 provides an example with real-life data.

2. MATERIAL AND METHODS

The problem of evaluating candidates for the logistics process is addressed by applying the proposed two-stage multi-attribute decision-making model. In the first part, the weights of the attributes are determined using the proposed CRITIC method. Secondly, the ranking of candidates is given using the TOPSIS method.

2.1. Defining the set of attributes

Attributes by which candidates are evaluated are taken from the literature [1]. These attributes are: Experience in logistics $(k = 1)$, Education/Training $(k = 2)$, Flexible work hours and overtime work $(k = 3)$, Proficiency in MS Office Programs $(k = 4)$, Package software used in the logistics field $(k = 5)$, and Recommendation letters $(k = 6)$. The attribute values are assessed on a scale ranging from 1 to 10. A value of 1 indicates the lowest attribute value, while a value of 9 indicates the highest attribute value.

2.2 The proposed CRITIC

The proposed CRITIC method is implemented through five steps, which are further formally presented:

Step 1. The decision matrix is constructed:

$$[x_{ik}]_{IxK}$$

Step 2. The normalized decision matrix is obtained through the application of Weitendorf's linear normalization [13]:

$$[r_{ik}]_{IxK}$$

where:

$$r_{ik} = \frac{x_{ik} - x_k^{min}}{x_k^{max} - x_k^{min}}$$

Step 3. The attribute weights have been determined:

$$W_k = \sigma_k \cdot \sum_{k=1,..,K} (1 - \rho_{kk'})$$

where:

$\sigma_k,$ standard deviation of normalized attribute values for $k = 1,..,K$

$\rho_{kk'}, k, k' = 1,..,K$ coefficient of correlation for each pair of attributes.

Step 4. The normalized weights vector is determined.

$$[\omega_k]_{Kx1}$$

where:

$$\omega_k = \frac{W_k}{\sum_{k=1,..,K} W_k}$$

2.3 The proposed TOPSIS

Step 1. The decision matrix is constructed:

$$[x_{ik}]_{IxK}$$

Step 2. The normalized decision matrix is constructed:

$$[r_{ik}]_{IxK}$$

Step 3. The weighted normalized decision matrix is constructed:

$$[z_{ik}]_{IxK}$$

Step 4. Determine PIS, f_k^+ and NIS, f_k^- according to the veto concept.

Step 5. Determine the distances from PIS, d_i^+ and NIS, d_i^-:

$$d_i^+ = \sum_{k=1,..,K} |f_k^+ - z_{ik}|$$

$$d_i^- = \sum_{k=1,..,K} |f_k^- - z_{ik}|$$

Step 6. The closeness coefficient is determined:

$$c_i = \frac{d_i^-}{d_i^- + d_i^+}$$

Step 7. The values of the coefficient c_i in descending order. The best alternative is the one ranked first.

3. CASE STUDY

The attribute values by which potential candidates are evaluated are taken from the paper of [1]. The decision matrix is presented in Table 1.

Table 1. *Decision matrix*

	$k=1$	$k=2$	$k=3$	$k=4$	$k=5$	$k=6$
$i=1$	4	8	5	6	7	1
$i=2$	3	8	8	5	1	1
$i=3$	3	6	8	7	1	1
$i=4$	4	1	10	6	1	1
$i=5$	9	5	3	6	5	1
$i=6$	4	10	10	7	8	8
$i=7$	3	10	6	7	1	1
$i=8$	3	7	6	8	5	1
$i=9$	3	10	8	8	6	5

3.1 Application of the proposed CRITIC

By applying the proposed algorithm (Step 2 to Step 3), the normalized decision matrix and standard deviation of criteria values are constructed and presented in Table 2.

Table 2. *The normalized decision matrix*

	$k=1$	$k=2$	$k=3$	$k=4$	$k=5$	$k=6$
$i=1$	0.167	0.778	0.286	0.333	0.857	0
$i=2$	0	0.778	0.714	0	0	0
$i=3$	0	0.556	0.714	0.667	0	0
$i=4$	0.167	0	1	0.333	0	0
$i=5$	1	0.444	0	0.333	0.571	0
$i=6$	0.167	1	1	0.667	1	1
$i=7$	0	1	0.429	0.667	0	0
$i=8$	0	0.667	0.429	1	0.571	0
$i=9$	0	1	0.714	1	0.714	0.571
σ_k	0.323	0.328	0.331	0.333	0.413	0.363

By applying the proposed procedure (Step 2 to Step 4), the weights of attributes have been determined as shown in Table 3.

Table 3. *Values of correlation coefficients and attribute weights*

	$k=1$	$k=2$	$k=3$	$k=4$	$k=5$	$k=6$	$\sum_{k=1,..,K}(1-\rho_{kk'})$	W_k
k=1	1.000	-0.351	-0.585	-0.323	0.246	-0.101	6.114	1.975
k=2	-0.351	1.000	-0.059	0.368	0.414	0.510	4.118	1.351
k=3	-0.585	-0.059	1.000	0.073	-0.166	0.506	5.231	1.732
k=4	-0.323	0.368	0.073	1.000	0.331	0.378	4.174	1.389
k=5	0.246	0.414	-0.166	0.331	1.000	0.634	3.541	1.463
k=6	-0.101	0.510	0.506	0.378	0.634	1.000	3.074	1.116

The normalized weights vector of the considered attributes is obtained by applying the proposed algorithm (Step 5), as follows:

$$[0.219 \quad 0.150 \quad 0.192 \quad 0.154 \quad 0.162 \quad 0.124]$$

3.2 An application of the proposed TOPSIS

By applying the proposed procedure (Step 1 to Step 4), the weighted normalized decision matrix and reference point are determined and presented in Table 4.

Table 4. *The weighted normalized decision matrix, PIS and NIS*

	$k=1$	$k=2$	$k=3$	$k=4$	$k=5$	$k=6$
$i=1$	0,676	0,963	0,786	0,844	0,975	0
$i=2$	0	0,963	0,937	0	0	0
$i=3$	0	0,916	0,937	0,939	0	0
$i=4$	0,676	0	1	0,844	0	0
$i=5$	1	0,885	0	0,844	0,913	0
$i=6$	0,676	1	1	0,939	1	1
$i=7$	0	1	0,850	0,939	0	0
$i=8$	0	0,941	0,850	1	0,913	0
$i=9$	0	1	0,937	1	0,947	0,933
f_k^+	1	1	1	1	1	1
f_k^-	0	0	0	0	0	0

By applying the proposed algorithm (Step 5 to Step 7), the distances from PIS and NIS, closeness coefficient, and rank of candidates are calculated. The results are presented in Table 5.

Based on the obtained results, it can be concluded that candidate $i=6$ is the most suitable for the considered position in the logistics process.

Table 5. *The rank of candidates*

	d_i^+	d_i^-	c_i	rank
$i=1$	1.756	4.244	0.707	3
$i=2$	4.100	1.900	0.317	8
$i=3$	3.208	2.792	0.465	5-6
$i=4$	3.480	2.520	0.420	7
$i=5$	2.358	3.642	0.607	4
$i=6$	0.385	5.615	0.936	1
$i=7$	3.211	2.789	0.465	5-6
$i=8$	2.296	0.913	0.152	9
$i=9$	1.183	4.817	0.803	2

4. CONCLUSION

Based on the conducted research, the proposed two-stage multi-attribute decision-making model, which combines the CRITIC method for attribute weighting and the TOPSIS method for ranking candidates, proves to be an effective tool for personnel selection in the logistics process.

The CRITIC method is objective as it minimizes subjectivity in determining attribute weights, making it suitable for this problem. The TOPSIS method is beneficial because it provides a clear and nearly unique ranking of candidates. Also, the model can handle both quantitative and qualitative attributes, making it applicable to a diverse range of evaluation criteria.

The case study demonstrates the model's ability to accurately identify the most suitable candidate, confirming its practical applicability and efficiency in enhancing decision-making in human resource management.

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The Importance of the Implementation of the 1C:ERP WE Information System in the Digitization of Organizations

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Abstract: *The purpose of the research work is to indicate the importance of the implementation of information systems in the digitization of business. With the practical application of the 1C:ERP WE information system, this paper will evaluate the efficiency of the work process in the sales sector. Conclusion will be made about the role of the 1C:ERP WE software in the development of the economy as a whole in information technologies and computer sciences. It will also show the importance of information systems in general on business operations, digital transformation, data protection and the role of information technologies.*

Keywords: *1C: ERP WE; information; information systems; business process; analysis*

1. INTRODUCTION

Information technologies and computer sciences play a major role in the growth and development of the economy. The digital economy is a creation of computer science and is key to the progress of both the public and private sectors. The transformation of the economy accelerates work processes, in the form of reduction of paperwork, automation, reduction of manual labor and user satisfaction.

The productivity of the company depends on the business information systems, especially on the implementation of the ERP system. In this paper, the emphasis will be placed on 1C:ERP WE software, whose practical example will point to the advantages of introducing this type of information systems into the company's operations.

The application of information technologies and computer sciences lead to a digital revolution in the business practice of both companies and the economy as a whole. The digital economy has conditioned the rapid growth and development of companies, reduced mass administration, protected logging due to extensive paperwork and accelerated the work process within the organization. The importance of studying computer science for business is of great importance, because it is a way to reach higher quality information solutions, which will contribute to the productivity of the company. In this paper, the statistical methodology and the method of logically oriented reasoning of observational research will be addressed.

The subject of research in this paper is the impact of applying business information systems on the efficiency and effectiveness of enterprise operations, specifically on achieving higher performance and productivity in business practice. It examines the contribution of implementing ERP solutions to the efficiency of accelerated growth and development of business systems.

The aim of the research is to determine the impact of ERP business information solutions on achieving better results in business processes and enhancing the competitiveness of enterprises. This paper focuses on the benefits and justification of investing in business information systems, not only discussing the advantages and rationales for acquiring such systems but also addressing the benefits of deliberate efforts to protect and exploit organizational memory that is otherwise locked away within business information systems.

2. DIGITALIZATION OF BUSINESS

Nowadays, digital transformation in business is causing a lot of interest when it comes to not only business circles, but also research and development institutions. Digital technology is growing and experiencing a very large reorganization in a positive sense, practically without which one cannot imagine business today, both in business and in private life. What is important in digital transformation is the very notion of information. Information is the basic factor of digital transformation. Information represents the most important and sought-after resource of modern business. Digital transformation brings with it a new way of thinking, a new organizational design and approach to solving problems [1].

The purpose of the existence of any information system is to make information visible and accessible depending on the needs and requirements of users, both those who are in the external environment of the organization and its employees. Therefore, it is necessary that the information system is first of all secured and that there can be no misuse of information that is crucial for business and the execution of key work tasks, and then the speed and accuracy of presenting data and information necessary in a given situation. In order for all of the above to be fulfilled, it is necessary to maintain the System for entering and processing information. Confidentiality, which protects information and its disclosure by unauthorized persons, plays a major role in digital transformation. The most common threats to confidential information are:

- Attackers – those who try to discover AND obtain some protected information.
- Impersonation - misuse of another user's password.
- Unauthorized activity - when the user changes data in the system, copies, deletes, contrary to what he is authorized to do.
- Copying data to unprotected locations - when data is copied to systems with an appropriate level of protection,
- Malicious program – a program that can gain unauthorized access to the system.

Figure 1. shows the six stages of digital transformation.

Figure 1. *Six stages of digital transformation [2]*

Information systems date back to the fifties of the twentieth century, when the introduction of computers and simple application solutions for automating business processes began, and they were mostly used in bookkeeping and inventory management. Improving hardware (computers and equipment) and application solutions used in companies also influenced the development of information systems [3].

For the purpose of building the concept of information system development of an organization, it is necessary to study and understand that organization in its entirety, from the point of view of its form, essence, functions, structure, development and values. Using the analogy of living beings, it is considered that management information systems arise, grow, mature and disappear, and this process is called "life cycle".

In addition to the basic information system mentioned at the beginning, the following information systems are represented in the company "Docus": DocArt.Net, D-Max.Net, DocTrader, 1C:ERP 2.

The Doc.Art.Net information system is a solution for securities trading. The user is enabled to monitor a number of different records such as:

- Records of the principal,
- Records of orders with the form of the order book prescribed by law - Records of securities, both domestic and foreign,
- Records of transactions and concluded sales contracts,
- Records and calculation of calculations based on completed transactions,
- Records of required and executed payments according to transactions and orders.

All of these are standard features that should be provided by any such information system, namely order book management, client account management and support for foreign securities and currencies.

The business information system that provides complete computer support for the company is the D-Max.Net system. This system is primarily intended for small and medium-sized companies, as a result of many years of development and application of experience in this field.

This system provides great security and reliability. It is designed to enable and satisfy user requirements with its ease of use. Many years of experience in application development contributed to the fact that the user interface is "intuitive" and very easy to use. Each function is very similar to the previous one that we already know how to use.

Each user action is followed by a corresponding logical response from the program. If the given activity is an ongoing process, the user will have visual information about it. These mentioned functionalities have the effect of shortening the time required for user training, but also comfortable work for the user in the later use of the application.

When starting the program, the program asks the operator to log in with his username and password. This means that any manipulation of data in the database will carry with it information about which operator made the data changes, which is important for data security. The program enables the creation and printing of various documents and reports that follow the calculation of debts, the calculation and crediting of interest, the calculation and posting of lawsuits, the posting of settlements. D-Max.Net is a business system that actively monitors user requests.

The DocTrader information system stands out for its rich reporting capabilities, security mechanism and regulation of the right to use individual parts of the System, installation and operation in branches or outposts, additionally elaborated standardization system and various additional systems for communication with external systems.

This system is the central storage, information and communication system of the application. It is the central database of the application where all the data related to the processes occurring within the company are stored and it is based on Microsoft SQL Server 2005 RDBMS. This part of the application also undertakes successful communication processes either via the Internet/RAS, LAN or some other type of mobile device.

The client components of the System are implemented with Microsoft tools of the latest generation, VS.NET 2008. Such a modern tool enables the use of client components of the System independently of the device platform on which the component is located. The development of the application was realized with the concept of three-layer architecture. This concept enables the separation of the business logic of the System from other segments: the database and the user interface. In this way, corrections to business logic and business rules can be implemented very easily and quickly.

The most famous 1C solution is 1C:ERP2 - ERP system that has been implemented in over 25 thousand companies. It is designed for the automation of management and accounting in companies of various industries, activities and types of financing. This information system gives the opportunity to find solutions for complex automation of production, trade and service companies, products for financial management of large, small and medium-sized companies, accounting, payroll, human resources, various industrial and specialized solutions developed by the 1C company. The system architecture of this software ensures openness of application solutions, high functionality and flexibility, scalability from one to several hundreds of users, from the smallest to very large organizations and business structures. All the mentioned advantages bring this software great popularity in a large number of countries. Docus doo proudly points out that it is a partner of 1C solutions for Serbia and the region.

Each system represents a whole, a complex that is imbued with connections, information and relationships, which must be interconnected. The first place for every business system is information that can be of primary or secondary importance for it. What is important is that information passes through all levels of decision-making. For this purpose, it is very important to have a well-developed and improved information system, which, when used and controlled and thanks to the training of personnel, will first of all save time as a non-renewable resource, and then other material and non-material resources in the business system.

Information flows together with places where information is created, collected, stored, processed and with which information is directly used represent the information system of that System. The specifics of the information system are reflected in the following.

- To form an organizational function, at least one set of information is required, and usually several such sets participate,
- Each organizational function is accompanied by an appropriate set of information,
- One set of information participates in the formation of several organizational functions,
- The basic characteristic of information systems is that people participate in the creation, processing and transmission, which significantly affects its functioning.

What is common to all production systems is that their functioning can be divided into three basic activities - processes, namely: process, setting tasks and business goals (goal function), the process of managing the production system with the aim of realizing production tasks and goals (management function) and the process of realizing business goals. In figure 2, a schematic view is given.

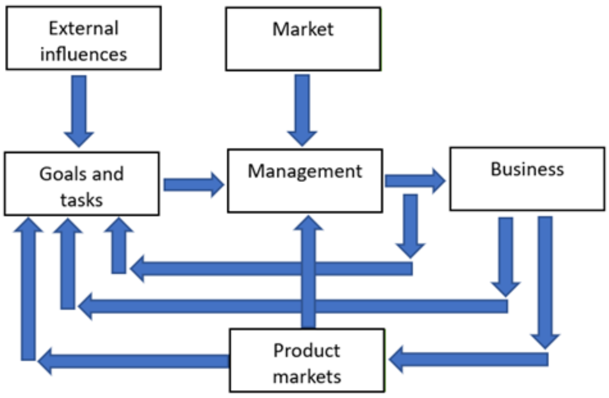

Figure 2. *Basic functions of the business system*

3. B2B BUSINESS MODEL IN THE FIELD OF INFORMATION TECHNOLOGIES

The need to increase the performance of business processes within the organization conditioned the implementation of one of the ERP systems. Accordingly, the B2B business model allows companies to reach the desired information system that will digitize their business. Elem, an IT company that provides and implements implementation, as well as training users of an ERP system, is oriented towards other companies that need software, which represents a B2B business model. The business model can be defined as: "Business-to-business" transactions are common in a typical supply chain, as companies purchase components and products such as other raw materials for use in manufacturing processes.

For example, the company DOCUS D.O.O. offers several business solutions, i.e. information systems, which enable companies to speed up business processes, that is, their implementation results in cooperation between two companies. By recognizing the needs of other businesses, a strategy and business steps for acquiring clients based on the B2B business model are created. Figure 3. will show the B2B business model on the example of an e-commerce solution.

Figure 3. *Schematic representation of the B2B business model of eCommerce solutions in correlation with other software [4]*

Business-to-business transactions are conducted through various categories of websites, including the following:

- Company websites. This is the simplest model of B2B transactions. The company uses its own website to sell goods and services directly to its business customers. Sometimes a company's website uses a secure extranet to give customers exclusive access to product catalogs or price lists.
- Procurement exchanges and product procurement. These online exchanges allow a company's purchasing agent to purchase supplies or raw materials from multiple suppliers, submit requests for proposals (RFPs), and, in some cases, make product bids. Also known as e-procurement sites, these exchanges can serve a range of industries and be tailored to niche markets.
- Specialized or vertical industry portals. These portals provide niche and vertical markets with a more targeted approach than sourcing sites. They can also support buying and selling, and provide information, product listings, newsgroups and other functions for industries such as healthcare, banking and transportation.
- Broker sites. These sites act as intermediaries between service providers and potential customers who need their services, such as leasing equipment or services.
- Informational sites. Sometimes known as infobrokers, these sites provide industry-specific information to companies and their employees. Information sites include specialized search sites and those of trade and industry standards organizations.

In a B2B collaboration, one business, often called a seller, sells products or services to another business. Typically, a sales team or department conducts these transactions, rather than an entire company or individual. Occasionally, one person on the buyer's side completes a transaction that supports the company's business goals. In contrast, some B2B transactions involve the use of products by the entire company, such as office furniture, computers, and software licenses.

For larger or more complex purchasing decisions, the procurement committee manages the B2B product selection and decision-making process. These committees usually include the following staff:

- A business decision maker, such as the person responsible for the budget.
- Technical decision maker who evaluates the capabilities of potential products.
- Influencers, such as individual users and employees who provide input on how the product will be used.

Every business must buy products and services from other businesses to start, operate and grow. B2B trade supports these activities. The company uses B2B suppliers to procure products and services, such as the raw materials they need for production, office space, office furniture, computer hardware and software. Food that companies store in their kitchens and signage on their office buildings are also examples of products and services purchased from suppliers.

B2B suppliers are more likely to engage in long-term business relationships with their customers compared to B2C companies. B2C transactions often involve ad hoc purchases from individual consumers, while B2B suppliers can expect more frequent and predictable purchases of goods and services by businesses. Many B2B vendors sell specialized and customized products tailored to specific business needs. According to the authors Elhajjar, S., Yacoub, L., & Ouaida: "The digital transformation of sales work" means that both simple and repetitive tasks and highly complex cognitive activities are taken over by technologies based on artificial intelligence [4].

B2B companies operate in many industries and markets. Here are some notable examples:

- Financial services. Banks, accounting firms and other financial service providers offer commercial lending, payment processing, commercial tax preparation, investment banking and similar services to business customers.
- Technology. Hardware, software and cloud services are vital to almost every business, and business users often have unique technology needs. Examples include CRM software, data center infrastructure, and cloud-based human resource management.
- Office supplies. Businesses rely on these suppliers to purchase large quantities of items such as paper, ink cartridges, and file storage.
- Manufacturing. Unlike other sectors, manufacturing is almost entirely a B2B market. Manufacturers sell materials, components and parts to other businesses who, in turn, use them to create new products. For example, semiconductor manufacturers' primary customers are companies that use chips to make computers, printers, cell phones, and other more advanced products.
- Marketing and advertising. Marketing and advertising agencies mainly serve business clients, making B2B commerce a cornerstone of their business model.

4. ANALYSIS OF BUSINESS PROCESS EFFICIENCY IMPLEMENTATION OF 1C:ERP WE INFORMATION SYSTEMS

The widespread use of various business information systems has led many companies to rely heavily on these systems for their operations. Furthermore, these systems have evolved from auxiliary tools of control to integral components of company operations. Business administration faces the challenge and need for systems that meet today's criteria, particularly systems designed to be informational, administrative, and operational. However, business information systems are not uniform, making IT support for business operations a crucial area of interest. For the informatization process to be effective, a company must examine how business information systems can help streamline business processes, allocate resources cost-effectively, and align digital workflows with actual business processes.

Despite the growing number of articles explaining the principles of e-business and providing case studies, there is much less understanding of the exact strategic advantages of business information systems and what companies need to do to achieve efficiency and effectiveness. Therefore, by presenting a role-oriented business information model for effective and efficient business coordination, the intention is to focus on analyzing the impact of business information systems on business processes.

Business efficiency refers to operations structured in such a way that resources are utilized in a manner that allows the venture to meet its objectives when designed with and managed by business processes and organizations.

In the twenty-first century, no company can function without an information system. The development of ERP has led to the need for implementation in companies, regardless of the activity and size of the organization. accordingly, for research purposes, the 1C:ERP WE information system will be analyzed on the example of a business process in the sales sector, where an insight will be gained into the performance and results that the aforementioned cloud software provides to companies. Accordingly, 1C:ERP can be defined as a flexible ERP solution that enables companies to respond to the digital challenges of today's business, grow faster and lead their markets [5].

Figure 4. will show data on the quality of the implementation of the 1C:ERP WE program in the company's operations.

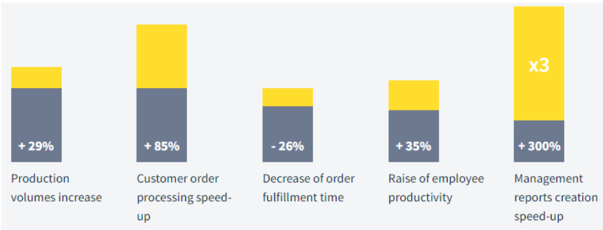

Figure 4. *Present benefits of 1C:ERP WE program [5]*

It can be said that the performance improvements are reflected in the following segments:

- Increased volume of production,
- Forming the processing of customer orders,
- Reduction of order fulfillment time,
- Raising the level of productivity among employees,
- Quick creation of management reports.

The greatest growth in performance during the implementation of 1C:ERP WE software was recorded in the segment of faster creation of management reports by as much as 300%. In the further analysis, the effectiveness of the implementation of the 1C:ERP WE software in the Sales module will be examined. Figure 5. represents the interface of the program [6].

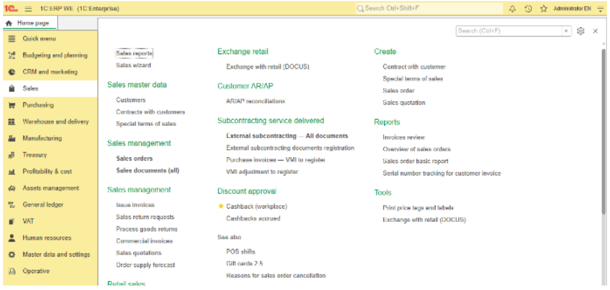

Figure 5. *Interface 1C:ERP WE in the Sale modules[6]*

User interaction is only one of the advantages of the program. In addition, the software is suitable for implementation both in the private and public sector, regardless of the activity and size of the organization. Figure 6 will show the creation of a sales order where you will see some of the advantages of the software.

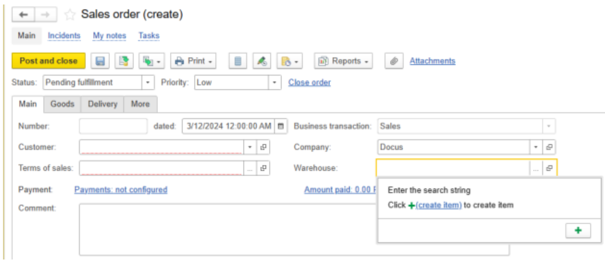

Figure 6. *Practice examle creating sale order on 1C:ERP WE software, [6]*

The creation of the sales order is automated, it is a simple data filling, which speeds up the business process, without the need for redundant paperwork. This enables digitization of the organization's operations. Figure 7. shows the business process on the merchandise card.

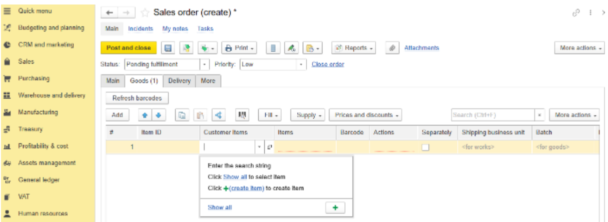

Figure 7. *Fill in Goods*

The selection of goods will be made possible by choosing an option from the drop-down menu, the items are automatically selected, which can be seen in Fig. 5, as well as a simple entry of the barcode using the "Refresh barcode" option. All segments on the Goods tab have an automated business process, which makes business more efficient, and therefore better performance and work results, as errors in data entry are eliminated. Accordingly, Figure 8. defines the upcoming step of delivery of the sales order.

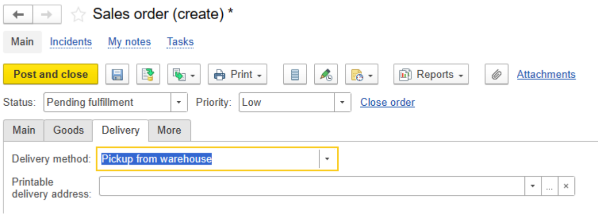

Figure 8. *Delivery of Sale order*

With a simple selection from the drop-down menu, the "Delivery" data is filled in, which significantly facilitates and speeds up the work for users. After considering the steps and advantages of the 1C:ERP WE information system, it is important to note that DOCUS D.O.O. Čačak creates a version of the software in the Serbian language for the needs of the domestic market.

5. CONCLUSION

The application of business information systems has significantly improved efficiency and productivity in operations. In an era where the volume of knowledge is rapidly increasing, business information systems are increasingly viewed as tools for leveraging knowledge and contributing to the organization's survival.

Organizational memory is defined as a database/record of experiences that is available within an organization for reuse. Business information systems, as a component of organizational memory, are conceptualized as cybernetic devices that facilitate decision-making and the collection, sharing, and reuse of knowledge. To prevent the benefits of business information systems from diminishing over time, an increasing number of companies have embraced the ideal of a learning organization and have begun to devise methods for protecting and exploiting organizational memory. Additionally, by examining how knowledge is conceptualized, captured, indexed, stored, retrieved, and distributed, and how internet search engines and business information systems operate, the potential of business information systems as tools for leveraging knowledge as a basis for competitive success is assessed.

According to all of the above, after a short analysis it can be determined that the 1C:ERP WE software program digitizes the operations of organizations, makes business processes more efficient and increases the productivity of performing work tasks. In addition to the mentioned software, other mentioned softwares, which are products of the company "Docus", have a large and significant role in the work of modern organizations and in general of every individual who deals with computer science.

At the very end, it can be concluded that without timely and verified information, good software and an information system that ensures security and data protection, there is no quality product, and what is understood to exist in a quantitative and qualitative sense is the human factor.

The importance of the introduction of a business information system is first of all reflected in the effectiveness and efficiency of the work of employees, leading to the achievement of good business results. First, the possibility of human factor error is minimized, the process of performing work tasks is accelerated, which directly affects the improvement of the company's performance. In addition, it can be stated that the automation of business processes would not be possible without the implementation of information systems, such as 1C:ERP WE, which affects both the competitiveness and development of the company, as well as the competitiveness and development of the economy as a whole.

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Simulation of a Chess Game with an Industrial Robot

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Abstract: *This paper presents a simulation of a chess game with an industrial robot designed for educational purposes, focusing on the integration of automation in various industries. By using the FANUC ER-4iA robot in a FANUC educational cell, we explore the robot's ability to perform precise and complex movements that are important for the chess game. The simulation is carried out using the ROBOGUIDE software, which enables detailed programming and visualization of the robot's movements. The process includes configuring the coordinate system, defining the robot's gripper parameters and programming the robot to precisely manipulate the chess pieces on a virtual chessboard. The results show that the robot performs the set tasks efficiently and demonstrates its educational potential in teaching robotics concepts and programming skills. Although the simulated application showed high precision in motion execution, certain limitations were noted in automation has become a key factor in increasing efficiency and productivity in various industries. Industrial robots have established themselves as indispensable tools in this process, enabling the automation of complex and repetitive tasks with a high degree of precision and reliability. This paper explores the application of industrial robots for educational purposes terms of the robot's reach and carrying capacity.*

Keywords: *industrial robot; FANUC ER-4iA; education; ROBOGUIDE*

1. INTRODUCTION

Nowadays, automation has become a key factor in increasing efficiency and productivity in various industries. Industrial robots have established themselves as indispensable tools in this process, enabling the automation of complex and repetitive tasks with a high degree of precision and reliability. This paper explores the application of industrial robots for educational purposes by simulating a game of chess with a robot with six degrees of freedom. [1, 2, 3]

Chess, a game that requires strategic thinking and planning, is an ideal framework for demonstrating the capabilities of robotic systems. In this study, the FANUC educational cell is used to simulate a game of chess and demonstrate the robot's ability to perform precise and complex operations. Using the ROBOGUIDE software, which allows detailed programming and simulation of robot movements, the potential of robots to simulate this complex game is analyzed. The process begins with the placement of the chessboard in the simulation space, followed by the addition of the chess pieces. The coordinate system is configured to match the required robot movements, using the "Joint" system to control individual robot axes. After setting up the board and pieces, the robot gripper parameters are defined to simulate the interaction with the chess pieces.

The main objective of this paper is to demonstrate the practical application of industrial robots in education and to explore the possibilities of their further development and implementation in various industrial sectors. The paper contributes to a better understanding of the capabilities of industrial robots and illustrates their potential not only in manufacturing processes but also in the educational context, where they can serve as powerful tools for the training of future engineers and technicians.

2. FANUC EDUCATIONAL CELL

FANUC has developed an educational cell that includes the very popular FANUC ER-4iA standard industrial robot. The FANUC ER-4iA industrial robot is compact and precise and is therefore very suitable for education and training. The educational cell is primarily designed for educational institutions such as schools, universities or training centers and is aimed at students, providing them with an excellent robotics training package. With this educational cell, users can develop skills such as programming the robot and processes, controlling movements and familiarizing themselves with the basic concepts of robotics, while also offering insights into safety aspects. The content of the cell is highly relevant to modern industrial applications and contains everything students need to acquire comprehensive knowledge. This educational cell can also be integrated with FANUC's ROBOGUIDE software, which enables advanced learning and research in robotics. The software allows users to virtually create their work cells, set up and program robots, and simulate and analyze workflows. This enables users to visualize how the robots will work in the real world, identify and solve potential problems and optimize workflows before they are used in a production environment. In addition, the educational cell offers the option of using a machine vision camera for component recognition and detection, which is mounted on top of the cell to detect components. The educational cell consists of the following components:

- FANUC ER-4iA robot
- R-30iB Plus controller
- iPendant hand controller
- Educational cell (mobile structure with a table)

Figure 1. *3D model of Fanuc educational cell*

3. CHESS GAME SIMULATION

The simulation is carried out with the ROBOGUIDE software from FANUC. It is necessary to determine and configure the coordinate system, but the "Joint" coordinate system is preset in the learning cell, so no additional configuration is required. The "Joint" coordinate system represents the coordinate system of the individual robot axes, with each joint rotating around its central axis. In addition to the "Joint" coordinate system, there are also Cartesian coordinate systems, which are represented by displacements along the X, Y and Z axes and by rotations around the W, P and R axes. There is also the "World" coordinate system, which is predefined and cannot be changed. The "User" and "Jog" coordinate systems are defined on the basis of this coordinate system. The "User" coordinate system refers to the tool and defines its center and rotation relative to the "World" coordinate system, while the "Jog" coordinate system is defined by the user and is generally used to facilitate robot movement in manual mode.

The first step in the chess simulation process is to import the necessary 3D models into the program. This is achieved by selecting the "Fixtures" tab from the drop-down menu on the left-hand side, right-click on "Fixtures"," select the "Add Fixtures" option and then select "Single CAD File" for the chessboard and "Multiple CAD File" for the pieces. A window will then open in which the 3D model of the chessboard that was previously created in Fusion360 must be located. Once the board is inserted into the workspace, it must be positioned accurately to ensure that the work cell is set up correctly.

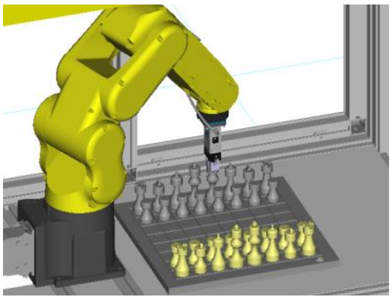


Figure 2. *Work cell after importing chessboard and chess pieces*

In the next step, it is necessary to define how the gripper holds the chess pieces during the simulation. In the drop-down menu under the "Tooling" tab, select the option "UT: 1 (Gripper)" to open the gripper settings. In the newly opened window, select the "Parts" tab. Select the chess piece in the opened window, click on "Apply" and then select "Edit Part Offset" to position the piece in the gripper. After positioning, deselect the options "Visible at Run Time" and "Visible at Teach Time," and confirm again with "Apply" Repeat this process for all chess pieces.

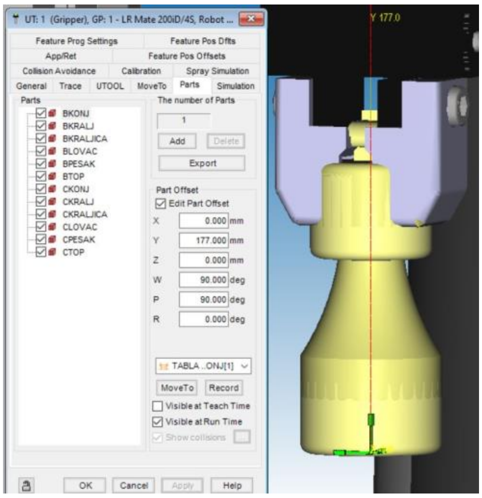


Figure 3. *Position of chess piece in gripper*

Programming the movement of a single chess piece begins with finding the previously created program in the Teach Pendant. To access the program, press the "Select" button and select the desired program using the arrow keys on the keyboard, followed by confirming the selection by pressing the "Enter" key Next, you must insert the appropriate number of lines of code by using the "EDCMD" option and selecting "Insert" The number of lines added does not have to be exact, as lines can be added or deleted later as needed.

The next step is to define the tools and coordinate systems. Use the arrow keys to position the cursor on the first line of code, select the "INST" option and go through the menu until you reach "Offset/Frame"," where the "UFRAME_NUM=" option is set. Enter the number of the coordinate system, e.g. the "Joint" system, and confirm the selection. The same procedure is repeated for selecting the tool by selecting "UTOOL_NUM="," where in this case the tool is the gripper, so that the corresponding number is entered in the code.

The robot is then moved to the "Home" position and the gripper is opened with the "CALL program" subroutine, selecting "AA_HOME" to return the robot to the home position and "HAND_OPEN" to open the gripper. Then the robot is positioned above the desired chess piece to be moved by selecting the "Move To" option in the program tree. Once the robot is positioned above the piece, the "POSN" option is used to adjust the coordinates of the robot, especially the Z-axis, to position the robot at the desired height above the piece. When the positioning is complete, the position is saved in the code by pressing "SHIFT", "F1" and "POINT".

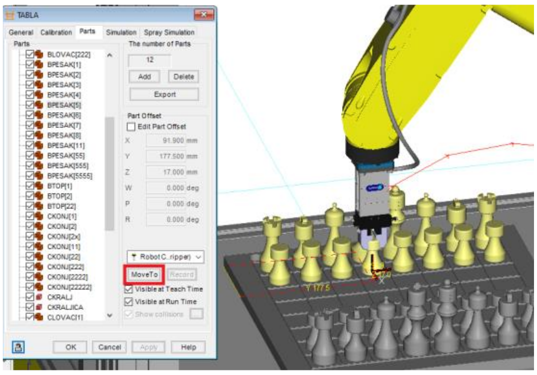
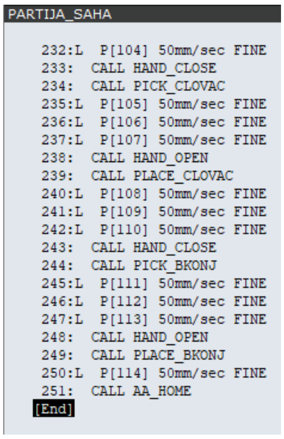


Figure 4. *Point and path definition*

Finally, the robot is lowered to the exact position to grip the piece using a linear movement defined in the code. Once the robot is in the correct position, the gripper is closed with the "Macro" program "HAND_CLOSE" successfully gripping the piece, which is then ready to be moved. This process is repeated for all subsequent movements.



```
PARTIJA_SAHA
232:L  P[104] 50mm/sec FINE
233:  CALL HAND_CLOSE
234:  CALL PICK_CLOVAC
235:L  P[105] 50mm/sec FINE
236:L  P[106] 50mm/sec FINE
237:L  P[107] 50mm/sec FINE
238:  CALL HAND_OPEN
239:  CALL PLACE_CLOVAC
240:L  P[108] 50mm/sec FINE
241:L  P[109] 50mm/sec FINE
242:L  P[110] 50mm/sec FINE
243:  CALL HAND_CLOSE
244:  CALL PICK_BKONJ
245:L  P[111] 50mm/sec FINE
246:L  P[112] 50mm/sec FINE
247:L  P[113] 50mm/sec FINE
248:  CALL HAND_OPEN
249:  CALL PLACE_BKONJ
250:L  P[114] 50mm/sec FINE
251:  CALL AA_HOME
[End]
```

Figure 5. *Program part*

In order to visualize the movement of the chess pieces in the simulation, it is necessary to create simulation programs for opening and closing the gripper, which should be called after the line in which the gripper is actually closed. The simulation program is created by right-clicking on the "Programs" tab in the tree on the left-hand side and selecting the "Add Simulation Program" option. A name is entered in the new program, for example "PICKBPIJUN".

By running the simulation of the robot, you can test the application. Once the application has been tested, it is transferred to the physical robot controller and the robot is put into operation. In order for the program to work on the physical controller, you must delete the simulation programs. The program is then transferred from ROBOGUIDE to a USB drive and then from the USB drive to the robot controller.

When the USB drive is connected, press the "MENU" button, select the "FILE" option in the next window and then "File" again. If you press the "F1" key, the "Type" menu opens, in which you select the ".TP" option for easier searching. A menu will then open with the programs available on the USB drive. Position the cursor on the desired program and load it by selecting the "LOAD" option or pressing the "F3" key.

Figure 6. *Chess game on physical robot*

4. CONCLUSION

This study successfully created a basic version of a pick-and-place application on the robot, which represents the first step in the programming of industrial robots. The simulation showed a high degree of precision in the manipulation of the chess pieces. However, limitations were identified in terms of working range and payload, which could be improved by using a robot with a higher payload capacity or better suited to certain tasks.

In addition, the integration of software tools such as ROBOGUIDE enables efficient planning and simulation of complex tasks before they are transferred to the real environment. The FANUC ER-4iA robot accurately executed all the prescribed moves on the chessboard, demonstrating its ability for precise positioning and repeatability of movements.

Future studies could explore the integration of advanced artificial intelligence systems to enable more autonomous interaction between the robot and its environment, potentially allowing the robot to play a game of chess against a human opponent. The results indicate a high level of precision and reliability, suggesting the potential for further applications of such systems in both education and industry.

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Advantages and Disadvantages of M-Learning in University Teaching

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Abstract: *In the context of contemporary university teaching, the questions of the characteristics, advantages and disadvantages of m-learning have attracted increasing interest, especially in regard to the importance of this type of learning for students' initial education and their professional work in the future. In view of this, research was conducted with the aim of investigating the students' attitudes towards the advantages and disadvantages of m-learning in university teaching, as well as the impact of sociodemographic and educational variables on the students' attitudes. The sample comprised 308 students from the faculties of education and philosophy from 4 universities in Serbia. The survey technique was used for data collection, and the instrument was a questionnaire with the assessment scale designed specifically for the purposes of this research study. The research results show that the surveyed students see the availability and possibility of free use of mobile applications, as well as the access to current topics and content as the greatest advantages of m-learning, while the difficulties in assessing the validity of knowledge tests, mobile device addiction and the Internet access are seen as its greatest disadvantages. The obtained results also imply certain recommendations as to how the students can better recognize the importance of m-learning as an aid to the learning process, the ability to follow lectures and learn content.*

Keywords: *mobile devices; teaching; higher education; learning; mobile applications*

1. INTRODUCTION

Although the use of mobile devices as a support for learning is not new [1], the concept of mobile learning has been introduced into the wider scientific discourse in education over the last two decades. Various reasons have contributed to this, and in particular the following ones: an increase in wireless internet access [1, 2], an increase in the number of mobile device owners in both student and general population [2, 3, 4], the increased use and improvement of mobile technology functions [1, 5], and their ubiquity in everyday life [1].

M-learning has the potential for transforming and innovating education systems, primarily because of its ability to increase the usability of information and communication resources, reduce costs, overcome the disadvantages of traditional teaching, and achieve educational outcomes [6]. It is also thought that the use of m-learning improves the quality of higher education, thus making it more efficient and more available [7]. Although there is no standard attitude about the definition of m-learning, its relationship to other related terms, the importance or possibilities of its integration into teaching, it is indisputable that mobile devices and technologies play an increasingly important role in initial education and academic life of students. Various mobile devices are used in m-learning: mobile phones, smartphones, tablets, e-readers, players, netbooks, cameras and digital cameras [3, 8, 9].

M-learning is defined as a form of distance learning based on mobile technology [5], i.e. a form of e-learning delivered through various mobile devices [10]. It is also defined as learning that is delivered through social and content resources, by using personal electronic devices in various contexts [11], and sometimes [6] as a "type of hybrid teaching supported by mobile devices, applications and web tools" (p. 1046)". In the early stages of m-learning development, some authors questioned its use and definitions [12], while others thought it was a term that needs to win credibility within the existing network of scientific terms [1].

Differences in the definition of m-learning exist not only with regard to its range (e.g. whether it is an autonomous form of learning or simply a subtype of e-learning), but primarily as regards its content, i.e. whether it is a type or form of learning [5, 10, 11, 13, 14], an approach to learning or a type of teaching [6].

Within the contemporary definitions [11, 13, 14, 15], four constructs of m-learning are emphasized: educational, technological, contextual and social;

therefore, m-learning is understood as learning across different contexts, through social and content interactions, by using personal, i.e. mobile devices and technologies. Taking into consideration the existing definitions, in this paper, m-learning is understood as a subtype of e-learning in which learning takes place through interactions with other people and content in formal, non-formal and informal contexts by using mobile devices and technology. These different approaches and definitions support the fact that m-learning is constantly being developed and redefined, as a result of the intensive development of mobile devices and technologies, and new approaches to teaching and learning.

1.1. Advantages and disadvantages of m-learning: a literature review

Ever since m-learning came into wider use in higher education, the research focus has been on considering the advantages and disadvantages of its use, most commonly through self-evaluation [16, 17, 18] and systematic reviews [2, 3, 19, 20].

Within the context of higher education, the results of many studies [2, 8, 11, 16, 17] suggest that m-learning can be used as a support for learning. Research results [2] show that m-learning significantly improves learning efficiency, communication and collaboration between students and teachers, and interaction in content creation. The most important characteristics that recommend mobile devices as a support for learning are: portability, collaboration, ubiquity, usability, perception and acceptance [8]. Chetri [11] emphasizes the following possibilities of m-learning: it enables personalized learning (e.g. content and assignments are sent to students on a personalized level), it enables individualized (student-oriented) and collaborative learning, which is tailored to students' individual needs and interests, it promotes students' problem-solving skills, communication, creativity, and motivation. The advantages of m-learning are also visible in its potential to combine learning in formal and non-formal contexts, encourage active learning and student-oriented learning [20].

In one study [16], the students stated that the most useful aspects of m-learning are a simple approach to course resources and materials and improved communication with other students and teachers. In addition, m-learning helps students develop analytical and note-taking skills. M-learning provides a fast and flexible approach to various educational content types and information sources, anytime, anywhere. This characteristic of m-learning provides students with the possibility of choosing the place, time and dynamics of learning in acquiring and applying knowledge. Similar results were obtained in other studies. Rysbayeva et al. [17] found that the students consider a fast and flexible approach to information and relevant content, anytime, anywhere, as well as the possibilities of using a variety of learning methods to be the greatest advantages of m-learning. Based on the students' attitudes, mobile applications for learning increase motivation, facilitate learning and are also useful, whereas disinformation, the need for mobile support and their high price are seen as disadvantages.

Research results [21] show that m-learning positively influences the acquisition of knowledge, as well as the development of skills and attitudes of prospective teachers during initial education. Students who used educational software during m-learning demonstrated greater knowledge of the course content than those who did not use such advanced educational tools [9].

M-learning contributes to greater education availability, especially for those individuals who live in the communities with low socio-economic conditions, limited infrastructure and resources, since the use of mobile devices and technologies reduces the costs of learning, thus providing unlimited access to information [7, 22].

One of the advantages of m-learning is its potential to facilitate and improve communication of those students who suffer from anxiety as they can anonymously participate in learning activities [23, 24]. It was found that the use of mobile applications in anatomy teaching can be an efficient method not only for improving learning, but also for reducing students' anxiety [23].

As regards the integration of mobile technology in educational activities [25], the students reported the following advantages: *technological advantages* (e.g. access to materials and other resources, portability, e-courses, fast data storage, online books, etc.), *efficient communication* (exchange and flow of information, in-group and student-teacher communication), *information* (access to information, diversity of information sources, information quality and quantity), *opportunities of educational process* (effective learning, collaborative learning, interactive teaching, knowledge application, knowledge assessment and feedback), *personal development* (personal time optimization, cognitive, moral and social development, regulatory process development, possibilities of sharing personal experience), *economic and ecological advantages.*

Given all of the above, m-learning offers many advantages: a fast and flexible approach to information and learning resources [16, 17, 25, 26], improved academic performance [9, 18, 23, 27, 28], increased motivation [3, 16, 27, 29], self-regulated learning [25, 30], social interaction and collaboration with other students and teachers [2, 8, 11, 16, 25].

Despite many advantages m-learning has in higher education, there are some factors that directly influence the acceptance and use of mobile devices and technologies. The following factors are particularly emphasized: small screen size, limited processing power, reduced input capacity [31], prejudices against and bans on mobile devices [10, 32], costs associated with mobile devices [17, 33], incompatibility of operating systems [33], and personal data protection and security [34]. The use of m-learning is also faced with the problems related to interface, costs and dependence on infrastructure [20]. The use of mobile phones in education meets resistance of a social and educational community, which is why their use is banned in many educational institutions [10], or teachers reluctantly encourage students to use mobile devices for learning. Besides, it was found that obstacles to using mobile technologies in education can be categorized into 6 groups: negative influence on students' personal development (health issues, sedentary behavior), technology-related issues (technology addiction, prejudices against m-learning), information quality and credibility, reduced communication and social skills, negative effects on the educational process, economic, ecological and ethical disadvantages [25]. The use of mobile devices in education is also associated with the existence of some behavioral problems in young people such as cheating, disruption, cyberbulling, accessing and sharing inappropriate content and the like [35]. One other disadvantage of using mobile phones in teaching is related to the avoidance of academic responsibilities (e.g. texting in class, cheating on exams, taking photos, etc.) [36]. There are many obstacles to successful integration of m-learning into teaching. Some challenges are also due to lack of self-efficacy to integrate technology, negative attitudes towards technology and lack of pedagogical strategies [37]. In their analysis of the concept of personal mobile devices in higher education, Trivunović and Gajić [38] concluded that their use is faced with two key problems: technical requirements and teachers' non-acceptance of the concept.

The literature review on m-learning provides an insight into the main research areas and questions that need to be addressed. Students' attitudes towards mobile technology are one of the key factors in accepting and using mobile devices in education. Therefore, we considered the investigation of students' attitudes towards the advantages and disadvantages of m-learning in higher education to be an important issue.

2. RESEARCH METHODOLOGY

2.1. Research aims and tasks

Considering the importance of m-learning for initial education and students' professional work in the future, the aim of this paper was to investigate students' attitudes towards the importance of m-learning in higher education, i.e. the advantages and disadvantages of m-learning in university teaching. The general *aim of the research* was specified through two tasks:

(1) investigate the advantages and disadvantages of m-learning in university teaching; and

(2) determine whether there are any significant differences in the students' attitudes with regard to sociodemographic and educational variables (sex, year of study, study programme, university, frequency of use of mobile applications, course type and status).

Based on the previous research results, *two research hypotheses* were formulated and tested in this paper:

Hypothesis 1: The students highly value the advantages and disadvantages of m-learning in university teaching. We hypothesize that their evaluations of the advantages and disadvantages of m-learning will be related more to the characteristics regarding its ease of use than the usefulness of mobile devices and technologies.

Hypothesis 2: There are significant differences in the students' attitudes with regard to sociodemographic and educational variables (sex, year of study, study programme, university, frequency of use of mobile applications, course type and status).

2.2. Research sample

The sample comprised 308 students from the faculties of education and philosophy in Serbia, aged 19–33, of whom 89.3% were females and 10.7% males. The sample comprised students from 4 universities: Kragujevac (48.7%), Niš (25.6%), Belgrade (13.0%) and Novi Sad (12.7%). 44.5% of the students were enrolled on the Preschool Teacher programme, 31.5% of the students were enrolled on the Primary School Teacher programme, and 24.0% of the students were enrolled on the Pedagogy programme. 33.1% of the students were first-year students, followed by fourth-year students (20.5%), first-year MA students (20.5%), third-year students (14.3%), and second-year students (11.7%).

2.3. Research methods, techniques and instruments

A survey research method, survey and scale techniques were used in this study. The research instrument was a questionnaire with the assessment scale.

The first part of the questionnaire included questions about the students' sociodemographic and educational characteristics (sex, year of study, study programme, university, frequency of use of mobile applications, adequacy of courses (as regards their type and status) for the use of m-learning).

The second part of the instrument, i.e. the Likert-type scale, included 29 statements, grouped into two subscales. The first subscale – *Advantages of m-learning in university teaching* – included 17 statements (e.g. *By using m-learning, students learn at their own pace, anytime, anywhere; Mobile devices reduce learning and studying costs).* The second subscale – *Disadvantages of m-learning in university teaching* – included 12 statements (e.g. *M-learning contributes to the display of socially unacceptable behavior in class (disruption, cheating); The data and content amount in m-learning is limited*). The initial scale and the two subscales meet the theoretical reliability requirements ($0.7 \leq \alpha < 0.9$) as the calculated values of Cronbach's Alpha coefficient are: 0.87 for the whole scale, 0.89 for the first subscale, and 0.83 for the second subscale. The students were asked to state their agreement with the statements on the five-point scale (1 – *Strongly disagree*; 5 – *Strongly agree*). A higher score on the scale indicates that students highly value not only the advantages of m-learning, but also its disadvantages.

2.4. Data collection and analysis

A group and online survey (via Google Forms) was conducted during the summer term of the 2023/2024 academic year. Student participation in the survey was voluntary and anonymous. The following descriptive statistics measures were used in data analysis and interpretation: frequency, percentage, standard deviation, and skewness and kurtosis measures. For investigating statistically significant differences in the students' attitudes towards the advantages and disadvantages of m-learning, we used a one-way analysis of variance for non-repeated measures (ANOVA). T-test was used to test the differences in the students' attitudes with regard to sex. One sample t-test was used to test the significance of the value of the calculated arithmetic mean compared to the theoretical range of the scale.

3. RESULTS AND DISCUSSION

The results obtained by descriptive statistics (Table 1) indicate that the students have a moderately high attitude ($M=106.23$; $SD=14.71$) towards the advantages and disadvantages of m-learning in university teaching. The same direction and strength of the students' attitudes are found on both subscales, where the advantages of m-learning are considered separately from its disadvantages. The results of one sample t-test confirm the significance of the difference between the arithmetic mean ($M=106.23$; $SD=14.71$) and the theoretical arithmetic mean of the scale (min.29; max.145; $t(307)=18.981$, $p<0.01$). The obtained results suggest that our first research hypothesis can be accepted. Other studies [16, 17] have also found that students have positive attitudes towards the use of m-learning.

Table 1. *Descriptive parameters for the advantages and disadvantages of m-learning scale and related subscales*

Dependent variables	M	SD	Scale range
Advantages and disadvantages of m-learning scale	106.23	14.71	29-145
Advantages of m-learning	60.85	11.19	17-85
Disadvantages of m-learning	41.57	8.22	12-60
Legend: M – arithmetic mean; SD – standard deviation			

Considering the individual statements (Table 2), the results show that the greatest level of agreement was for the following advantages of m-learning: online availability of mobile applications ($M=4.15$; $SD=0.91$), free use of mobile applications ($M=4.03$; $SD=1.07$), and access to current topics and content ($M=4.02$; $SD=1.04$).

Table 2. *Descriptive parameters for the advantages of m-learning in university teaching*

Items	M	SD
M-learning is more suitable for shyer and more reserved students.	3.04	1.17
M-learning motivates students to study harder.	3.31	1.13
By using m-learning, students learn at their own pace, anytime, anywhere.	3.69	1.09
Learning through mobile devices is easier than traditional learning from books.	2.94	1.26
Learning through mobile devices is faster and more interesting than traditional learning from books.	3.18	1.21
M-learning fits the needs and interests of all students.	3.53	1.07
M-learning contributes to better academic performance (high grades, overall performance, etc.).	3.36	1.08
M-learning improves the learning process, thus providing a continuing support for learning.	3.54	1.01
Mobile devices reduce learning and studying costs.	3.61	1.20
M-learning improves student-teacher communication.	3.58	1.24
M-learning improves communication among students.	3.74	1.21
M-learning provides a considerable support for learning, following lectures and understanding learning content.	3.68	1.07
Current topics and content are more accessible via m-learning.	4.02	1.04
M-learning helps students better prepare for their future professional work.	3.53	1.09
There is no time limit for most mobile applications.	3.93	0.98
Most mobile applications are free.	4.03	1.07
Most mobile applications are available online.	4.15	0.91
Legend: M – arithmetic mean; SD – standard deviation		

The average scores for most items are higher than the neutral values (2.50–3.49), except for the five statements. The obtained results are in line with the previous research results [25, 39, 40]. Based on the students' attitudes, the greatest advantage of mobile applications in foreign language learning is their availability, the fact that they are usually free and do not involve additional costs, whereas the greatest disadvantages have to do with the quality of the available grammar exercises [39]. The research results [40] show that, according to students, the availability and ease of use of mobile applications are the most desirable characteristics of m-learning. It is also interesting that the characteristics related to the perceived ease of use of m-learning are seen as the greatest advantages by the students. According to the determinants of the Technology Acceptance Model (TAM) [41], the basic assumption is that the ease of use and usefulness of technology shape students' attitudes to and intention in using technology for learning.

On the other hand, the results in Table 3 show that the students see the following items as the greatest disadvantages of m-learning: validity of online tests, i.e. its potential for assessing acquired knowledge (M=3.81; SD=1.17), the impossibility of using mobile applications offline (M=3.69; SD=1.21), and mobile device addiction (M=3.66; SD=1.04). From the pedagogical, and more narrowly, docimological perspective, it is extremely important that grades and knowledge tests are valid, i.e. that students' achievements reflect the actual level of acquired knowledge [42], and not their improvisation skills in those assessment situations which are not uncommon in the digital environment [35][42]. The dependence of mobile applications on the Internet access [20] and mobile device addiction [25] have been seen as challenges of m-learning in previous studies as well.

Table 3. *Descriptive parameters for the disadvantages of m-learning in university teaching*

Items	M	SD
M-learning reduces student-teacher interaction.	3.45	1.25
M-learning is not suitable for all academic courses.	3.65	1.20
It is more difficult to assess learning results.	3.60	1.14
It is more difficult to assess the validity of online knowledge tests.	3.81	1.17
Some teachers do not allow students to use mobile devices for learning and following lectures.	3.56	1.28
M-learning contributes to the display of socially unacceptable behavior in class (disruption, sharing inappropriate content, etc.).	3.45	1.19
Mobile devices negatively influence students' concentration.	3.54	1.19
Most mobile applications require Internet access.	3.69	1.21
The speed of processing data and connecting mobile devices is low.	2.94	1.08
Screen size – a good layout of data – is a disadvantage of m-learning.	3.17	1.14
M-learning increases students' addiction to mobile devices.	3.66	1.04
The data and content amount in m-learning is limited.	3.05	1.02
Legend: M – arithmetic mean; SD – standard deviation		

As part of the second research task, we aimed to investigate the significance of the differences in the students' attitudes towards the advantages and disadvantages of m-learning in university teaching with regard to some characteristics of the students. Table 4 shows only statistically significant differences in students' attitudes. It is determined that only two observed variables possess significant influence: the frequency of use of mobile applications for learning and the adequacy of use of m-learning in different academic courses (general academic and professional application courses).

Table 4. *The significance of differences in the students' attitudes towards the advantages and disadvantages of m-learning with regard to independent variables*

Variables	Modalities	M	F
Frequency of use of mobile applications for learning	Very often	64.16	F=7.230 p=0.00 * LSD test 1-3; 1-4;
	Sometimes	60.73	
	Very rarely	56.38	
	Never	55.19	
Adequacy of use of m-learning in general academic courses	Strongly disagree	95.75	F=17.956 p=0.00* LSD test 1-4; 1-5;
	Mostly disagree	94.92	
	Neither agree nor disagree	102.11	
	Mostly agree	110.11	
	Strongly agree	115.14	
Adequacy of use of m-learning in professional application courses	Strongly disagree	99.36	F=15.445 p=0.00* LSD test 1-5; 2-4; 2-5;
	Mostly disagree	98.55	
	Neither agree nor disagree	101.74	
	Mostly agree	109.56	
	Strongly agree	116.16	
Legend: M – arithmetic mean; F - one-way analysis of variance for non-repeated measures; * – statistically significant at 0,01 level; LSD test – the least significant difference test.			

The students who use mobile applications for learning very often (M=64.16) more positively value the advantages and disadvantages of m-learning compared to those who use them very rarely (M=56.38) and those who never use them (M=55.19). It is observed that the students who use mobile applications more frequently, more highly value the advantages and disadvantages of m-learning. This was expected as only by using mobile applications more frequently are they able to better evaluate all the advantages and disadvantages of m-learning.

Statistically significant differences were observed in the students' attitudes towards the advantages and disadvantages of m-learning with regard to the adequacy of use of m-learning in general academic courses (F=17.956; p=0,00). The subsequent pairwise comparison tests (The least significant difference test – LSD test) indicated significant differences between the following pairs of students: a) those having a positive attitude (M=115,14) and those having a moderately negative attitude (M=94,92); and b) those having a positive attitude (M=115,14) and those having a negative attitude (M=95,75). The students who expressed greater agreement with the advantages and disadvantages of m-learning also expressed greater agreement with the adequacy of use of m-learning in general academic courses compared to the students who have a negative and moderately negative attitude.

There is a statistically significant difference in the students' attitudes towards the advantages and disadvantages of m-learning with regard to the adequacy of use of m-learning in professional application courses (F=15.445; p=0.00). The subsequent pairwise comparison tests indicated significant differences between the following pairs of students: a) those having a positive attitude (M=116.16) and those having a negative attitude (M=99.36); b) those having a moderately positive attitude (M=109.56) and those having a moderately negative attitude (M=98.55); and c) those having a positive attitude (M=116.16) and those having a moderately negative attitude (M=98.55). The students who more highly value the advantages and disadvantages of m-learning tend to have a significantly more positive attitude towards the adequacy of use of m-learning in professional application courses. Regarding the fact that general academic courses are introduced in the earlier stages of initial education, and professional application courses in the final years of undergraduate and master's studies, it is necessary to more intensively work on the integration of mobile devices and technologies into all years of study and courses (regardless of their type, so that students can evaluate the advantages and disadvantages of m-learning more critically. Besides, the studies on the efficiency of m-learning [9, 18, 23, 27, 28] suggest the need for a more frequent use of m-learning in higher education and provide ample evidence on the many possibilities for its use in various courses. Therefore, m-learning does not depend on the educational content and can be used in a wide variety of academic courses.

4. CONCLUSION

Although m-learning has long been used in higher education, in the context of the Serbian education system, it is still being developed, which is why research studies on students' attitudes are scarce. The fulfillment of m-learning potential is not possible unless all elements (student, teacher, environment, content and assessment) and characteristics of this learning type (ubiquitous, spontaneous, mobile, personalized, interactive, collaborative) are carefully considered, together with the knowledge of the environment and learning activities [43].

Based on the research hypotheses and the results obtained, the following conclusions can be drawn: a) The first research hypothesis is fully accepted. Students have a moderately positive attitude as regards evaluations of the advantages and disadvantages of m-learning in university teaching; and b) The second research hypothesis is partially accepted. There are significant differences in the students' attitudes towards the advantages and disadvantages of m-learning with regard to the frequency of use of mobile applications for learning and the adequacy of use of m-learning in general academic and professional application courses.

The obtained results imply the following *recommendations for teaching practice*: students' familiarization with various possibilities and limitations of m-learning and more intensive integration of mobile technologies into teaching, regarding the specificities of study programmes.

Implications for future research include: investigating students' attitudes towards the advantages and disadvantages of m-learning within theoretical models of technology acceptance and use; investigating determinant factors of students' attitudes towards m-learning that remained outside the scope of this paper such as: the frequency of use of mobile applications in general academic, theoretical-methodological and professional application courses. There is also a perceived need to replicate the research by using larger and more representative samples which would include other universities of different scientific fields.

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Mobile Application for Efficient Exam Enrollment for Basic Studies

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Abstract: *The paper discusses the rationale behind the development of a mobile app for online exam applications at the Užice Department of the Western Serbia Academy of Applied Studies (WSAAS). Throughout the app's implementation, numerous challenges were encountered and effectively addressed. A crucial aspect of the app's implementation involves outlining the developmental stages and essential modules to ensure smooth operation. A key benefit of the app is its ability to provide students with necessary information and streamline the exam registration process, minimizing errors. Exam registration data is transmitted to students via email and logged in the Firebase database, allowing for data extraction and customization to meet student service requirements. Firebase database offers a range of advantages and is an excellent choice for the mobile app for online exam applications because it does not serve a large number of users and provides all the necessary functionalities.*

Keywords: *exam registration, mobile application, Android Studio IDE, Firebase*

1. INTRODUCTION

E-learning has been a longstanding concept, with origins tracing back to the mid-20th century in England and towards the end of the 20th century in the USA, particularly within university settings. One common definition of e-learning describes it as a form of learning that incorporates computer technology, internet access, and information and communication technologies. The approach to e-learning presents both advantages and disadvantages, which have become more apparent as this educational method has gained wider usage. It is important to note that e-learning does not necessarily entail solely online instruction; instead, it often incorporates blended learning approaches that combine online and traditional teaching methods [1, 2].

The emergence of electronic applications for exams followed growth and expanding use of this form of education [3, 4, 5].

Challenges had to be tackled to ensure the and efficiency of electronic exam registration systems. Today, a range of solutions, encompassing diverse designs and options, exist to safeguard data and verify user identities [6, 7, 8].

In alignment with the evolving trends in higher education, the Užice Department of WSAAS opted to create an electronic examination application tailored to students' requirements. (Figure 1). A fundamental consideration arose at the outset of system implementation: whether to adopt existing solutions or develop a system internally with our own resources. The choice was to leverage our team for creating the electronic exam registration system, with testing scheduled at the Užice Department, slated for use starting January 2022.

Figure 1. *Application for exam registration – home page*

During the development of the mobile application, the goal was to create an authentic application that is fully tailored to the needs of the WSAAS. For this reason, we did not rely on similar applications or solutions. All functionalities the application are based on the suggestions and requirements of the students and the student services of the WSAAS.

In tandem with the progress of the electronic exam system, a mobile application for registering exams in both undergraduate and master's programs will be developed. This mobile app will be custom-tailored to the WSAAS, Užice Department's curriculum. The paper will demonstrate and elucidate the functionalities of the mobile application.

2. TECHNICAL REQUIREMENTS

The initial concept involves independently developing web and mobile applications to assess their respective strengths and weaknesses. As the applications are being designed and evaluated, a potential development pathway involves integrating both into a unified platform where the mobile application is linked to the web application. This merger offers the advantage of consolidating payments for both basic and master vocational studies, along with centralizing the database onto the school's server, thereby replacing the current dual-database setup. The ultimate choice between the standalone and integrated solutions will be determined following comprehensive testing of both applications.

For the mobile application to be realized adequately, it was necessary to define the steps in its implementation. After considering all the requirements, the application development process is defined through the following steps, which are presented in Figure 2:

1. Defining the application requirements
2. Defining the required modules in the application
3. Module development
4. Connecting the modules
5. Connecting the module to the database
6. Application testing
7. Use of the Application

Figure 2. *Application development flow [10]*

In outlining the application requirements, our focus was on user experience, envisioning students as the primary users. Our aim was to develop an application that simplifies exam registration and provides essential information for students. While the advantages of online exam registration are clear, our primary objective was to ensure the application offers distinctive and easily recognizable features, while remaining efficient and user-friendly.

3. MOBILE APPLICATION MODULES

Mobile applications operate on a distinct principle compared to desktop or cross-platform applications. The development of the mobile application utilized the Android Studio Integrated Development Environment (IDE) and encompasses four core models, each tailored to the Android operating system. The application's code is crafted in the JAVA programming language and kept separate from the application's resources. When referencing application resources, the focus is primarily on the user interface, a crucial element that influences user satisfaction and perception. These resources are presented through .xml files. Each screen within the application corresponds to a unique activity, represented by a distinct .xml file and associated Java code. Additionally, resources include various components such as images and videos that are not part of the code itself, ...

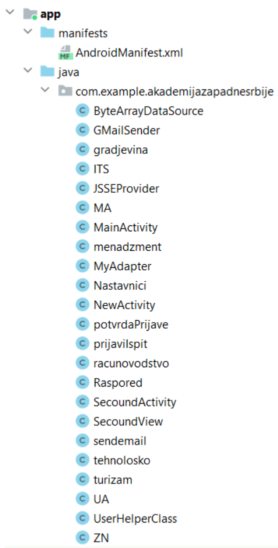

Figure 3. *Application module schematic*

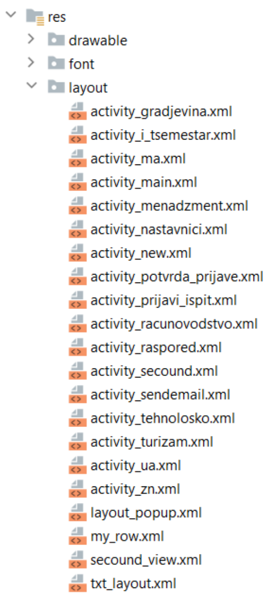

Figure 4. *Android Studio IDE: Building blocks of mobile applications*

During the application development process, we opted not to depend on pre-existing solutions but instead focused on addressing the specific requirements of the Užice Department while striving for originality. This choice was deliberate, as we identified a gap in the market where mobile applications tailored for electronic exam registration were scarce. Most existing solutions are web applications modified to accommodate mobile viewing, further emphasizing the unique approach taken in our development efforts.

Based on the outlined development stages and feedback from students, the application was envisioned to provide details about the instructors teaching in specific study programs, the subjects included in those programs, the lecture schedules for respective study programs, and the primary functionality of allowing electronic exam applications.

When establishing the application requirements, we collaborated with the student service department of the academy. In response to their specific needs, it was emphasized that aside from sending exam applications to the primary email address of the student service department, data should concurrently be stored in the database. This measure ensures that the information can be archived and integrated into the records of registered exams as needed.

The complete flow of activities from the beginning to the end of the exam registration process could be represented as an activity diagram, as shown in Figure 5.

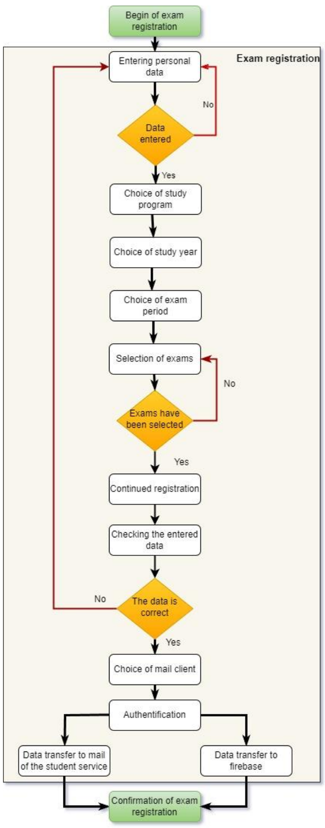

Figure 5. *Activity flow diagram [10]*

In the basic activity, students immediately indicate the purpose of the application. Figure 6 shows the basic screen of the exam registration application and the associated code.

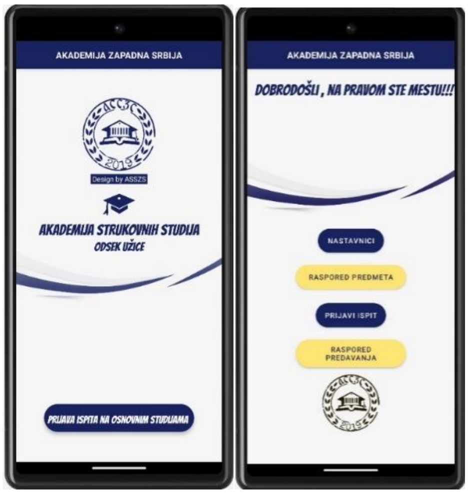

Figure 6. *The initial screens of the exam registration app*

In the upcoming activity, students will have the opportunity to familiarize themselves with the instructors teaching in the basic vocational studies, explore the subjects offered, review the teaching schedule, and proceed with exam registration for a specific exam period (Figure 7-11).

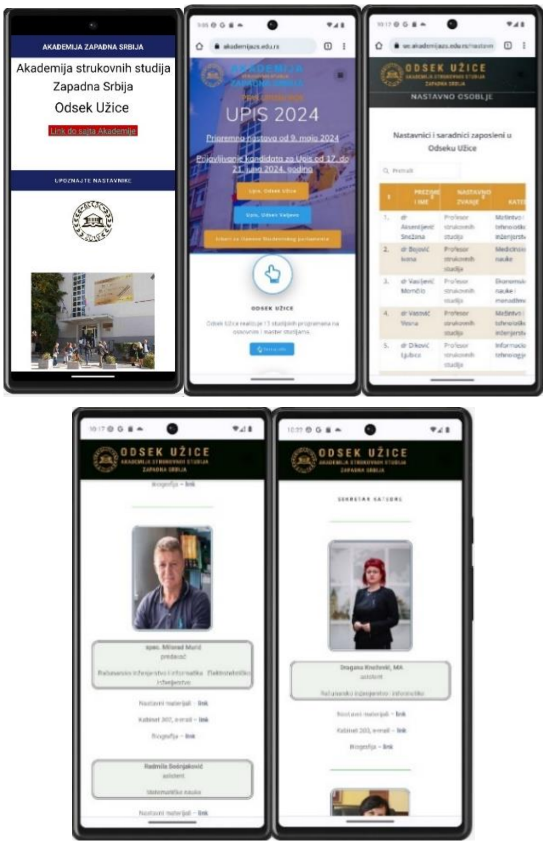

Figure 7. *Getting to know the WSAAS, Užice Department teachers*

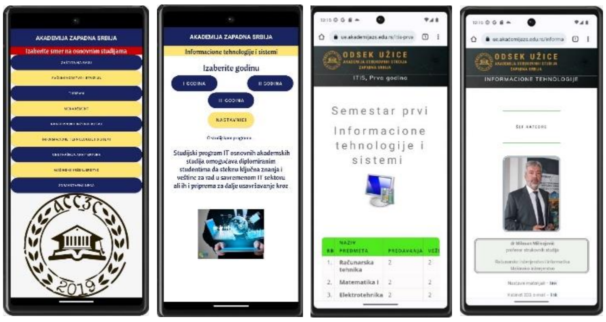

Figure 8. *Curriculum and list of teachers for basic vocational studies*

For each study program within the basic vocational studies, a consistent template is employed. Students can access the course schedule relevant to their selected year as well as view the instructors associated with that particular study program. Additionally, a brief description of the chosen study program is included to provide further context and information. (Figure 9).

Figure 9. *Teaching schedule for basic vocational studies*

The central feature of the application revolves around exam registration. During this process, students input their information, select their study program, specify their year of study, choose the exam period, and indicate the subjects for which they are applying (Figure 10).

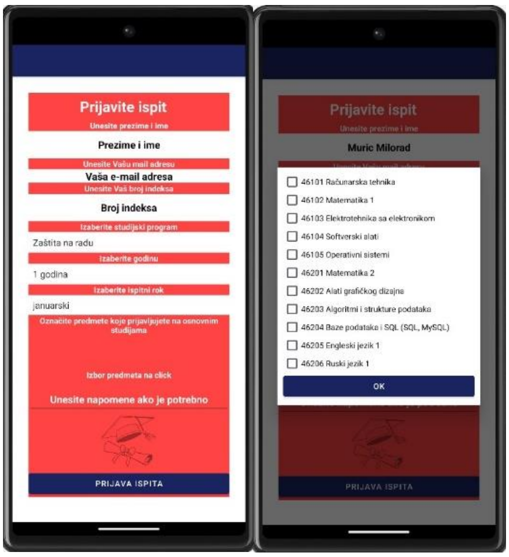

Figure 10. *Exam registration activity*

```
if (inputPrezimeIIme.getText().length()>0 && myEmail.getText().length()>0
        && inputIndeks.getText().length()>0) {

    Intent intent = new Intent( packageContext: this, potvrdaPrijave.class);

    String prezimeIime = inputPrezimeIIme.getText().toString();
    String myemail = myEmail.getText().toString();
    String indeks = inputIndeks.getText().toString();
    String studijski = (String) inputStudijski.getSelectedItem();
    String godina = (String) inputGodina.getSelectedItem();
    String rok = (String) inputRok.getSelectedItem();
    String predmeti = (String) izborPredmetaText.getText().toString();

    Bundle extras = new Bundle();
    extras.putString("prezimeIime", prezimeIime);
    extras.putString("myemail", myemail);
    extras.putString("indeks", indeks);
    extras.putString("studijski", studijski);
    extras.putString("godina", godina);
    extras.putString("rok", rok);
    extras.putString("predmeti", predmeti);
    FirebaseDatabase firebaseDatabase = FirebaseDatabase.getInstance();
    DatabaseReference databaseReference = firebaseDatabase.getReference( path: "osnovne");
```

```
private void addDatatoFirebase(String prezimeIime, String myemail, String indeks,
                               String studijski, String godina, String rok, String predmeti) {
    helperClass.setPrezimeIime(prezimeIime);
    helperClass.setMyemail(myemail);
    helperClass.setIndeks(indeks);
    helperClass.setStudijski(studijski);
    helperClass.setGodina(godina);
    helperClass.setRok(rok);
    helperClass.setPredmeti(predmeti);

    DatabaseReference submissionsRef = FirebaseDatabase.getInstance().getReference(UserHelperClass.submissions);
    String submissionID = submissionsRef.push().getKey();  //ovo je da imas jedinstven key za svakog studenta

    submissionsRef.child(submissionID).child( pathString: "prezimeIime").setValue(prezimeIime);
    submissionsRef.child(submissionID).child( pathString: "myemail").setValue(myemail);
    submissionsRef.child(submissionID).child( pathString: "indeks").setValue(indeks);
    submissionsRef.child(submissionID).child( pathString: "studijski").setValue(studijski);
    submissionsRef.child(submissionID).child( pathString: "godina").setValue(godina);
    submissionsRef.child(submissionID).child( pathString: "rok").setValue(rok);
    submissionsRef.child(submissionID).child( pathString: "predmeti").setValue(predmeti);
```

```
} else if (inputStudijski.getSelectedItem().toString().equals("Informacione tehnologije i sistemi") &&
        inputGodina.getSelectedItem().toString().equals("2 godina")) {

    predmetiZaIzbor = getResources().getStringArray(R.array.informacione2predmeti);

} else if (inputStudijski.getSelectedItem().toString().equals("Informacione tehnologije i sistemi") &&
        inputGodina.getSelectedItem().toString().equals("3 godina")) {

    predmetiZaIzbor = getResources().getStringArray(R.array.informacione3predmeti);
```

Figure 11. *Snippets of code for exam registration activity*

During the exam application process, students input essential information. In a subsequent step, they verify the accuracy of the entered data. Should any discrepancies be identified, students can navigate back to make corrections. Conversely, if the entered data is confirmed as accurate, students can proceed seamlessly with the exam registration procedure (Figure 12).

Figure 12. *Checking the entered data*

Following the verification of entered data, users can proceed with the exam registration process. In the subsequent phase, the application leverages a feature of the Android OS that enables the utilization of pre-installed system applications, such as an email application. In instances where multiple email applications are present on the device, users have the flexibility to choose their preferred email application for sending emails, thus successfully finalizing the exam registration procedure (Figure 13).

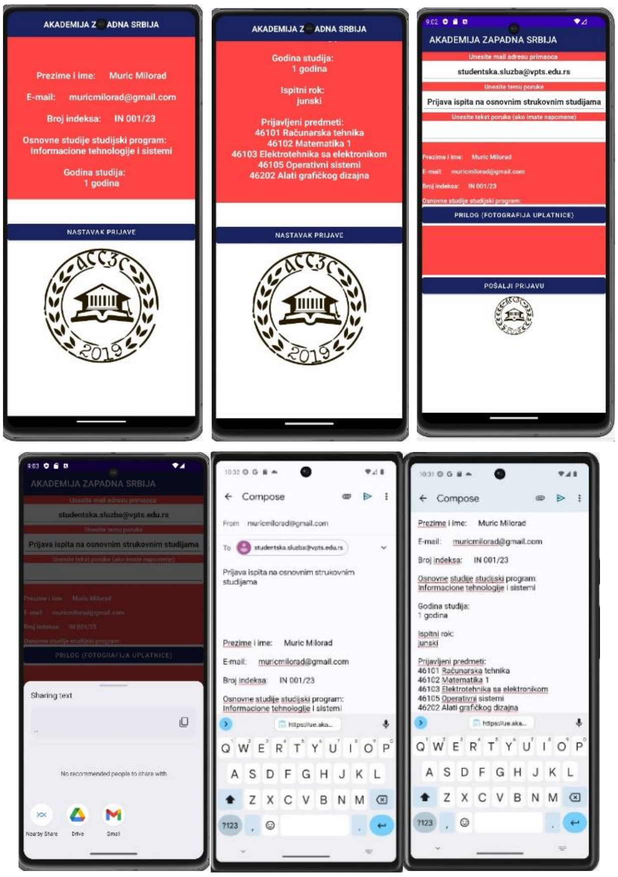

Figure 13. *Final verification of entered data and submission of the exam application*

Firebase, a database platform tailored for integration with Android Studio, was employed as the database solution for this application. Android Studio IDE facilitates a direct connection to the Firebase database. Detailed instructions have been provided within the Android Studio environment on how to establish connectivity between the application and the Firebase database.

Figure 14. *Layout of the database*

Each user logging in receives unique code, and all entered data is linked to that key, which cannot be changed, ensuring data security.

All entered data, i.e. data on registered exams, are visible in the database. Data can be exported in JSON format and further formatted as needed [8, 9] (Figure 15).

Figure 15. *Exporting data from the database*

Figure 16. *Security rules in Firebase database*

Advantages of using Firebase for Android applications are: rapid implementation, real-time database, user authentication, analytics and A/B testing.

Disadvantages of using Firebase for Android applications are: third-party dependency, scalability, performance limitations, costs.

4. CONCLUSION

The application for applying to the basic vocational studies at the Academy of Applied Studies (WSAAS), Užice Department, is currently undergoing testing. This custom-built system is entirely original and has effectively addressed the requirements of both students and staff at the Academy. The application is fully operational, efficient, and successfully fulfills all the specified development requirements. We believe that our objective of creating an authentic application that caters to the needs of students and staff has been achieved. An outstanding feature of the application is that it has been developed using internal resources exclusively. Feedback from students and staff involved in testing has been overwhelmingly positive. While the application is functional in its current state, future plans include enhancements and upgrades to further refine its capabilities.

Future improvements of the application primarily involve adding new functionalities, depending on user demands. Additionally, a detailed evaluation of the application's performance on various mobile devices is planned in order to improve user experience and satisfaction.

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The Use of M-Learning in Teaching Methods Courses at Faculties of Education

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Abstract: *The paper presents the results of the research conducted with the aim of investigating the university students' attitudes towards the use of m-learning in teaching methods courses. The theoretical background of the research study includes previous knowledge of the importance and use of m-learning in professional application courses at faculties. The sample comprised 161 final-year students of undergraduate and master's studies from the faculties of education from 4 universities in Serbia. The survey technique was used for data collection, and a research instrument – A Questionnaire with the Assessment Scale – was specifically designed for the purposes of this research study. The research results indicate that within the Primary School Teacher study programme m-learning is most frequently used in Teaching Methods of the Serbian Language and Literature, Teaching Methods of Mathematics, and Teaching Methods of Nature and Society, while the students of the Preschool Teacher study programme use m-learning most frequently in Teaching Methods of Environmental Studies, Teaching Methods of Speech Development, and Teaching Methods of Developing Initial Mathematical Concepts. The research results imply that it is necessary to shift the focus from lesson planning onto the practical implementation of lessons and activities in teaching methods courses.*

Keywords: *primary school teacher; preschool teacher; professional application courses; mobile devices; faculties of education*

1. INTRODUCTION

Owing to new technologies as well as a growing number of multimedia software types and mobile applications, learning has become contextualized, more authentic, ubiquitous and mobile [1]. Namely, mobile technology development offers many possibilities as regards multimedia experience and resources that transform learning: "from formal to informal, from static to dynamic, and from personal to shared" (p. 306) [2].

The integration of m-learning into study programmes at universities promotes the development of lifelong learning as these study programmes often fit neither the needs of students nor the stage of technological development [3]. The quality of contemporary university teaching is reflected in creating conditions for students' individualized and collaborative activities, which suit their abilities, interests, learning styles and motivation, and such concept of teaching is not possible without the assistance of contemporary information and communication technologies [4].

In the early definitions of m-learning [5, 6], the focus was more on technology. Therefore, m-learning was defined as an extension of e-learning, using mobile devices, i.e. as a form of learning delivered through mobile devices (personal digital assistants (PDAs) and mobile phones, etc.). Baran [7] emphasizes that the early definitions of the concept were focused on the availability, mobility and utility of mobile devices, while contemporary definitions tend to focus more on exploring the possibilities that result from the technological characteristics of mobile devices. Contemporary definitions [8, 9, 10, 11] tend to focus on various aspects, including not only technical aspects, but also educational, social and contextual aspects. One of the most frequently cited definitions [9] defines m-learning as "learning across multiple contexts through social and content interactions using personal electronic devices" (p. 4). A similar definition was given by Sharples, Taylor and Vavoula [11] who define m-learning as "the processes of coming to know through conversations across multiple contexts amongst people and personal interactive technologies" (p. 5).

In this paper, we focus on the use of m-learning in initial teacher education, and in professional application courses in particular, which are most closely connected with their future educational work and teaching practice. For today's teachers to be able to satisfy the educational needs of their future students, it is necessary to develop new ways of teaching and learning in initial teacher education, which are based on contemporary technologies [12]. Namely, improving initial teacher education provides a basis for the development of educational approaches that will influence and transform educational practices, from early childhood education and preschool education to higher education. Given all of the above, it is necessary to determine the extent to which m-learning is used in initial teacher education and also which segment of initial education (planning and implementation of practical lessons, pre-exam requirements, training in teaching methods, revising for exams, etc.) it is most frequently used in.

1.1. The use of m-learning in initial teacher education

The potential and use of m-learning have been studied in various contexts, with regard to educators such as: teacher training [13], teachers' professional development [12], early career of teachers [14]. Over the past few decades, the research focus has increasingly shifted onto exploring the possibilities of using m-learning in teacher education, i.e. in the education of students majoring in education [15, 16]. This tendency is reinforced by a growing number of projects aimed at using m-learning in teacher education. Various m-learning projects have been developed and implemented around the world: *MiTE: Mobile Technology in Teacher Education* (Ireland); *MTTEP: Mobilizing and Transforming Teacher Education Pedagogies* (the Netherlands, Norway, Germany and Australia); and *DEIMP: Designing and Evaluating Innovative Mobile Pedagogies* [17].

In addition to international frameworks [18], strategic frameworks [19] and education policy documents in Serbia [20, 21, 22] emphasize the importance of developing (preschool) teachers' digital competences during all stages of their education and professional work (initial education, work-study programs, professional development). Within the newest digital competence framework [22], the knowledge and skills of teachers for a new age are categorized into 6 areas: digital environment, digital resources, teaching and learning, developmental evaluation, assisting learners in the learning process, professional engagement and development. The framework was developed with the aim of providing support for teachers in "the process of digital concepts, tools and content integration in everyday educational practice" (p. 7). Hence the need to innovate study programmes at faculties of education, in line with scientific and technological advancements and challenges of contemporary society. The use of m-learning in teacher education has been reported in various research studies [15, 23, 24] and systematic reviews [7, 25, 26, 27].

In her systematic review of research on m-learning in teacher education, Baran [7] reports 6 main findings: (a) the integration of m-learning is on the increase; (b) the integration of m-learning is rarely associated with theoretical and conceptual perspectives; (c) there are variations in perceptions and attitudes of future teachers about m-learning; (d) benefits of using m-learning are especially emphasized; (e) challenges of m-learning are under-researched; and (f) specific educational means support the integration of m-learning.

In one other systematic review, Ngao et al. [25] identified 6 key topics related to the approaches used in the area of digital transformation of study programmes at faculties of education. The topics were categorized into three levels: a) *micro* – pre-service teachers conceptions about mobile technologies; b) *meso* – organizational levels; and c) *macro* – corporate issues on mobile technologies related to policies and financial support.

The study conducted by Burden & Hopkins [23] found that the first-order barriers in using iPAd in initial teacher education are: access to technology, time, lack of technical and administrative support, and lack of training courses on the use of iPad. The study also identified the following second-order barriers in using iPad in initial teacher education: *pedagogical beliefs* (e.g. inability to perceive pedagogical purpose or fit with curriculum), *beliefs about technology* (e.g. concerns about rapid pace of change in technology), attitudes towards change (e.g. beliefs about ability to implement change) and *classroom practices* (e.g. distrust of students ability to manage devices in school).

Price et al. [24] found that nursing students have a positive attitude towards social media networks and that they perceive social media networks as a way to promote discussion and share information, as well as to increase awareness of nursing issues within their course.

Jorgić et al. [15] conducted research with the aim of identifying the differences in the frequency of use of mobile phones by students majoring in education with regard to their socio-academic variables. They found that there is potential for improving teaching at faculties of education, as well as the need for training students – future teachers to use mobile phones for the purpose of improving learning of their future students.

Based on the results of the study by Sebbowa and Muyinda [16], future history teachers identified the following key advantages of using mobile phone forums: enhanced interaction with other students and teachers, collaborative learning and reflection on the past.

2. RESEARCH METHODOLOGY

2.1. Research aims and tasks

Starting from the importance of m-learning in higher education, and in professional application courses in particular, we conducted research with the aim of investigating the attitudes of students from faculties of education towards the use of m-learning in teaching methods courses. Accordingly, two research tasks were defined:

(1) investigate the students' attitudes towards the frequency and the possibilities of use of m-learning in teaching methods courses; and

(2) investigate the influence of sociodemographic and educational variables (sex, year of study, study programme, university, frequency of use of mobile applications) on the students' attitudes towards the use of m-learning in teaching methods courses.

Two research hypotheses were formulated and tested in this paper:

Hypothesis 1: The students highly value the frequency and the possibilities of use of m-learning in teaching methods courses.

Hypothesis 2: There are significant differences in the students' attitudes towards the frequency and the possibilities of use of m-learning in teaching methods courses with regard to sociodemographic and educational variables.

2.2. Research sample

The sample comprised 161 final-year students of undergraduate and master's studies from the faculties of education in Serbia, of whom 91.30% were females and 8.7% were males. The sample consisted of the students enrolled on two study programmes: Primary School Teacher programme (34.17%) and Preschool Teacher programme (65.83%). The students from the University of Kragujevac made up the largest percentage of the sample (37.88%), followed by the students from the University of Vranje (30.45%), the Univeristy of Novi Sad (17.39%) and the University of Belgrade (14.28%). With regard to the year of study, 45.34% of the students were fourth-year students, followed by third-year students (33.54%), and MA students (21.12%). Regarding the frequency of use of mobile applications, the students who use mobile applications very often made up the largest percentage of the surveyed students (64.60%), followed by those who use mobile applications sometimes (18.01%), those who use them very rarely (13.04%) and those who never use mobile applications (4.35%).

2.3. Research methods, techniques and instruments

A descriptive, non-experimental method, survey and scale techniques, and a questionnaire with the assessment scale were used in the research. For the purposes of the research, a special research instrument – a combination of a questionnaire and an assessment scale – was designed. The first part of the research instrument was used to collect data about the students' sociodemographic and educational characteristics (gender, year of study, study programme, university, frequency of use of mobile applications) and the frequency of use of m-learning in professional application courses. The second part of the research instrument included a five-point scale with 9 items which was used to investigate the students' attitudes towards the possibilities of using m-learning in teaching methods courses. A higher score on the scale indicates that the possibilities of using m-learning in teaching methods courses are valued more positively by the students, and vice versa, a lower score indicates that the students have a more negative attitude towards the possibilities of using m-learning. The initial scale had a satisfactory reliability, since the calculated value of Cronbach's Alpha coefficient was 0.87.

2.4. Data collection and analysis

The research was conducted in two ways: in person and online during the summer term of the 2023/2024 academic year. Student participation in the survey was anonymous and voluntary.

The collected data were processed and analyzed using descriptive statistics (frequency, percentage, standard deviation, and skewness and kurtosis measures) and inferential statistics (t-test, ANOVA).

3. RESULTS AND DISCUSSION

The first research task was aimed at investigating the frequency and possibilities of use of m-learning in teaching methods courses, from the perspective of the students majoring in education. The descriptive measures (Table 1) indicate that m-learning is used in teaching methods courses of the Primary School Teacher programme with varying frequencies and most frequently in the following courses: Teaching Methods of the Serbian Language (M=4.10; SD=0.73), Teaching Methods of Mathematics (M=3.89; SD=0.81) and Teaching Methods of Nature and Society (M=3.88; SD=0.87). In the Preschool Teacher programme, m-learning is most frequently used in the following teaching methods courses: Methods of Speech Development (M=3.78; SD=0.95), Methods of Environmental Studies (M=3.78; SD=0.92) and Methods of Developing Initial

Mathematical Concepts (M=3.77; SD=0.93). Since the average values for all items exceed the neutral values (2.50–3.49), the hypothesis that the students of both study programmes moderately highly value the frequency of use of m-learning in teaching methods courses at faculties of education can be accepted. Based on the students' attitudes, m-learning is used very often in all teaching methods courses of both the Preschool Teacher and Primary School Teacher programmes. Similar to our findings, Tong et al. [27] concluded that m-learning is used in various courses, and most frequently in foreign language courses.

Table 1. *The frequency of use of m-learning in professional application courses*

Professional application courses	Mean	SD
Teaching Methods of the Serbian Language and Literature	4.10	0.73
Teaching Methods of Mathematics	3.89	0.81
Teaching Methods of Nature and Society	3.88	0.82
Teaching Methods of Music	3.76	0.85
Teaching Methods of Art	3.83	0.85
Teaching Methods of Physical Education	3.55	0.90
Methods of Inclusive Education	3.73	0.82
Methods of Speech Development	3.78	0.95
Methods of Developing Initial Mathematical Concepts	3.77	0.93
Methods of Environmental Studies	3.78	0.92
Methods of Music Education	3.69	0.95
Methods of Art Education	3.69	0.99
Methods of Physical Education	3.61	0.96
Methods of working with children with special educational needs	3.57	0.97

The abovementioned is supported by the results regarding the average values for the whole scale (Table 2), which show that the students moderately highly value (M=33.59; SD=6.29) the possibilities of using m-learning in teaching methods courses.

The average scores for most items on the scale of the possibilities of use of m-learning in teaching methods courses (Table 3) are above the neutral values (2.50–3.49), thus indicating that the students moderately highly and highly value the use of m-learning in various course aspects: *planning and implementing of practical lessons, pre-exam requirements, training in teaching methods, exam revision, lesson/activity planning, etc.*

Table 2. *Descriptive parameters for the scale of the possibilities of use of m-learning in teaching methods courses*

M	SD	Sk.	K.	Theoretical range of the scale
33.59	6.29	-.466	.021	9-45

Note: M – arithmetic mean; SD – standard deviation; Sk. – Skewness; K. – Kurtosis

Table 3. *Descriptive parameters for the items on the scale of the possibilities of use of m-learning in teaching methods courses*

Items	Mean	SD
M-learning is suitable for planning practical parts of the lessons in teaching methods courses.	3.78	0.98
M-learning is suitable for implementing practical parts of the lessons in teaching methods courses.	3.92	0.99
M-learning is suitable for fulfilling pre-exam requirements in teaching methods courses.	4.08	0.91
M-learning facilitates revising for exams in teaching methods courses.	3.62	1.03
M-learning contributes to more interesting and easier content learning in teaching methods courses.	3.82	0.95
M-learning facilitates the implementation of training in teaching methods courses.	3.66	1.04
I use mobile devices in writing a lesson/activity plan mostly in its introductory part through experiential-cognitive motivation.	3.73	1.02
I use mobile devices in writing a lesson/activity plan mostly in its main part.	3.43	1.01
I use mobile devices in writing a lesson/activity plan mostly in its concluding part.	3.55	1.03

The greatest agreement among the students was for the possibilities of use of m-learning as regards the aspects of its usability and importance of using m-learning in professional application courses: *M-learning is suitable for fulfilling pre-exam requirements in teaching methods courses.* (M=4.08; SD=0.91); *M-learning is suitable for implementing practical parts of the lessons in teaching methods courses.* (M=3.92; SD=0.99); *M-learning contributes to more interesting and easier content learning in teaching methods courses.* (M=3.82; SD=0.95). Although the students' attitudes as regards the use of mobile devices in planning the introductory, main and concluding parts of lessons/activities are above the neutral values, these aspects are less represented: *I use mobile devices in writing a lesson/activity plan mostly in its main part.* (M=3.43; SD=1.01); *I use mobile devices in writing a lesson/activity plan mostly in its concluding part.* (M=3.55; SD=1.03); *I use mobile devices in writing a lesson/activity plan mostly in its introductory part through experiential-cognitive motivation.* (M=3.73; SD=1.02). Therefore, as suggested by the obtained results, the students believe that m-learning is important for revising exams, fulfilling pre-exam requirements, as well as for practical aspects in teaching methods courses, but they use it less frequently for writing lesson/activity plans.

The second research task referred to the investigation of the influence of sociodemographic variables (sex, year of study, study programme, university, frequency of use of mobile applications) on the students' attitudes towards the frequency and possibilities of use of m-learning in teaching methods courses. The results (Table 4) suggest a significant influence of the year of study (F =3.467; p<0.01) and the frequency of use of mobile applications for learning (F = 3.514; p<0.01) on the students' attitudes towards the possibilities of use of m-learning. Namely, we found that the students in the final years of study and those who more frequently use mobile applications for learning more positively value the possibilities of using m-learning in professional application courses. There is also an assumption that experience, thorough knowledge of and training in teaching methods of the fourth-year and MA students have a great influence on their attitudes, compared to those of the students in the third year, when teaching methods courses are introduced for the first time. Previous research studies [25, 26, 27, 28] also emphasized the importance of improving initial teacher education through the use of contemporary information and communication technology in the teaching process.

The results of the subsequent pairwise comparison tests indicate that there are significant differences in the attitudes of the MA students (M=35.14) and the third-year students (M=31.15).

Also, the subsequent pairwise comparison tests show that there are significant differences in the attitude s of the students who use mobile applications for learning very often (M=35.23) and those who use them very rarely (M=30.37).

Table 4. *Students' attitudes towards the possibilities of use of m-learning in professional application courses and sociodemographic variables*

Variables	Modalities	Mean	F
Year of study	Third year UAS	31.15	F=3.467 p=0.09 1-3;
	Fourth year UAS	33.45	
	Master's studies	35.14	
Frequency of use of mobile applications in teaching	Very often	35.23	F=3.514 p=0.01 1-3;
	Sometimes	33.44	
	Very rarely	30.37	
	Never	33.59	

4. CONCLUSION

Previous research and systematic reviews point to not only the importance of using mobile devices and technologies in teacher education, but also to the many challenges in the implementation of m-learning and development of students' competences in using m-learning in their work with preschool children and children in younger grades of primary school.

Starting from the research aims and hypotheses, the following two conclusions can be drawn:

(a) The students have moderately high attitudes as regards the frequency and possibilities of using m-learning in teaching methods courses. Namely, the students of both study programmes (Preschool Teacher and Primary School Teacher) emphasize the fact that m-learning is very frequently used in all teaching methods courses at faculties of education and in their various aspects such as: planning and implementing of practical lessons, fulfilling pre-exam requirements, training in teaching methods courses, revising for exams, lesson/activity planning, etc.

(b) The students' attitudes towards the possibilities of using m-learning in teaching methods courses are significantly influenced by the frequency of use of mobile applications for learning and the year of study. It was found that the students of the final years of study and those who more frequently use mobile applications for learning more positively value the possibilities of using m-learning in teaching methods courses.

The research results also suggest some *pedagogical implications* with regard to the use of m-learning in teaching methods courses. Primarily, there is a perceived need to shift the focus from lesson planning onto the implementation of practical lessons and activities in teaching methods courses, by using various mobile devices and technologies. It is also necessary to provide support for educators in initial teacher education as regards developing, using and evaluating innovative mobile technology approaches to teaching and learning. Teaching methods courses at faculties of education may have an important role in the acquisition and development of the competences of prospective preschool and primary school teachers as regards the use of m-learning and mobile technologies in their work with preschool children and children in younger grades of primary school. If the knowledge acquired during studies is improved through later pedagogical experience, it becomes an important factor of the quality of future students' education, which is why it requires special attention [29].

The research conducted in this paper does not provide definitive answers to the initial research question; therefore, there are some *recommendations for future research*. Firstly, a relationship between various m-learning models in teaching methods courses and specific educational outcomes for some academic courses and subject areas within these courses may be investigated. Since (preschool) teachers are, along with other participants in the education process, the key factor in the implementation of innovations and changes in education policy, it is necessary to conduct more extensive research into the contributions of study programmes at faculties of education to the development of (preschool) teachers' competences for using m-learning. A judicious, creative and safe use of mobile devices and technologies in preschool and primary education is not possible without competent (preschool) teachers. This implies not only a quantitative, but also a qualitative analysis of students', i.e. future (preschol) teachers' attitudes towards these questions, as well as the analysis of the study programmes. It is also possible to explore the influence of various social and cultural factors (an individual's relationship to certain activities within the fields of science, engineering, culture, art, media and sport) on the use of mobile technologies in teacher education.

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Expanding the Possibility of Performing Laboratory Exercises Using Solutions Based on the use of SCPI and LoRa Networks

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Abstract: *Laboratory exercises are an important part of the teaching process at many faculties. However, despite the fact that today the implementation of laboratory exercises is carried out on modern equipment, the full potential of that equipment is often not used, that is, often some of the possibilities of modern equipment are not fully used in student practice. In the paper, it will be shown on two cases from practice how the student user experience can be expanded by using exactly those "forgotten" options. In the first case, a solution based on the full use of Standard Commands for Programmable Instruments (SCPI), which are implemented on most modern measuring devices, will be presented. The second case will consider the application of open source hardware and software supported by LoRa connectivity, which enables the expansion of the spectrum of exercises performed by students. It will be shown that both solutions can be implemented without a high level of complexity and large financial efforts for the higher education institution itself.*

Keywords: *Arduino, ESP, higher education, instrumentation, Linux, LoRa, SCPI*

1. INTRODUCTION

The modern teaching process conducted within various curricula and accredited study programs at different levels of study within higher education today implies different forms of teaching realization depending on the subjects themselves and defined learning outcomes. The mentioned forms of teaching implementation can carry different names depending on defined nomenclatures and different classifications used, or depending on higher education institutions where class itself will be realized. However, regardless of the mentioned specificity in defining teaching types, it is generally possible to see two general types of classes. The first type represents theoretical lectures and another type involves practical classes. Practical teaching can also be divided into two categories. The first category will include the exercises that are performed in the classroom and on which the solving of certain tasks from a certain area is practiced by calculation. The second category of practical teaching involves the realization of certain tasks within the framework of the foreseen exercises using some instrumentation and the performance of this type of practical teaching is practiced in specially formed laboratory spaces within the higher education institution provided for that purpose.

When talking about laboratory exercises, the way they were performed, until recently, generally meant that they were performed exclusively in special laboratory spaces and in strictly defined terms. This practically means that the students must appear at the defined time in the laboratory and that for a certain time they must carry out the planned laboratory exercise due to the limitation of laboratory spaces in terms of size, amount of equipment, and therefore the time available. It should be mentioned here that in the modern definition of the teaching process, in addition to the teaching implementation model within the premises of the higher education institution, there is also an online teaching implementation model, as well as a hybrid model that includes the combination of the previous two models.

The previously mentioned affects the transformation of the performance of laboratory exercises and the need to modernize them in order to respond to the modern challenges of the teaching process. In this sense, in addition to the performance of laboratory exercises in the mentioned traditional sense, which remains one of the dominant methods of performance, new approaches are also being introduced. The backbone of these new approaches is the increasing introduction of modern information and communication technologies into laboratory processes, as well as the introduction of new methods of realization of laboratory exercises based on ICT. It should also be mentioned that there is a desire to enable the implementation of laboratory exercises based on the principles of remote access to laboratory resources, that is, the possibility for students to realize their tasks using remote principles. In addition, there is a desire of students to obtain practically usable knowledge. Students want to work with equipment that they can encounter in real working conditions, in the field, in companies, institutions, to meet real problems that they can encounter in their future work and after schooling.

On the other hand, the aforementioned often represents additional financial efforts for higher education institutions, especially for those with more modest budgets. There is also the issue of allocating additional space for the implementation of laboratory exercises, hiring additional staff, additional quantities of various equipment, and the like. All this is especially expressed when it comes to larger groups of students in which each student should be given equal treatment and be provided with an equally high-quality approach to achieving learning outcomes.

The paper will show that there are still certain methods that can be applied to the existing classical equipment and that are feasible even with more modest budgets intended for the realization of modern laboratory exercises, and that can provide students with an insight into modern concepts and provide competitive knowledge for further performance. Two real use cases prepared for the improvement of the performance of laboratory exercises in the field of the use of measuring techniques, which can find useful value in a large number of engineering subjects taught at technical faculties, will be considered.

2. THE PROBLEM OF DATA TRANSFER FROM THE MEASURING DEVICE TO THE COMPUTER AND POSSIBLE SOLUTIONS

In relation to the considerations presented in the previous chapter, it is observed that the main task, which should be carried out in order to obtain a complete modern solution for the performance of laboratory exercises, is the integration of appropriate measuring instrumentation into the appropriate computer system in order to obtain a unified information system intended for the realization of laboratory exercises. Several cases can be encountered here.

It may happen that the corresponding measuring instrument does not have the possibility of direct connection with the computer. In that case, it is necessary to create a specialized solution for the acquisition of measurement data that will enable the connection of the instrument and the computer. Such a solution introduces additional complexity into the implementation of the targeted solution, and it can also represent significant expenses for the institution, since the entire measurement-acquisition system must be adequately designed. Also, the appropriate components of the system must be acquired and such a system must be incorporated into the desired solution. Therefore, this solution is not recommended in the implementation of the aforementioned laboratory solutions.

The higher education institution should opt for the acquisition and use of appropriate measuring equipment that has adequate communication capabilities that can be used for further integration. However, before presenting suitable options for the implementation of such a solution, it is necessary to point out the corresponding problems that should be avoided and in this case they may represent undesirable phenomena and solutions both for the institution itself and for setting up a functional laboratory solution.

Today, there is a whole series of measuring devices on the market that have exceptional modern communication capabilities. In recent years, there has been a trend of wirelessly connecting such devices to LAN networks, that is, using classic computer networks for further integration of such devices into larger systems. However, it should be noted here that it is often the case that the implementation of this type of connection of devices often significantly increases the price of the device itself. That often place devices in the category of highly professional devices that are not primarily intended for use in educational processes. The previously mentioned are complicating factors for the procurement of such devices by the majority of higher education institutions due to limited funds within the budget intended for the implementation of such projects. One should bear in mind the fact that it will rarely be the case of the procurement of only one device, but it will be necessary to in accordance with the scope of the teaching process, procure a larger quantity of the same or different measuring instruments.

On the other hand, there are measuring devices that are accessible for purchase by higher education institutions and that have appropriate communication capabilities. However, with such devices, the problem of further integration into laboratory systems may arise, since simplicity of implementation and ease of use by students is desired, while also enabling the overcoming of certain identified problems previously presented in this and the previous chapter. We will explain the above on the example of the Mastech MS8226 DMM (Digital Multi Meter) measuring device shown in Figure 1.

Figure 1. *Mastech MS8226 DMM*

MS8266 is a multifunctional measuring device intended for measuring different quantities in different measurement ranges, where the given range can be selected automatically or manually. What is characteristic of the mentioned device is the ability to act as a suitable data logger [1]. The connection with the computer is originally realized via an RS232 connection. It can also be made by using appropriate RS232 to USB converters, in which case the classic USB port on the computer is used.

Data logging from the measuring device works perfectly when using the connection and the dedicated software that is delivered with the device itself. Through the dedicated software, reading and recording data is performed in a limited format during the measurement. The problem arises when you want to implement functionality outside of the supplied software, that is, when the institution wants to develop its own solution that will be used by the given device. This practically means that the existing software will not be used. It is desired to connect the device to some other software that represents a laboratory exercise, remote access to that software, recording and display in the desired format, and the like. Mentioned are not possible to achieve with the supplied original software.

When you need to write your own program code that will enable work with the instrument, a problem arises. There is no official documentation that explains the way in which the connection with the instrument will be achieved at the level of the program code. In other words, in most cases there is no official documentation from the manufacturer of the measuring instrument that explains the communication protocol. In the specific case of the MS8226 there is no official documentation on the implementation of the serial protocol, so unofficial documentation from different channels such as the one described in [2] and [3] must be used for achieving integration goals. Figure 2 shows an unofficial representation of the Mastech MS8226 serial protocol.

```
Mastech MS8226 serial protocol

2400 8n1
14 Bytes , watch out for serial IR receiver sending junk 15byte strings
First four bits of each byte are position in message , from 1-14
Last four bits are data , each bit represents one element on LCD

  4    3    2    1    __a_
 __   __   __   __   |    |
|  | |  | |  | |  |  f    b
|__| |__| |__| |__|  |_g__|
|  | |  | |  | |  |  |    |
|__|.|__|.|__|.|__|  e    c
    P3   P2   P1     |__d_|

Digits
0         10        20        30        40        50  |
01234 5678901 2 3456789 0 1234567 8 9012345 6789012345678901234 5
00110 1111101 0 0011111 0 0100111 1 1111111 0000000000000000100 034.8
00110 1111101 0 1011011 0 0111110 1 0011111 0000000000000000100 025.3
00110 1111101 0 1011011 0 0100111 1 0011111 0000000000000000100 024.3
00110 1111101 0 1011011 0 0000101 1 0111111 0000000000000000100 021.9
00110 1111101 0 1011011 0 0000101 1 0010101 0000000000000000100 021.7
00110 1111101 0 1011011 0 0000101 1 1111110 0000000000000000100 021.6
||||| 4444444 P 3333333 P 2222222 P 1111111 |||||||||||||||||||
      efadcgb 3 efadcgb 2 efadcgb 1 efadcgb    d i s p l a y

Display
0         10        20        30        40        50  |
01234567890123456789012345678901234567890123456789012345
00110111111010000010111111101000001010100000001000000001000 nF
00110101101110000101000001010101101110000000100000000001000 uF
01110111111011111110101111101011111010000000000000010001000 A
01110111111010111111011111110101111101000010000000010001000 mA
01110111111010111111010111111011111110110000000000010001000 uA
00110111111010101101100111111011011011000000000000000000100 C
00010000001010000010100111111111111111000000000000000101000 Hz
00010111111010111111010111111010011111000001000000000001000 %
00010000000001111110101101000100000000000000001000000001000 Ohm
00010000000001111110101101000000000000000100000001000000001000 KOhm
00010000000001111110101101000000000000000001001000000001000 MOhm
00010000000001111110101101000000000000000100000000001001000 Diode
00010000000001111110101101000100000000000000101000000001000 Beep
01011111111010000010100000101101111110000010000000001001000 mV
01111111111011111110101111101011111010000000000000001001000 V
01110111111011111110101111101011111010000000000000101001000 Hold
01011111111011111110101111101011111010000000000001001001000 Rel
ADAR-||||||||||||||||||||||||||||||||||unKDeNPBFORHAVHXXCXX
CCUS            d i g i t s           i  e hEo  z
  T2                                  o  e mL1
  O3                                  d  p  d
   2                                  e

51 is probably low battery
```

Figure 2. *Unofficial explanation of Mastech MS8226 serial protocol [3]*

As you can see from the above picture, there is an extraordinary complexity in understanding the serial protocol defined in this way. During a given serial transmission, the buffer that contains the read data at a given moment does not contain simple, easy-to-understand textual data. Data is coded in binary, and it is necessary to understand the coding method to adequately interpret it. At the same time, that method of coding depends on many factors and differs from device to device depending on which quantities can be measured by the device, which ranges are in question, how the given quantities are presented on the given device, display construction and the like.

In the case of the mentioned MS8226, the buffer consists of 14 or 15 bytes that are binary coded , so extraordinary efforts are needed to interpret what was sent from the device at the moment. This method is certainly not conducive to the realization of a laboratory system that will be intended for student training. That system requires simplicity of access and implementation, comprehensibility and the possibility of implementation in a way that is suitable for use by the students themselves, but also for the exercise implementer. Also, since it is a more complex software development, there is a great possibility that in the final implementation, the price of the solution itself will increase, which is not at all in favor of higher education institutions and their budgets.

Therefore, the question arises whether it is possible somehow to realize the laboratory system intended for use by students in some other simpler way. Fast, accurate and simple implementation with the maximum reduction of costs must be enabled, while at the same time the basic idea of such a system realized reflected in the availability and adequate use by students. A possible solution is offered in two directions, which will be presented in the following chapters.

3. USING OF SCPI (STANDARD COMMANDS FOR PROGRAMMABLE INSTRUMENTS)

The Standard Commands for Programmable Instruments (SCPI) [4] was created as a result of the desire to find a uniform way to connect measuring instruments and computers and relies on the IEEE 488.2 standard which already standardized codes, formats, protocols and common commands for those purposes [5]. An important feature that makes a significant difference in the usual practice described in the previous chapters and that enables overcoming the problems encountered with instrumentation is that the entire communication will be correlated with ASCII text. This practically means that all commands given using the SCPI measuring device will be in the form of a classic text string, and also any feedback, whether it is about actual measured data, error messages or status messages, will usually also be given as ASCII text [6]. Therefore, the use of SCPI enables simple, easy, comprehensible and unambiguous two-way communication with the measuring device. These makes it an ideal candidate for use in the implementation of various laboratory exercises in the field of higher education. Thanks to its unique characteristics, SCPI syntax can be easily integrated into numerous programming languages and development environments [7]. It offers a very simple way to integrate into already existing solutions, or the development of a completely new solution that can be started without the need for some more demanding resources.

As an illustration, the development of a laboratory exercise intended for students of technical faculties will be presented, in which the change in impedance depending on the change in the frequency of the electrical signal is observed. A RouShui 4091C LCR meter (shown in Figure 3), which enables the measurement of impedance values for given frequencies in the range from 10 Hz to 100 kHz [8], was used for the realization. The measuring instrument had only an RS232 port [9], so an RS232 to USB adapter was used for connection. The use of such an adapter in no way affects the implementation of the measurement process and the results of the measurement itself.

Figure 3. *RouShui 4091C 100KHz LCR Meter*

For the given frequency values, the value of the given impedance is measured based on the corresponding model connected to the LCR meter. Figure 4 shows an example of such a developed model for the purposes of implementing a laboratory exercise. It should be noted here that several different impedance models have been developed that are connected to the corresponding LCR meters. This was done in order to ensure the diversity of the obtained measured results among the students. If only one model is used, there would be a possibility to exchange results between students based on only one measurement performed. This would reduce the value of the learning outcomes because all interpretations would be based on identical results obtained. Based on the applied method, the student never knows which model is currently connected to the LCR meter, and therefore can only rely on the obtained results of the actual measurement procedure.

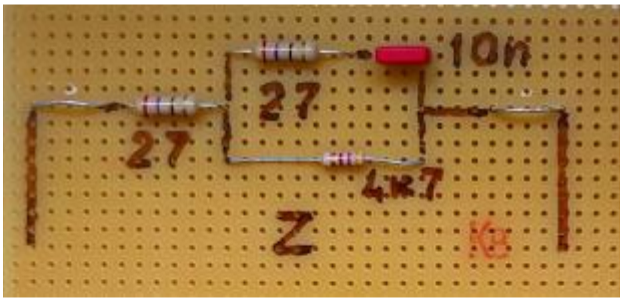

Figure 4. *Example of created model for impedance measurement*

The scheme of the laboratory experiment used by the students is shown in Figure 5.

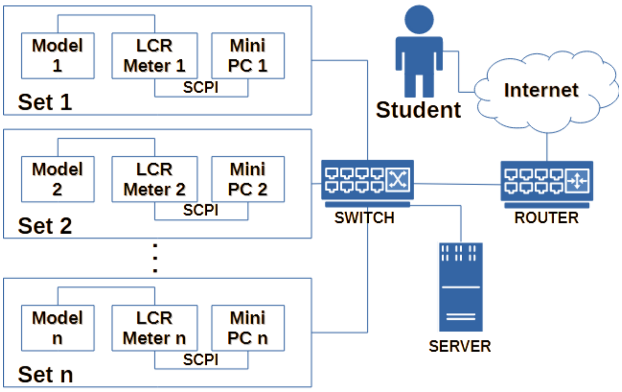

Figure 5. *Scheme of instrumentation for remote conducting of the experiments based on the LCR meter use*

The student remotely accesses the server of the higher education institution that serves the corresponding laboratory sets. The server enables the student to access the appropriate laboratory set that is currently available, that is the one on which the experiment is not in progress. After that, that laboratory set is declared occupied and a console is opened for the student which are located on corresponding mini PC which connected to the proper LCR meter of the laboratory set, on the basis of which the student sets the initial work parameters and starts the laboratory exercise. The measurement cycle lasts about 10 minutes, during which measurements are made for about 40 different frequencies. About 100 individual impedance measurements are performed for each of the frequencies, and then based on those measured values, the mean value of the measurement is calculated. All recorded mean measurement values for the corresponding frequency are stored in the corresponding database. At the end, a suitable Excel file is generated for the student about the completed laboratory exercise with all calculated mean values and corresponding frequencies. This file is later used by the student in order to realize his report on the completed laboratory exercise.

All communication with the LCR meter takes place using a mini PC that is connected using the same SCPI commands used with LCR meters [10]. For example, to set the appropriate measurement frequency, the corresponding SCPI command that is passed to the instrument will be:

FREQ *Frequency_value_in_Hertz*

Data representing the measured values from the measuring instrument are also obtained by sending the appropriate SCPI command to the instrument in the form:

FETCh?

on the basis of which the instrument sends a corresponding text record via serial connection that contains the measured values and which can be further processed as needed by reading them from the corresponding buffer of the serial port. The realization of the entire experiment is therefore based on the communication of the appropriate mini PC with the LCR meter using SCPI commands. These commands are incorporated into the appropriate program code developed in the Python programming language using the standard Python serial module that enables serial communication through the appropriate COM port.

What should be noted is that the entire system was originally developed for Windows operating systems, and then it was successfully developed with slight modifications for the Linux operating system. It should be emphasized that the only modifications concern the fact that the communication with the serial ports and the marking of the serial ports on Windows and Linux operating systems are different. The overall code, including the part related to the implementation of SCPI commands, remained unchanged.

4. CREATION OF OWN MEASUREMENT INSTRUMENTATION BASED ON OPEN SOURCE SOLUTIONS

Modern studying implies that students should be trained to work in real conditions in order to adequately respond to the challenges of the modern environment and expectations set by today's labor market. This means that in terms of setting up the laboratory exercises that the student needs to master, it is sometimes necessary to leave the traditional laboratory framework. This is quite a challenging task that poses many challenges to the higher education institutions. Some of them are the variety of equipment that the higher education institution must own, the spatial and temporal limitations of the laboratories, issue of fitting into the budget projections of the higher education institutions themselves.

Today, this task is easier to do than in an earlier period, thanks to the appearance of a large number of highly available open source software and hardware solutions. What makes these solutions accessible for the implementation of the mentioned tasks in the higher education environment is their affordability, very good documentation, the existence of various support through large online communities, availability on wider markets, including less developed ones, and having the possibility of easy integration into the most diverse solutions. All of this means that today these open source solutions are increasingly being used to accomplish a variety of tasks, not only in home conditions, hobby projects and the like, but that they are slowly being included in industrial applications [11, 12]. It is considered that they should be known and practiced through the system of higher education, since students will encounter, if not identical solutions, then at least similar ones.

One such exercise implemented on the basis of open source hardware and software will be presented below. The exercise simulates the operation of modern measuring stations used in industry to monitor environmental impacts. The developed environment consists of four battery-powered measuring stations, two of which measure temperature and humidity, and two of which measure the concentration of CO_2 gas. All measuring stations are connected via the LoRa network to the corresponding receiving station, through which the data is further transmitted to the LAN network and further, via the Internet, to the corresponding server where the received data is stored.

The entire instrumentation is based on the use of the Arduino compatible board shown in Figure 6.

Figure 6. *Arduino clone with integrated ATMEGA 2560 and ESP8266EX chip on one board*

This board is based on the use of the ATMEGA 2560 chip [13], which allows us to collect data from the appropriate connected sensors. The board has been expanded with appropriate WiFi functionality thanks to the integration of the ESP8266EX chip [14], so it can be connected wirelessly to a suitable LAN network.

To achieve the appropriate functionalities related to the LoRa network, the appropriate Arduino shield manufactured by Dragino company specialized for IoT solutions, shown in Figure 7 was used.

Figure 7. *LoRa shield for Arduino compatible boards*

The RF96 chip [15], which represents the Low Power Long Range Transceiver, was responsible for achieving the LoRa connection in this case. Since the solution was implemented on the territory of the Republic of Serbia, the entire communication is based on the use of the 868 MHz band in accordance with the existing and valid legal regulations.

Figure 8 shows the sensors that were used to obtain values from the environment in which they were located.

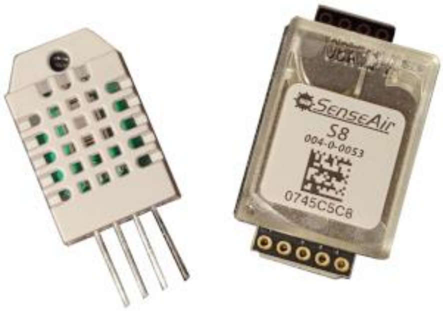

Figure 8. *Used temperature/humidity sensor (left) and CO_2 sensor (right)*

The measurement of temperature and humidity was realized using a standard DHT22 sensor [16] intended for the realization of different temperature projects using Arduino compatible boards. This sensor can also be found on the market labeled as AM2302. The CO_2 gas concentration was measured using the SenseAir S8 LP sensor [17] (SenseAir S8 sensor with identification number 004-0-0053).

Illustrative representation of one measuring station is given in Figure 9. In real operation the corresponding measuring stations are packed in the proper waterproof case. The receiving station is similar in design to the measuring station. There is no physical connection to any sensor at the receiving station. It is consisted only of an Arduino compatible board, a LoRa shield and an appropriate antenna.

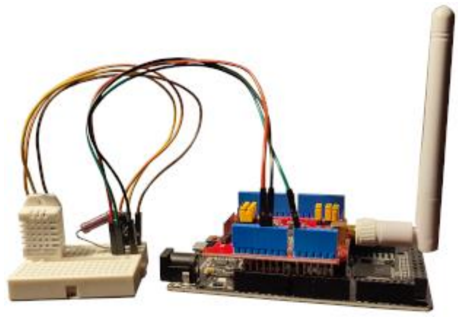

Figure 9. *Example of station for measuring temperature and/or humidity and transfer recorded data via LoRa based network*

At the measuring stations, appropriate LoRa 868 MHz antennas of length 90 and 275 mm were used, while at the receiving station, a corresponding LoRa 868 MHz antenna of 550 mm length was used. All measuring stations were arranged within the faculty campus at a maximum distance of 130 m from the receiving station with a suitable line of sight without significant obstacles that could interfere with the signal. All stations are powered via USB using batteries with a capacity of 10000 mAh (3.7 V/37 Wh) with an output of 5V/2A.

Measuring stations record data from appropriate locations and transfer them via the LoRa network to the receiving station. Thanks to the basic characteristics of LoRa transmission, the transmission is achieved at low speeds that are quite sufficient for data transmission, but that is why the energy consumption is very low and battery power supplies can be used, which enable smooth work of students. At the receiving station from the LoRa network, data is received and converted, and then, thanks to the Wi-Fi connection to the institution's LAN network, that data is stored on a specific server. Students access data from the server via the Internet using special dedicated software written in the Python programming language that enables adequate data export through appropriate Excel files. The students then analyze those files and, based on the analyzed data, prepare an appropriate report that will be proof of the completion of the laboratory exercise. The schematic representation of the key elements is shown in Figure 10.

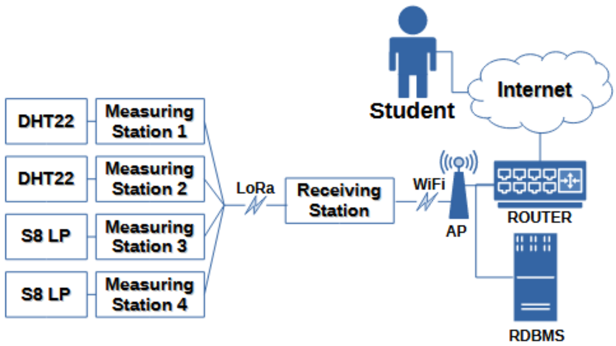

Figure 10. *Scheme of connectivity between key elements of the measurement instrumentation*

This setting enables students to get acquainted with much larger and more complex systems that can be encountered in real work, for example, like the National network of automatic stations for air quality monitoring of the Republic of Serbia [18]. Students can now become familiar with the functioning at different levels of implementation and use, from the data collection sensor to the processing of the collected data. In this way, students get to know the principles that are encountered today during real work in the field in industrial conditions. The segment of data acquisition in the field through specialized measuring stations is covered, as well as the aspect of data transmission from remote locations in the field to the point of receiving that data (collector). Then the students encounter different data transmission technologies (LoRa, WiFi) to the place of data storage. After that, the students get acquainted with the consolidation of data for a certain period of data recording, their analysis and interpretation, and finally, through their reports, the students specialize in giving appropriate explanations based on the collected data (statistical analysis, prediction, etc.). As one of the importance of using this kind of hardware and software environment in the work and education of students, it should be noted that by using this setup, students avoid working with artificially generated data, which is a common practice. Students complete their tasks in this way by using data obtained in real working conditions, that is, they perform all analyzes on real data sets. This further increases the knowledge and ability of the students because mistakes that can occur when using artificial data sets are avoided.

Such realization of the complex conditions in which the given exercise is carried out would previously require various efforts for a higher education institution. The introduction of open source technologies, as can be seen from the previous lines, can bring the realization of such an exercise to a level that is accessible to a large number of academic institutions, regardless of budget size intended to support the implementation of various teaching processes.

5. CONCLUSION

The modern teaching process involves approaching the real needs of the labor market. This practically means that there must be an aspiration that during the implementation of the activities provided by the curriculum, students will encounter real problems and tasks that they will apply as engineers of tomorrow within their work assignments. Sometimes it becomes a very complex task in which you have to overcome a whole series of challenges. One of the frequent challenges that higher education institutions face is the lack of laboratory space, the lack of a sufficient number of equipment for performing laboratory exercises, modest budgets intended for the purchase of equipment for performing laboratory exercises, and the like.

The aim is to enable, in addition to the traditional ways of conducting the teaching process, the implementation of the teaching process in accordance with the modern requirements of the time in which we live. One of those ways is the online teaching process, and it tends to fit laboratory exercises into that process. In the past, these procedures required a very large commitment of various resources, however, there are certain approaches that can make these procedures extremely accessible to higher education institutions.

Two such potential approaches have been discussed in previous chapters. One approach is based on the use of SCPI, which has been present for a long time on the market of measuring equipment, but which, in addition, has not been used to a sufficient extent in the domain of higher education. Although not the latest technology, SCPI certainly has a lot to offer the academic domain. This kind of approach can expand the functionality of measuring equipment in ways that are extremely beneficial to higher education institutions. In a very simple and flexible way, a completely new modern outfit can be added to the existing laboratory educational systems that can help in improving the existing learning outcomes.

Another approach based on the use of open source solutions has long been unfairly labeled as an approach exclusively for home use and hobbyists. However, here lies an underutilized and untapped potential for academic institutions that, with minimal investment, can give students an insight into the most modern processes encountered in today's industry and in other domains of human activity.

The mentioned solutions should definitely be seriously considered in the future, because they can be crucial when it comes to creating an educational model that is modern, competitive and oriented towards students as engineers of the future.

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Conveying Expression in E-Learning Transactions with Asymmetric Audiovisual Learning Tools

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Abstract: *Recently, an increase in asymmetric learning transactions has been recorded. Asymmetric learning is traced in situations when students have different needs or abilities in assimilation as they do not have the same rate for understanding and absorbing knowledge as other students; constant repetition and persistence is usually needed in order to absorb basic cognitive elements. The overall state of affairs is usually a challenge for instructors as well as the schooling environment (alongside the family surroundings of the learners) since all the aforementioned parties have to conform their teaching strategies to often irregular or exquisite needs of their learners. A certain such case in a Computer Music topic is presented in this research that elocates individualized methods, differentiated instruction and the use of technology to support instruction.*

Keywords: *Asymmetric Learning Transactions; Audiovisual Technology; Music Technology & Education*

1. INTRODUCTION

Human Communication relies heavily on how we perceive and manage overall the acoustic signal. In the multimedia world we live in, in sensory terms, 89% of input is ascribed to vision, 10% to hearing, and 1% for all the other senses. Nevertheless, in practical everyday communication, hearing is much more important than a mere 10% [1]; as it is mingled with some other tasks, its contribution to Interactive Learning is rated significantly higher than the 10% that is credited to sonic stimuli perception.

To give some practical examples, a listener receives a multitude of aural signals that trigger the sensory mechanisms for hearing when talking to his phone, when listening to music in his car or when harking at the discussions of his professional environment.

Nevertheless, the cornerstone, since the first years of intelligent communities in the earth's life, the foremost concern of human beings remains the expansion of their knowledge. From the first teachers, ever recorded in artistic depictions [2], with few pupils in simple school constructions, to contemporary schools and universities. The primary concern in this diachrony and synchrony of education systems continues to be, though, the ample, structured, and unlimited access to knowledge [3].

A new reality has come into play, with major researchers and companies, looking every possible and, occasionally, diverse way to help schools and university communities to expand their role in space and time. For starters, a topic for group discussion has to do with the continuity of learning [4].

Although this research will not dip into this topic, it has issues under scrutiny that are heavily dependent on what pervasiveness and uninterrupted connection (not to say union) in time result as effectual understanding, as enduring performance, and, sometimes, as an exaggerated behavior, throughout an area or group of people under instructional influence [5]. All these activities may trigger processes involving a great deal of unnecessary time and effort for accomplishing successful artistic operations, for example, which is exactly the scope of this article.

Even further, the excessive elaborateness in the use of Distance Learning resources during the Covid-19 lockdowns has ameliorated the quality for exceeding the appropriate limits in the continuity of learning [6].

In other words, much of the instruction offered is online, since then, and it seems that it will stay put although the previous state of things in teaching has been officially restored.

Many interactions, lavish teaching styles and special IT applications from that period have been continually used as a Computer Based Training workbench, for developing learning skills and managerial qualities as well.

Therefore, Distance Education acquires gradually variant forms, some of which are expected to be established as new presets of learning styles for the next few years in all universities and schools worldwide.

As improved AI tools come to aid the instructional activities at both ends, the schooling environments and the living accommodations, lessons, assignments, and lectures are reshaped when interactive multimedia recourse personalize reciprocal activity over wide-area cooperation platforms [7].

A very interesting piece of theoretical advances, related to computer music activities is about Multiple Intelligences based practical implications.

The profiles of intelligences and their basic description defined by the Multiple Intelligence theory are [8, 9]:

- Verbal/linguistic – represents the primary means of communication amongst humans. It is reflected in symbolic thinking, language, reading, and writing;
- Logical/mathematical – is used for data processing, pattern recognition, working with numbers and geometric shapes;
- Visual/spatial – navigation, map-making, visual arts, architecture, and perspective;
- Bodily/kinaesthetic – reflects the precise self-body motion control, non-verbal emotion expression, dance, and fine hand-eye coordination;
- Musical/rhythmic – recognition and use of rhythmic and tonal patterns, recognition of sound, speech, and music instruments. It is used to interpret and create music;
- Natural – recognizing patterns in nature, classification of objects and types of wildlife;
- Interpersonal – the possibility of cooperation in small groups, communication with other people, the individual's ability to recognize other people's intentions, mood, motivation, non-verbal signs;
- Intrapersonal – recognizing own abilities, capacities, feelings, emotional reactions, self-reflection

This research will present well-substantiated explanations for a set of phenomena that are linked to rather special structural learning environments. I.e., situations characterized by asymmetry in their cognitive or instructional arrangements.

2. PROBLEM FORMULATION

Human Communication has some inherent links with Phonology.

Conjugate fields are also Physiology, Anatomy, Linguistics, Physics, Computer Science, Psychology and some more similar to these; they stipulate useful tools and methodologies so to put in writing phonological activity using formal methods of Mathematics and Engineering.

While artists rely more on synaesthetic terms for communicating their sonic perception, scientists are inclined to use more accurate depictions based on facts about, for instance, tuned voicing, spectral emanations, acoustic augmentation and similar features that characterize the richness of the oral and aural communication channel.

When singing is involved, proper tuning and generally speaking spectrum analysis relies on explaining the relevant terms from the psychoacoustic literature point of view. For instance, the perception of aspiration, accentuation, vowelization, syllabisation, subvocalization, sibilation, mispronounciation, or devoicing, to name a few, is somehow closely related to (but also quite distinct from) the physical notion of the spectrum of a certain sound.

Likewise, the perception of "tuneless" performance is in some manner related to quantitative measurements on sensory consonance. The main focus for consonance and dissonance are not the intervals of scales per se, but linked with vocalizations of melodic notes according to the proper height within a scale; furthermore, the pitch and duration of a musical sound may be linked to spectrum, timbre, or tonal quality of phonation [10].

As in disordered voicing the proper conditions for speaking or singing are deranged in terms of vocal affections and music expression, estimates of dissonance and consonance are bound to be used for quantifying how pop art, for instance, changes within a certain region in an interval of say 100 years or how the "same" song may be rendered in neighboring countries sharing to some degree common traditions.

Neurophysiological studies point out the functional fragmentation that is pointed out when prosodic utterances are related to musical patterns [11]. In Greek for instance, it is expected for foreigners, from the speaker's side of view, to fall more easily to anarthria, cataphasia, dysarthria, dyslogia, dysphonia, lamdacism, stammer or stutter.

In multilingual environments, in everyday performances, as is the case in the Balkans for instance, the coexistence of these forms of expression illustrates such phenomena to the general public more frequently than usual.

When it comes to audiovisual sensing, such events or circumstances may be observed in diachrony and synchrony. Since footage with sound are roughly one century old, the development of such analyses will be conceptualized in their practical formulation according to the manner of expression for starters.

As far as diachrony is concerned, in Figure 1 are depicted two manifestations of a Greek military band's repertoire that are 100 years apart.

Figure 1. *Greek military bands performing parts of their repertoire with a century's interval. Left picture: a characteristic march, first years of the 20th century. Right picture: carols in a TV broadcast, first years of the 21st century.*

The same manifestations may be found, with notable local color variations for all the Balkan states more or less.

When analyzing such audiovisual events, many intellegencies are involved. Since these topics are immense in size, this short paper will focus on the course of study for musical and in general acoustic impressions.

As far as synchrony is concerned, similarly in Figure 2 are depicted two manifestations of a historical site within the Balkans, related somehow with such events since its foundation in 1351 AD.

Figure 2. *Left, a characteristic impression of the Holy Patriarchal and Stavropegic Monastery of Vlatadon from above, with a snapshot from a drone, and right, its Web portal with navigation in Greek uncials.*

Again, the focus is on identifying essential features related to sonification paradigms linked to Web technologies and learning. One such example is depicted in Figure 3.

Figure 3. *Left picture, N. Antonov's choir performing in a concert in Sofia. Right picture, the same choir performing the well known "Axion estin" of K. Pringos in the Vlatadon monastery.*

The choir of Nikolai Antonov, musicologist and director of the chorus in the Nativity of Christ church in Sofia, Bulgaria, performs in a video lesson the very well-known throughout the world of Byzantine Music "Axion estin" (Достойноесть) in Mode Plagal A΄ (5th Mode), composed by K. Pringos. This rendition is registered as "Patriarchal".

It is a composition of the Archon Protopsaltes of the Ecumenical Throne K. Pringos (1892-1964) which has been printed in a series of periodicals published since 1953 in issues under the title "Patriarchal Forminx" in Turkey. The last publication we have taken into account is that of the "Apostoliki Diakonia" of the Church of Greece in 2009.

What is important with this melody is the following: Pringos is one of the great masters whose own voice has been recorded somewhere in the late 1950s, with all the shortcomings and defects of the audio technology of that era. However, restorations and improvements using modern technology have been extensively used. Even further, due to the wave of enthusiasm this melody has created, recordings of this hymn have been released repeatedly on the Internet and anyone interested can search for it and hear it relatively easily. Performed by a multitude of eminent chanters.

Particularly important is its rendition by K. Pringos himself – it is not that widely distributed, but, with some added difficulty this recording can also be found. If we put side-by-side these two versions, one in Greek and the other in Bulgarian, then we draw the comparison seen in Figure 4.

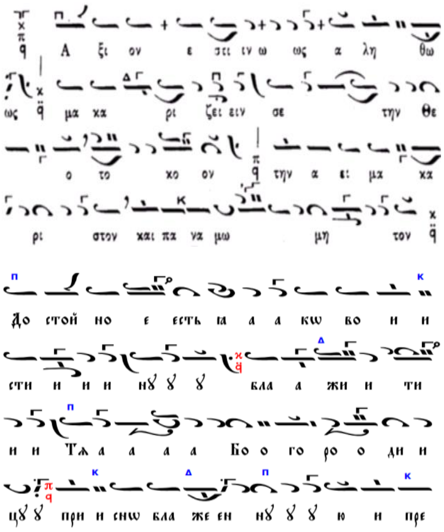

Figure 4. *The "Axion estin" of K. Pringos as composed in Greek by Pringos himself and as adopted in Bulgarian Slavonic by N. Antonov.*

Although it is conceptually the same melody, without doubt, in terms of Information Theory the two renditions are not identical.

Perhaps, in terms of phonology, they are variant forms, yet somehow affiliated since they have been sharing the same "melodic contours".

What is more important, is not whether the primogenitor form is more or less relative to an offspring, in its various musical complexities, but the way of acceptance within a certain society at a definite time.

Linguistic, musical and overall cultural identities within the contemporary sphere of mental attitudes are the axes with which a society receives social goods as adequate or suitable.

Putting all these together, as the Internet gives us an unprecedented potential of Interactivity in tracing the techniques alongside the composing characteristics of particular periods, places, musicians or artistic movements, the distinctive cognitive styles discussed in this section may be audio-visually trailed if the reader seeks to hear two very popular versions of "Достојнојест" (i.e., "Axion estin") in Serbian - see Figs. 5 & 6.

Fortunately, they have been abundantly uploaded in various renditions at YouTube™ or similar social media platforms.

The first version, virtually in alignment with the progenitor version, is the "Достојнојест" performed at the historical Visoki Decani Monastery.

It is composed in Mode Plagal A′, but it is not the Pringos mellurgy. It summarizes, however, very distinctively the musical guidelines for how the cultural representation of Mode Plagal A′ (i.e., the 5th Mode) has been retained historically in Serbia.

Seen from the point of view of audiovisual events it would be what Arnheim [12] had designated in 1957 as a cinematographic representation of a reality - but the question punctually coming up is "which reality?".

As it has been pointed out by Gola in 1979, the potential of audiovisual presentations is not only representative but transformative as well [13].

This can be readily conceptually traced if a newer version of "Axion estin" is brought to surface: indeed, in the *VII Međunarodni Festoval Horova*, held between 7-9 October 2022 in the St. Jerome church of Herceg Novi, a polyphonic rendition was presented by the "Krančević" Youth Choir from Sremska Mitrovica, directed by Jovanka Ivanić (Fig. 5).

Figure 5. *A snapshot from the Youtube™ footage from the "Достојнојест" in Mode Plagal A′ as uploaded at the official channel of the Visoki Dečani Monastery.*

The rendition presented was composed by the legendary Serbian composer Kornelije Stanković somewhere around 1860.

Figure 6. *A snapshot from Youtube™ footage from the polyphonic "Достојнојест" rendition of composer Kornelije Stanković as performed by the "Krančević" Youth Choir.*

Stanković, living in the prominent mellurgic centers of the Austrian-Hungarian Empire, is inherently situated to provide the most striking features of a polyphonic version for "Достојнојест".

In the very same manner that he has transcribed bulk Serbian folk music for many voiced orchestras.

A systematic musical review is beyond the scope of this paper. What would be of focus, instead, in terms of IT methods for processing information, is how computer systems may support perpetual ontologies in confronting methodologies.

The readers are directed at this section to see argumentation as negotiation: The hymn "Axion estin", musically transcribed primarily in Greek, and afterwards in Slavonic under the "Достојнојест" or "Достойноесть" translation, as performed the last 150 years in various forms and formats in the Balkans, does it pertain

- similar linguistic prosodic characteristics?
- comparable mode and expressivity?
- other stereotyped or stylized musical patterns?

It is not merely a question of whether a new version surpasses its predecessor - it rather is what modifications does it provoke to a transcription system or what typological changes does it bring to the actual hearing, in terms of absolute measurements. Such are the ones that come out of Signal Processing systems.

If things seem to be that complicated for a hymn like ""Достојнојест", which, after-all, has a well-defined liturgical background and a sound melismatic approach, then, what cross-linguistic and cross-melismatic research may be held on more loose subjects like carols and pop-folk music?

3. TOWARDS A SOLUTION FOR ADVANCED AUDIOVISUAL "TRANSLATION"

The state of things, as presented in the previous section, may give the impression that the whole issue is an audiologic communication matter regarding internal forms of expression. If so, it would be better suited for a musicological conference than an ITC forum.

Nevertheless, as it can be seen in Figure 7, it is a highly technological matter for the doings of the 21st century.

Figure 7. *Professor Paris and his disciple B. Yilmaz from Ankara, Turkey, demonstrate in a video-lesson how a traditional ecclesiastical melody may be reproduced by a tambour, a tuned to non-tempered scales instrument.*

Putting all the above together we may conclude that Byzantine Mellurgy had developed mainly in Greek, but, with firm conviction we may assume that the languages of particular localities were used as well.

From the surviving folk music of the Balkan states, which is contextual to the listenings in focus, we may well assume that a more or less common style for artistic expression had developed albeit the linguistic diversity.

We don't have very much evidence of palaeography for other languages before the 10th century AD, but, following the historical development of recent years, as professor Maria Alexandrou has studied in detail [14], there are writings in the various languages of the palimpsest of the Ottoman regime, for example in Romanian. In both Cyrilic and Latin script.

Allow us to redirect at this point the focus on something pointed out by A. Toynbee [15] about the so called Rummilleti within the Ottoman Empire, whose head was the Ecumenical Patriarch of Constantinople: The Rummilleti included not only Greeks but Serbs, Bulgarians, Romanians, Albanians, Georgians, Karamanlides and Arabs. They were brought together because they acknowledged the same religion but did not express any political solidarity.

This lack of fellowship for common policies has decisively influenced the formation of the new arrangements of language (and music) used by the Balkan states in the 19th century. Without probing into linguistic profiling, one could say that to some degree the prescribed course was expected for new states that were being formed in a multipolar world with centers of influence, for the first time, beyond the geographical neighborhood of the Mediterranean.

Of course, there were strong influences from the long-standing poles, Constantinople and Rome, but influential decision-making centers located in the German-speaking countries (Austria-Hungary &Germany), France, England or Russia (for the Slavic-speaking populations mainly, but, for others as well) shaped cultural values that were different from the traditional formations.

In recent years strong influences from the American culture, language and technology have been added to this mosaic.

In any case, the aforementioned ethnic languages have been consolidated in the 20th century and public worship is conducted in them.

During this period, we have consolidated recordings of historical significance for the first time.

On a "macroscopic" level, the differentiation of the melodies has to do with the (recently revived) Modes. That is, in modal music we can, based on these characteristics, identify the various "ethnic schools" of contemporary music and detect other local or non-local parameters that create fields of differentiation [16].

However, modality is not something that arbitrarily groups the music of Greece, with whatever peculiarities it may have, with the music of the countries of the Eastern Mediterranean, the Middle East or North Africa [17]. Or even the Balkans [18].

The Greek scene has clearly been influenced by its long-term coexistence at an administrative and cultural level with the hearsay of the Arab-Persian or Ottoman tradition. Thus, the rebetika songs, the amanedes and the tsiftetelia as characteristic events of contemporary “folk” or “pop” tradition have obvious parallels with the maqams of Oriental music [19].

Also, modal music obviously deviates from convention, and uses a multitude of scales that are not always the well-tempered scales implied by the so-called Common Music Notation paradigm. This is the phenomenology of the subject [20]. It is also the technological problem in focus.

In any case, this inability of European Music to preserve modal characteristics in its staged music from the 16th century and onwards has led to diversification. As harmony, the fugue, counterpoint and the polyphony begin to prevail, the modal characteristics begin to decline and the overall musical paradigm shifts away from the musical tradition of the Eastern Mediterranean basin [21].

This is the case of the listenings associated with Figures 5 and 6.

At this point, as IT enables the massive spread of hearings, for the first time in human history, we will see how the technological problem uncoils. A renowned musicologist, Paul Landormy, already a century ago in a landmark book, the "History of Music" [22], connects the modes with the three genres of Greek Music: the diatonic, the chromatic and the harmonic.

For the diatonic, he states that the arrangement of the intervals in the lower four-chord of the scale is as follows (Fig. 8):

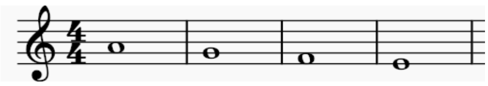

Figure 8. *The diatonic scale, according to Landormy.*

He also explains the origin of its name: the strings of the lyre reached the greatest degree of tension (diateno = stretch).

His observation about the other two genres is important: “Over time, various complications entered Greek Music, of Eastern origin of course, under the names of the chromatic genre and the harmonic genre”.

The chromatic genus is similarly described with the following arrangement for the lower part of the corresponding scale (Fig. 9):

Figure 9. *The chromatic scale, according to Landormy.*

Of course, Byzantine Music experts will not disagree on the principle, but will raise the issue of the correct rendering of the intervals (see Fig. 7). Landormy's observation, which is transferred as such, is important at this point: "The harmonic genre, very different from today's arrangement, introduces the quarter tone into the scale. Because in today's notation we have no way to indicate the quarter tone, we will represent it with an *F* with a *bemol* (flat) with a line in the middle that descends a quarter tone to the lowest four-note part of the well-tempered scale." (Fig. 10)

Figure 10. *The harmonic scale, according to Landormy.*

We have the impression that the Byzantine Music scholars would not agree completely for the arrangements of notes and intervals on the aforementioned scale.

But consider the transcendence to which Landormy invites his readers! Those who were taught music in the conservatories of Western Europe.

A century ago, when recordings were vague, and hearings from the East nearly exotic. Imagine, he instructs his readers, a microtonic scale. An scale that uses intervals smaller than a semitone.

It is not a matter of whether we can eliminate subjectivity by defining the exact mathematical definitions in a scale with more precise quantitative terms. It is a matter of cognition [1]. It is also a matter of study at the level of semiology [14, 16].

A tourist listening to what music is played in Greece during the summer period might be entitled to make such associations. A scientist, however, never.

Indeed, Sir James Jeans in 1953 in his book [2, p. 169] had put the matter on the right footing: "Medieval music and ecclesiastical music in particular, took over the Greek Modes". Both the medieval (secular or not) music as well as the so-called ecclesiastical, are conceptually based on definitions derived from the wider musical tradition of the Greek world during the Hellenistic period and onwards.

What has survived in Western Europe is documented as the Gregorian chant. It was categorized into 8 modes, although as many as 12 have been recorded in the 16th century [23]. Each mode is distinguished by its final, dominant, and ambitus. The final is the ending note, which is usually an important note in the overall structure of the melody.

Nevertheless, if multimedia enhancements are not given, it is not easy to understand what means modal music (Figures 3, 4 and 5).

Professor Eleanor Selfridge-Field, who, perhaps, more than anyone else has studied the issue of describing musical information through (electronic) notation, characteristically states: "From the accents for tonal inflection in many of the world's languages, through the neumes representing chant in medieval monasteries, to the solfege of musical pedagogy in recent centuries, codes for sound have always had the purpose of prescribing consistency of practice.” [24]

It is clearly related to the language that is spoken or sung. The notational symbols used, and the invested aesthetic factor exploit the communicative parameters of the language and charge them accordingly.

4. RE-ENACTING THE MUSICAL DIVERSITY WITH INFORMATION TECHNOLOGIES

The previously described series of steps give a rather systematic description of the intricate nature of melodic coordination.

This situation seems to be an ordinary combination of everyday circumstances for the peoples of the Balkans.

The last 200 years they have been, for instance, using their own languages and the very same time they were cross-communicating one with each other through the use of *lingua francas* like French, German, English, Turkish and to a lesser extend Russian or Italian.

Therefore, their linguistic and melismatic approach, even in everyday matters, was biased by a multipolar world indeed.

Accenting, de-accenting, stylizing or changing with elasticity movements, motifs and patterns seems to be an accepted convention biasing towards habitual, dependable to influences.

With no apparent effort sometimes; in other cases by impelling vigorous conforming measures.

Various students within the Aristotle University in their Computer Music assignments attempted to reproduce the instrumental and vocal *acquis* of the aforementioned period.

Primarily, they attempted to give understanding with contemporary cognitive tools about the style differences. Multimedia enhancements, a commodity within the 21st century learning strategies, serve well making clear what the issue is about.

In Figure 11, video-lessons made by Aristotle University students and uploaded to the e-learning platform in use enhance learning within the curriculum.

It has been found that if students have ample multimedia support in topics related to sensual apprehension (in our case audiovisual enhancements), then, the learning processes within the e-learning environment are accelerated.

Figure 11. *Video-lessons for work centered focus within Computer Music teaching and instruction.*

Nevertheless, once acoustic and visual stimuli have been provided, for such high-level approaches and understanding required in tertiary education teaching, the representational level has to follow.

For the folk or pop musics of the Balkans the last 200 years, the period under scrutiny in this paper, score writing tools and digital audio workstations are the main axes for depicting in writing what ontologies are involved.

And so, in Figure 12 the actual melodic contours may be as accurately as possible modern technology allows us to “describe” the melody.

Figure 12. *The score for “Lygaria”, one of the folk melodies reproduced by students - musicians.*

What is amazing with contemporary IT modules is that they can reproduce in hearing, increasingly accurately the last few years, the instrumental part of nearly any melody.

Please keep in mind, that what has been extensively pointed out in the previous sections is the behavior of “missing elements”. In terms of ontologies, confronting cognitions, which is the essence of this paper, have to do with inability to represent a situation as a “class” or, even, as a mere “object” in the programming part.

Using recent advances in computer tools, the musical operations described in section 3, and pointed out by Landormy a century ago, can be put as "arguments", as symbols in score writers at last (Fig. 13).

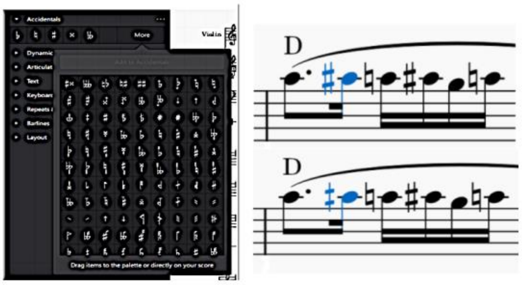

Figure 13. *The 3rd meter of the score for "Lygaria", as corrected using extensions for accurately depicting the interval involved.*

It is a notable step ahead that symbols like the ones seen in the left part of Figure 13 may be used to write down the peculiarities pointed out in the argumentation for chromatic renditions, for graphical computer-mediated communication.

The last few years, score writing systems have extended their semiotic representations thus far.

Nevertheless, what can be seen as argumentative activity in Figure 13, as an advent in precisely processing chromatic scales and intervals other than that of the well-tempered scale, comes at a cost.

While the score-writer can reproduce the melody seen in Figure 12 for violin, guitar, bass and tablas, when the correction seen in Figure 13 takes place, then no accurately identified sound is produced.

Graphically the song is correctly depicted, at last, but it is not punctually reproduced in acoustic terms. This is how far away virtualization may advance in 2024.

To enhance mutual apprehension in view of this shortcoming and recognizing that the services of a human expert seen in Figure 7 are sort of a rarity, the Computer Music community of the Aristotle University has created interactive multimedia tools that cure this shortcoming.

In Figure 14, a virtual tambour player is depicted, made available to Computer Music students for use with their tablets, mobile devices or laptops that can support touch gestures [25].

All the above-mentioned tools and applications are made available one way or the other as courseware enhancements. Some of them are distributed as open and free software, for instance via Play Store™, others are plugins that have been purchased under certain limitations and end-user distribution licenses, and a few have been accessed as in-house productions.

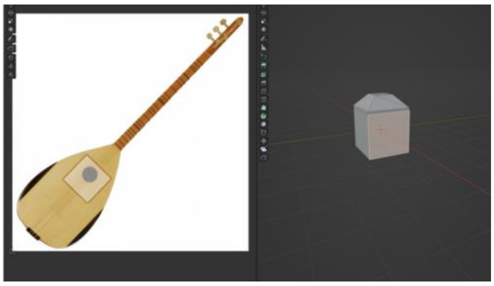

Figure 14. *A virtual tambour that can reproduce intervals in the variety for the understanding of musical chromatic argumentation.*

A certain level of skillware is needed to combine them altogether as argumentative tool-based activities in courses [26].

Not all students may have this background knowledge in putting together the bits and pieces required to combine such diverse technologies for problem solving. Usually, students studying, Computer Science or Engineering may take full advantage of them.

The asymmetry of learning transactions is revealed when trying to put together cognitive styles, learning strategies and diverse understandings.

In the case of the Computer Music domain, it is not granted that scientists and artists express themselves in a common way; it is not that much acknowledged as a supposition that they have the same intelligence assessment.

The IT field has the driving force; it lacks however the deep knowledge in some musicological matters.

Even further, it is not granted that in near future it may be able to overcome the "Balkanization" of music.

As in the region of the Balkans some 10 official languages are used in the everyday communication between the peoples living there, with the same impetus some 100 modes, maqams and sub-genera are met in musical performances. Even further, there are variable schemes for the representation of scales, for the progression of steps and tonal heights, for conveying emotional manifestations for artistic communication.

Again it is pointed out that from the 3-4 intelligences directly involved, emphasis is given to the acoustic dimension with some kinaesthetic enhancements.

It is granted, though, that apart from bodily/kinaesthetic sensing, the verbal/linguistic domain is a very influential factor for the constituents of musical composition, while rhythmic patterns are related not only with intonation contours but with non verbal expression closely linked with that as is the way of dancing.

As too many details would have to be added in this paper to explain in an ITC caucus matters that are covered extensively in specialized books or lemmas [16, 17, 28], an audiovisual Learning Object has been made so to give the readers an exact acoustic impression of the particular entities involved as compositional ontologies for music theory consistency.

The readers are thus kindly asked to consult this YouTube™ video (Fig. 15):

https://www.youtube.com/watch?v=F-4JvvotLvg

Figure 15. *A video acting as a Learning Object that points out the acoustic distinctive traits, the characteristic features and the collectible special worth for asymmetries in music education.*

While in the literature of musicology it is granted how different is the music of the Balkans [31, 32], in ITC research there have not been any reports on measurements, like for instance on the transactional distance that such variable approaches may produce.

Par example, in Figure 16 the transactional distance that chromaticism [32] induces may be seen as a dependency of factors like the extended use of microtonal scales and intervals or languages that have different phonological attributes.

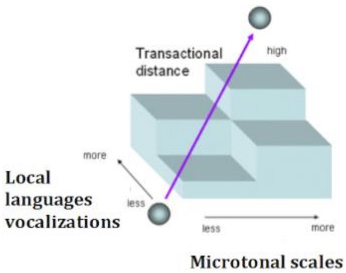

Figure 16. *A quantitative approach to why Balkan music sounds distantly related to the dominant contemporary pop music.*

Indeed, for a neutral observer the hearings of Balkan musics when reproduced by Machine Learning tools sound as if the rendering mechanism has been suffering from dysarthria, dysphonia or dysmusia of some kind. Indeed, Barsky has stated since 1996 [31] that there is a historic drift between East and West in Europe, as far as music is concerned, and the dividing line is somewhere around the Balkans.

To make things worse, the linguistic palimpsest in such a small region, with some 10 languages spoken intensively for centuries, creates stereotypes which also have not been evaluated in strict ICT terms.

It is very interesting, for instance, that a renowned composer like Bregović may be characterized as "Balkan", but what does it mean in terms of transactional distance or other mathematically oriented metrics? [33]

Therefore, the next stage of things this research seeks to establish, in practical terms, is the upgrade of Course Management Systems (aka CMSs) so that they can support with inherent computational media the considerations presented thus far in relation to learning (Fig. 17).

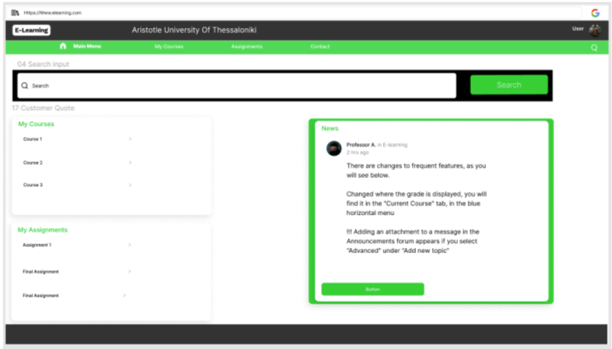

Figure 17. *Planning for CMS enhancements able to sustain special learning mechanisms and collaborative multimedia interactions.*

For this research we have used a Learning Object uploaded in YouTube™, but, this approach is lacking didactic orientation and does not eliminate the transactional distance by increasing the learning curve.

Occasionally YouTube™, radio or TV may be used as didactic enhancements, but they are not educational media per se.

When conflicts and confrontations occur in e-learning based activities, guidance or collaborative work with both a computer expert, a music expert, and a linguistics expert is needed to provide sound scientific acquisition of knowledge. Currently, CMSs do not facilitate this level of argumentative communication [27].

For this paper, we have profited by recent advances in Machine Learning and AI that help computers reproduce with some success "Balkan" melodies (Fig. 15).

By no means, however, such approaches may be considered artistically sufficient or scientifically valid.

Some kind of argumentative enhancement is needed when communicating via CMSs for instruction and research so that mutual understanding between neighboring traditions may be enhanced by increased interactivity.

AI and Machine Learning tools may help for starters; nevertheless, high-end tools enhancing cognition on such matters are yet to come.

5. CONCLUSION

If not multimedia enhancements accompany artistic renditions, there is usually not enough information given to make a comprehensive assessment based on empirical evidence.

For the expert, however, usually there is enough information presented so that he can shape in his mind (and accordingly perform) with a good deal of success.

As such experts are not that widely available, in terms of AI and Machine Learning the question is the following: may we have enhancements that develop the extensive or complex theme according to the cultural heritage of a certain place, according to the capabilities of the performer, according to the rules of composition based on aesthetic factors, with variety of expression in order to highlight the interdisciplinary fields connected with the performed melody?

This article gives insight on what musical codes may imply and how with some ITC support a user may be provided with tools enduring a reasonable functionality for team development and challenging remote teaching.

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The Role of AI Tools in Education: Opportunities and Challenges

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Abstract: *Artificial intelligence (AI) has significant potential for raising the quality of knowledge acquired by students. Advanced AI tools provide invaluable support in their learning endeavors. This study explores the perceptions of 953 primary and secondary school students, as well as university students, regarding the integration of AI in teaching methods. The research sample consists of Serbian students: 618 primary school students from Čačak and Belgrade, 233 secondary school students from Čačak, and 102 students from the Faculty of Technical Sciences in Čačak. The authors designed a targeted questionnaire to collect relevant data. The findings reveal a significant gap in the understanding of AI from the perspectives of different groups of students, particularly concerning applications more complex than the basic tools such as chatbots. This paper offers a comprehensive analysis of the most common AI tools in educational environments and presents conclusions and recommendations for improving the integration of AI tools in teaching to enrich the educational experience.*

Keywords: *artificial intelligence; AI tools; education; research; chatbots*

1. INTRODUCTION

Artificial intelligence (AI) is becoming a key factor in various industrial sectors, including education. Thanks to rapid technological advancements and the support of innovative companies like OpenAI, AI tools are becoming invaluable resources for students seeking to enhance their educational experiences.

These tools are designed to be easy to use, affordable, and accessible to users of all skill levels. By providing a wide range of functionalities through a single platform, AI tools eliminate the need for multiple programs. This enables users to efficiently and easily perform various tasks, significantly reducing effort and increasing productivity.

Although AI tools offer enormous benefits, there is legitimate concern that students may become overly dependent on automation, potentially impacting the development of critical thinking skills. However, banning AI tools (especially ChatGPT) in educational institutions for these reasons seems excessive and unjustified. Instead, numerous AI tools can significantly enhance students' creativity and accelerate the learning process, allowing them to explore topics of interest more deeply and efficiently. AI not only transforms education but also enriches it, opening new horizons for future generations of pupils and students. The introduction and proper integration of AI tools into the education system can create a dynamic and inclusive learning environment, where technology supports rather than substitutes for human curiosity and creativity.

AI enables students to utilize new and innovative tools to enhance their education. The best AI tools for students support understanding complex concepts, researching topics efficiently, and even preparing for exams. AI has the potential to transform learning by providing personalized experiences that are tailored to each student's individual needs. [1].

Many previous works have explored the application of AI tools in education, providing valuable insights and recommendations comparable to the findings presented in this paper. One notable study published in the International Journal of Educational Technology in Higher Education examined trends in the application of AI in education (AIEd) through a systematic review. This research identified that AI tools are predominantly used to enhance personalized learning experiences, automate administrative tasks, and create intelligent learning support systems. It was emphasized that it is important to integrate artificial intelligence as a support for learning and not as a substitute for traditional educational methods [2].

A comprehensive review published in Education Sciences detailed the potential and implications of using AI, particularly ChatGPT, in educational contexts. This research highlighted AI's dual impact: while AI tools can significantly aid in understanding complex concepts, provide personalized feedback, and enable continuous learning, there are concerns about over-reliance and a possible decline in critical thinking skills among students. The study recommended integrating AI tools with traditional teaching methods to balance technological benefits and critical skill development. This approach leverages AI's advantages while encouraging students' critical thinking and analysis skills [3].

A report from Old Dominion University provided practical applications of AI tools in teaching, learning, and research. Citing specific examples such as creating practice tests, providing personalized study advice, supporting research activities by generating literature reviews and bibliographies, and converting course materials into different formats for better accessibility, the report highlighted the diverse possibilities that artificial intelligence offers in an educational context. He placed special emphasis on the importance of guiding students on how to effectively and ethically use artificial intelligence tools. He encouraged teachers to design assignments that encourage original thinking and critical analysis, rather than passive dependence on AI-generated content. This approach promotes active learning and the development of key skills in students, while at the same time using advanced technological resources [4].

Hosseini et al [5] analyzed received responses to questions about the use of ChatGPT in various contexts. According to the results, only 40% of the audience had tried ChatGPT. In the article the greatest uncertainty was shown regarding the use of ChatGPT in education. During the discussion, both pros and cons were raised for the application of this technology across education, research, and healthcare contexts.

Together, these studies suggest that while AI tools hold great promise in improving educational outcomes, we must apply them carefully to avoid potential drawbacks such as reduced critical thinking and academic integrity issues. Integrating AI tools with a balanced approach can lead to richer learning experiences and better educational outcomes. This approach makes it possible to take advantage of technology while encouraging the development of key skills in students and preserving educational integrity.

2. AI TOOLS IN EDUCATION

AI tools have revolutionized education, transforming how students acquire knowledge and enhance their learning experience. These tools offer personalized learning experiences tailored to students' unique needs and preferences. This technology supports students with different learning styles or disabilities, fostering more inclusive education. AI-powered learning platforms allow learners to progress at their own pace and receive relevant feedback on areas needing improvement [6].

Teachers can use AI tools to create personalized lessons adapted to each student’s pace. AI-powered chatbots can act as virtual tutors, providing instant support and guidance, further facilitating the learning process outside traditional classes.

Given the trends in the development and use of artificial intelligence in education, it is necessary to monitor current regulations at the level of the Republic of Serbia, as well as innovations through available standards. The development strategy of artificial intelligence [7] provides an overview of goals and measures in the field of education. A specific goal involves the development of education tailored to the needs of modern society and the economy conditioned by the advancement of artificial intelligence.

In addition, AI can improve student engagement and motivation. AI-powered virtual tutors can interact interactively with students, offering personalized feedback and guidance, contributing to more stimulating and dynamic learning. AI should be seen as a useful tool that complements and enhances the teaching and learning process, not as a substitute for human interaction.

3. POSSIBILITIES OF CHOOSING NEW AI TOOLS FOR LEARNING

AI tools have fundamentally changed the educational landscape, opening the door to personalized learning experiences, and resulting in more accessible education and greater student engagement. These technological advances promise a bright future for education, adapting to meet the growing and changing needs of students. Below is an overview of the most commonly used groups of AI tools in education [8, 9]:

- **Chatbots:** Automated computer programs that simulate a human conversation to solve user queries. They use artificial intelligence, machine learning, and natural language processing to provide support and answer routine queries [10].
- **Visual & Design Tools:** Tools that enhance the aesthetic appeal and usability of designs and products, helping to create compelling and aesthetically pleasing designs [11].
- **Lesson Design & Content Creation Tools:** Software and platforms that help teachers plan and create content for lessons, based on curriculum goals and pedagogy [12, 13].

- **Teaching Aides:** AI tools that support teachers in customizing learning experiences and making informed decisions based on data analytics [14].
- **Quiz/Assessment Generators:** Tools that automatically create custom quizzes and tests, helping to assess student knowledge in a fun and engaging way [15]. The grading generator allows you to choose how many of each type of question you want on the exam. Questions can be chosen from multiple choice, numerical answer, short answer, and more [16].
- **Collaboration & Communication Tools:** Software that facilitates communication and collaboration among team members, enabling effective remote work and physically present work [16, 17].

Table 1 provides an overview of popular AI tools from the Chatbots, Visual & Design Tools, and Teaching Aides groups, representing only the tip of the iceberg of AI's possibilities in education [9].

Table 1. *The most popular AI tools are Chatbots, Visual & Design Tools and Teaching Aides*

Group	AI tool	Description	Function	Price and terms of use	Multilanguage (Serbian)	Access/ link
Chatbots	ChatGPT	Generative AI chatbot[1]	Allows users to communicate and receive answers.	Free version and ChatGPT Plus version ($20/month)	Yes	[18]
	Bing Chat	ChatGPT-4 robot	Enables web browsing, answers the question	Free	Yes	[19]
	Perplexity	Generative AI chatbot	Provides concise answers and detailed response	Free	Yes	[20]
	Gemini	An experimental service for chatting with artificial intelligence	Provides answers to user questions	Free	Yes	[21]
	PI	Personal AI companion for various tasks and answering questions	Enables communication via text or voice commands	Free	Yes	[22]
Visual & Design Tools	Adobe Express with Firefly	Includes Adobe Firefly generative AI model for creating custom images and text effects	Provides tools for creating visual content	Free	N/A	[23]
	Bing Image Creator	Generates AI images using DALL-E technology	Allows creation of new images with text and graphic queries	Free	N/A	[24]
	Pictory	AI platform for creating interesting videos	Provides tools for creating videos with visuals	Free trial, then monthly subscription ($19)	N/A	[25]
	Canva Classroom Magic	AI tools suite for educators	Magic Design for visual content, Magic Writing for text generation	Free through a Canva EDU Pro account	N/A	[26]
Teaching Aides	gotFeedback	An AI tool for providing feedback to students	Provides feedback on student work	Free version for three teachers and administrators	Yes	[27]
	Grammarly	AI writing assistant	Detects and corrects writing errors	Free version and paid version ($12/month)	No	[28]
	Goblin Tools	Tools for neurodivergent people	Help with tasks that are considered difficult	Free	Yes	[29]
	Hello History	AI-powered app for "conversations" with historical figures	Allows users to interact with historical figures	Limited free version with in-app upgrade option	No	[30]
	Chat PDF	AI tool for interacting with PDF documents conversationally	Summarizes and answers questions about PDFs	Free for two PDFs per day, max 120 pages per document	Yes	[31]

4. METHODOLOGY

The *research aims* is to assess the general knowledge about artificial intelligence (AI) and AI tools in education among pupils and university students and to analyze their attitudes and experiences regarding the use of AI processes in teaching. The research aims to discover:

1) How familiar are students with the concept of artificial intelligence and its tools?
2) How and how often to they use AI technologies in everyday life and education?
3) What are their views and experiences with AI, including potential abuses?
4) How interested they are in learning about AI tools as part of a school or university curriculum?
5) How do they evaluate the usefulness of AI tools and Chatbots in education?
6) Are they satisfied with the quality of answers provided by Chatbots?
7) How much do they believe that AI tools can improve their ability to learn?

[1] A generative AI chatbot is a type of artificial intelligence that can generate authentic responses based on text input, using deep neural networks or similar techniques. These chatbots are capable of understanding and responding to various user queries, simulating a conversation with humans.

Research Design, Privacy, and Data Protection

The *research design* used in this study is a descriptive research design with elements of quantitative analysis. Questionnaires were used in the research to collect data on the knowledge, attitudes, and experiences of pupils and university students regarding AI and AI tools in education.

The research was conducted during May 2023/24. among primary and secondary school students in Čačak and Belgrade, as well as university students from the Faculty of Technical Sciences (FTS) in Čačak. The surveyed sample included a total of 953 pupils and university students.

Participation in the survey was completely voluntary. The respondents were informed about the purpose of the study and were assured of the confidentiality of their answers. To ensure anonymity, the surveys were conducted on paper without any identifying information and were completed in the presence of the professor. This approach protected respondents' privacy and encouraged candid responses. The collected data were used exclusively for this research and were handled by applicable *data protection* regulations.

An overview of the *surveyed sample* shows the following structure:

- Group A: Students of the 5th and 6th grades of elementary school - 289
- Group B: Students of the 7th and 8th grades of elementary school - 329
- Group C: Students of 1st and 2nd grades high school students - 137
- Group D: Students of 3rd and 4th grades of high school - 96
- Group E: Students from FTS in Čačak - 102

The *survey* consisted of two parts:

1. First part - General information about artificial intelligence and AI tools in education: It contained a series of statements with provided answers, and the results are summarized in Table 2.
2. Second part - Students' evaluations of artificial intelligence and AI tools in education: This part contained an evaluation scale from 1 (not at all) to 5 (very much), with a special focus on experiences in using chatbots. The results are shown in Table 4.

5. RESULTS AND DISCUSSION

5.1 The First Part of the Survey

The first part of the survey aimed to assess the general knowledge of artificial intelligence (AI) and AI tools in education among pupils and university students. Table 2 presents the respondents' answers categorized by age group.

Table *2.* *Percentage responses of pupils and university students in the first part of the survey*

No.	Question	Answers offered	Age/Group (values are in %				
			A	B	C	D	E
1.	How familiar are you with the term artificial intelligence?	I have never heard of her.	4.2	2.4	3.6	3.1	0.0
		I know it exists, but I don't understand it well.	25.3	21.5	19.6	5.2	2.9
		I have a basic understanding of how AI works.	46.0	50.6	48.6	56.3	59.8
		I am well-versed in various fields of artificial intelligence.	24.6	25.5	28.3	35.4	37.3
2.	In your opinion, which statement best fits the concept of AI (only 1 answer)?	A robot that performs tasks.	30.4	32.2	29.2	9.4	18.6
		A type of program that can learn and remember information.	48.8	43.2	46.0	69.8	53.9
		Human intelligence inserted into a computer.	20.8	24.6	24.8	20.8	27.5
3.	How often do you use technologies that rely on artificial intelligence?	Several times a week.	22.5	29.8	29.2	34.4	33.3
		Every day.	39.8	28.0	19.7	18.8	16.7
		Once a week.	10.0	11.6	12.4	17.7	19.6
		Less than once a week.	16.3	23.4	35.0	24.0	29.4
		Never.	11.4	7.3	3.6	5.2	1.0
4.	Did you learn about AI in your educational institution (school, faculty)?	Yes, intensively.	12.1	7.9	1,5	5,2	2.0
		Yes, occasionally.	39.4	36.5	24.1	54.2	52.9
		No, but I would like to.	29.8	32.2	40.1	29.2	38.2
		No, and I don't want to.	18.7	23.4	34.3	11.5	6.9
5.	How would you describe your attitude towards AI in one word?	Fascinating.	17.0	13.7	16.8	7.3	5.9
		Useful.	60.9	63.5	59.1	68.8	63.7
		Scary.	5.2	7.3	11.7	10.4	15.7
		Promising.	8.0	8.2	4.4	6.3	13.7
		Needlessly.	9.0	7.3	8.0	7.3	1.0
6.	Have you had a negative experience with AI?	Yes, several times.	15.6	13.7	21.2	30.2	26.5
		Yes, once.	11.8	14.0	5.8	14.6	11.8
		No never.	46.4	45.6	48.2	46.9	48.0
		I do not know.	26.3	26.7	24.8	8.3	13.7
7.	Would you like to learn more about AI tools in your school/college curriculum?	Yes, very.	26.3	19.5	14.6	18.8	27.5
		Yes, but not too much.	41.9	35.3	41.6	50.0	54.9
		No, it is not my priority.	17.0	31.3	32.1	26.0	15.7
		I am not sure.	14.9	14.0	11.7	5.2	2.0
8.	Do you think that AI can be used for the misuse of learning and information?	Yes, absolutely.	37.7	37.7	37.2	37.5	47.1
		Yes, but only in certain cases.	48.4	45.6	46.0	54.2	44.1
		No, I believe that AI is always in the service of good.	13.8	16.7	16.8	8.3	8.8
9.	As a student, did you use AI in your educational process and was there any misuse?	I did not use artificial intelligence in teaching.	40.5	37.7	24.8	9.4	17.6
		I used artificial intelligence in class and did not abuse it.	36.7	36.2	40.1	53.1	77.5
		I used artificial intelligence in class and abused it.	7.3	6.4	16.1	19.8	2.9
		I used artificial intelligence in class and may have misused it	3.5	4.3	7.3	7.3	2.0
		I don't want to answer this question.	12.1	15.2	11.7	10.4	0.0

5.1.1 Discussion

Question 2: Nearly half of the respondents (49.1%) perceive artificial intelligence as a type of computer program capable of learning and retaining information. Younger participants exhibit less understanding, while older ones demonstrate better comprehension. Conversely, only a small fraction of respondents associate artificial intelligence with robots performing tasks.

- **Question 3:** The youngest respondents (group A) use AI-based technologies most often (39.8%), while university students (group E) use AI the least (16.7%).
- **Question 5:** Despite most respondents viewing artificial intelligence as useful and promising, university students express the most apprehension. Moreover, university students and senior high school students report more negative experiences with AI compared to younger respondents.
- **Question 6:** University students and senior high school students had more negative experiences with artificial intelligence compared to younger students.
- **Question 8:** A significant number of respondents, especially senior high school students and university students, believe that AI can be misused.

Figures 1-3 offer graphic summaries of the respondents' answers to Questions 1, 4, and 7 from this part of the survey.

- **Question 1:** Figure 1 shows the summary response of the respondents to the question "How familiar are you with the concept of artificial intelligence?"

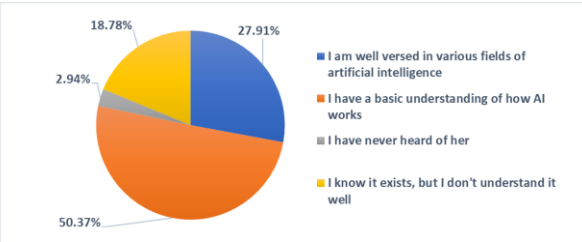

Figure 1. *"How familiar are you with the term AI?"*

Almost half of respondents (50.37%) have a basic understanding of artificial intelligence, while 27.9% of respondents are well-versed in various areas of artificial intelligence. However, a significant number of respondents (18.78%) only know that artificial intelligence exists, but do not fully understand it.

- **Question 4:** Figure 2 shows the summary response of pupils and university students to the question "Did you learn about artificial intelligence in your educational institution (school, faculty)?". More than a fifth of the respondents (20.57%) did not learn and do not want to learn about artificial intelligence, while slightly less than half (46.49%) occasionally or intensively learned about artificial intelligence in their schools or faculties.

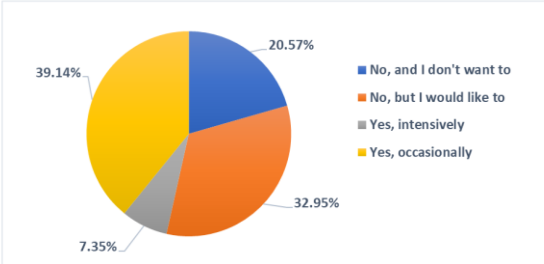

Figure 2. *"Did you learn about artificial intelligence in your educational institution (school, faculty)?"*

- **Question 7:** Figure 3 shows how willing the respondents are to learn about AI tools within the school or university curriculum (question "Would you like to learn more about AI tools in your school/ faculty curriculum?").

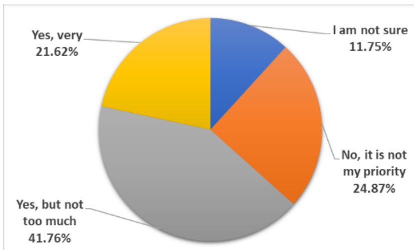

Figure 3. *"Would you like to learn more about AI tools in your school/faculty curriculum?"*

Of all respondents, 21.62% of respondents expressed a very high level of interest in learning AI tools, while 41.76% of respondents were moderately interested. On the other hand, 24.87% of respondents believe that learning AI tools is not their priority.

- **Question 9:** Table 3 shows the percentage answers of the respondents to the question "As a student, did you use AI in your educational process and was there any misuse?" It was interesting to compare the results by gender.

Table 3. *Respondent's answers to the question: "As a student, did you use artificial intelligence in your educational process, and was there any misuse?"*

Answers	Female	Male	Total
I did not use A in teaching.	34.14%	30.12%	31.69%
I used AI in class and did not abuse it.	45.97%	41.14%	43.02%
I used AI in class and abused it.	4.84%	11.88%	9.13%
I used AI in class and may have misused it.	4.57%	4.48%	4.51%
I don't want to answer this question.	10.48%	12.39%	11.65%

Men were almost 2.5 times more likely to use artificial intelligence and report misuse (11.88% compared to 4.84%), while 11.65% of respondents did not want to answer this question. A higher number of respondents use AI in teaching without misuse (43.02%) compared to those who did not use AI in teaching (31.69%).

5.1.2 Conclusion and Recommendations

- *Knowledge of artificial intelligence (AI):* The majority of respondents believe that AI is a type of computer program that can learn and remember information. Younger respondents are less knowledgeable about AI, while older ones understand its essence more. The majority of respondents use AI-based technologies, with younger people using AI technologies more often than university students.
- *Attitudes towards AI:* Most respondents see AI as useful and promising, but university students express the most fear. University students and senior high school students have more negative experiences with AI compared to younger students.
- *Possible abuse of AI:* A large number of respondents believe that AI can be used for abuse, especially older high school students and university students.
- *Interest in learning about AI and AI tools:* Most respondents want to learn about AI and AI tools, with more than half expressing interest.
- *Use of AI tools in education:* Male respondents use AI tools more in education and are more prone to misuse compared to female respondents. A greater number of respondents use AI tools in teaching without abuse.

These results point to a pressing need for enhanced education regarding artificial intelligence to comprehend its capabilities and limitations adequately. Moreover, there's a necessity to prevent potential misuse. Further research should delve into AI's impact on education and identify avenues for improvement. Additionally, measures like the introduction of ethical guidelines and teacher training on AI technology's proper utilization are warranted.

5.2 The Second Part of the Survey

Table 4 presents the average responses of surveyed students to questions in the second segment of the survey, using a scale of 1-5 to rate their perceptions (1 - not at all, 2 - very little, 3 - good, 4 - significant, 5 - very much).

Table 4. *Assessment scale (1-5)*

No.	Questions	Age/Group					Total
		A	B	C	D	E	
1.	What is the level of awareness of AI technology in your school/faculty?	2.72	2.66	2.35	2.43	3.27	2.67
2.	How would you rate (in general) the usefulness of AI tools in education?	3.22	3.12	3.24	3.33	3.54	3.23
3.	How familiar are you with Chatbots in education?	2.56	2.63	2.80	3.04	3.07	2.72
4.	How would you rate the usefulness of Chatbots in education?	3.05	3.03	2.99	3.10	3.12	3.05
5.	How much can AI tools improve your ability to learn?	3.17	3.01	3.07	3.09	3.60	3.14
6.	How satisfied are you with the quality of responses provided by chatbots?	3.25	3.13	3.10	2.94	2.77	3.10
7.	How much will using chatbots for learning help students?	3.25	3.17	3.35	3.18	3.51	3.26

5.2.1 Discussion

Figure 4 provides a comprehensive summary of students' assessments for Questions 1-7 from Table 4. Overall, respondents exhibit moderate awareness of AI technology (average: 2.67) and are relatively uninformed about chatbots in education (average: 2.72). However, they rate the usefulness of AI tools (average: 3.23) and chatbots (average: 3.26) positively. Moreover, they believe that AI tools can significantly enhance learning abilities (average: 3.14) and express satisfaction with chatbot responses (average: 3.10).

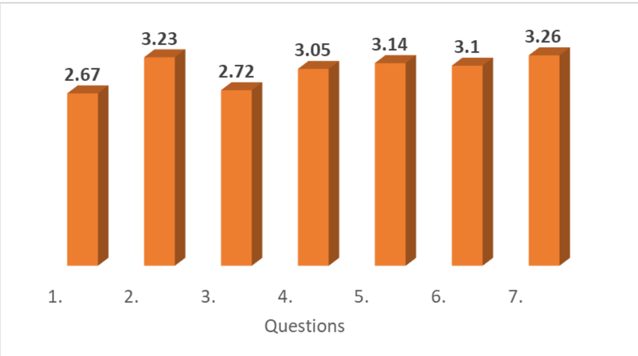

Figure 4. *Summary of grades for primary, secondary, and university students for Questions 1-7 from Table 4*

Further analysis of responses by gender for Questions 5 and 6 is presented in Tables 5 and 6.

Table 5. *Estimates of respondents' responses to the question "How much can AI tools improve your ability to learn?" (Question 5)*

Age	Male	Female	Total
Elementary school V, VI-grade	3.21	3.11	3.17
Elementary school VII, VIII-grade	3.11	2.88	3.01
High school I, II-grade	3.09	3.03	3.07
High school III, IV-grade	3.11	3.05	3.09
University students	3.70	3.44	3.60
Total	**3.20**	**3.04**	**3.14**

On average, men rated the potential to improve learning with AI tools higher, with an average rating of 3.20, while women gave slightly lower ratings, with an average rating of 3.04. University students rated this item the highest, with an average score of 3.60, while elementary school students gave slightly lower, but still quite high scores, ranging from 3.01 to 3.17.

Table 6. *Estimates of respondents' answers to the question "How satisfied are you with the quality of answers provided by chatbots?" (Question 6)*

Age	Male	Female	Total
Elementary school V, VI-grade	3.32	3.16	3.25
Elementary school VII, VIII-grade	3.15	3.10	3.13
High school I, II-grade	3.25	2.69	3.10
High school III, IV-grade	3.08	2.45	2.94
University students	2.90	2.56	2.77
Total	**3.18**	**2.99**	**3.10**

Men generally rated the quality of chatbot responses higher, with an average rating of 3.18, while women gave slightly lower ratings, with an average rating of 2.99. Again, university students rated this item the lowest, with an average score of 2.77, while elementary and high school students scored slightly higher, but still below average, ranging from 2.94 to 3.25.

5.2.2 Conclusion and Recommendations

The analysis of the second part of the survey reveals significant insights into the attitudes and perceptions of students about artificial intelligence and AI tools in education. There is a basic understanding of AI technology among respondents, with university students being better informed compared to primary and secondary school students. Nevertheless, there is a general interest in learning about AI tools in educational institutions, although some respondents feel insufficiently informed about these technologies.

Assessments of the usefulness of AI tools in education are positive, especially when it comes to using chatbots for learning. However, a variation in ratings was observed between genders, with females expressing greater caution and less satisfaction with the quality of responses provided by chatbots compared to male respondents. This may be the result of various factors, including individual perceptions, experiences, and attitudes towards technology and education.

The insights gleaned from the second part of the survey shed light on students' attitudes and perceptions toward AI and AI tools in education. While there's a basic understanding of AI, there's a need for more comprehensive training and information dissemination. Additionally, adjustments in AI tool implementation considering user preferences, especially potential gender disparities, are essential for maximizing educational benefits.

6. CONCLUSION

The research presented in this paper provides a deeper insight into the attitudes and perceptions of pupils and university students towards artificial intelligence (AI)-based technologies. The main findings indicate a positive attitude towards AI tools in education, particularly among younger respondents, while older individuals express more caution and skepticism. Specifically, 39.8% of younger respondents actively use AI tools compared to 16.7% of university students, demonstrating significant variation in technology usage across age groups.

Despite broad consensus on the potential and usefulness of artificial intelligence, concern remains high among university and high school students, who frequently report negative experiences and fear the potential misuse of this technology. Although there is significant interest in learning AI tools, with 21.62% of respondents showing a very high level of interest and 41.76% moderately interested, it is notable that 24.87% do not prioritize this learning.

The implications of these findings underscore the necessity for additional education and awareness of artificial intelligence among students. Educational institutions should actively address these fears and negative experiences to foster a more inclusive and supportive learning environment. Integrating AI literacy into curricula can significantly contribute to overcoming knowledge gaps and enhancing students' competencies in utilizing AI technology, thereby potentially improving educational outcomes.

This study significantly contributes to understanding the complex relationship between students, AI technology, and education, emphasizing the need for further research and actions in the field of AI education and implementation within the educational system. While integrating AI technologies in education offers numerous advantages, achieving a balance between technology and the human factor, and safeguarding against potential risks and shortcomings, requires the development of a robust strategy. Deeper risk analysis and the formulation of ethical guidelines are crucial steps towards achieving this balance.

For future research, it is recommended to focus on aspects that promote the comprehensive and ethical use of artificial intelligence in education, ensuring that AI not only enhances the learning process but also preserves key elements of the educational experience that encourage critical thinking, creativity, and independence among students.

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The Integration of Artificial Intelligence across Educational Levels: From Primary School to University

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Abstract: *In recent years, the integration of Artificial Intelligence (AI) in education has shown transformative potential across various educational levels, from primary school to university. This paper examines the multifaceted applications of AI in education, highlighting its role in enhancing teaching and learning experiences, as well as personalizing educational content. The aim of this paper is to shed light on the implementation of various AI tools in primary, secondary and tertiary education through practical examples gained through action research. At the primary school level, AI tools are employed to create engaging and adaptive learning environments, catering to the diverse needs and learning paces of young students. In secondary education, AI facilitates the development of critical thinking and problem-solving skills through interactive and personalized learning platforms. At the university level, AI is revolutionizing research methodologies, providing sophisticated data analysis tools, and supporting the creation of innovative learning management systems. Additionally, the paper highlights the challenges and ethical considerations associated with AI integration in education, such as data privacy, algorithmic bias, and especially the need for teacher training in AI literacy. Conclusively, we provide an overview of the benefits and limitations of AI in education, offering insights into future trends and implications for educational stakeholders.*

Keywords: *AI in education; AI in primary education; AI in secondary education; AI in teaching*

1. INTRODUCTION

Imagine a classroom where every student receives personalized attention, and learning is tailored to their individual needs. This is no longer a futuristic dream but a reality made possible by Artificial Intelligence (AI). AI not only engages students by creating interactive and immersive learning experiences but also significantly eases the burden on teachers by automating administrative tasks, providing real-time insights into student performance, and offering personalized recommendations for instructional strategies.

In recent years, the integration of AI in education has gained momentum, promising to revolutionize traditional teaching methods and enhance educational outcomes. By using AI, educators can create more dynamic and adaptive learning environments that cater to the diverse needs of their students. From intelligent tutoring systems and adaptive learning platforms to AI-driven administrative tools, the potential applications of AI in education are vast and varied. While AI offers significant opportunities to enhance learning experiences and outcomes, its implementation must be carefully managed to address ethical considerations and ensure equitable access. Through a comprehensive analysis of current AI applications, case studies, and future implications, this paper aims to provide a deeper understanding of how AI can transform education and what it means for teachers and students alike.

2. AI IN EDUCATION

AI algorithms can be used to create personalized learning plans for students based on their individual needs, interests, and abilities. This can help improve learning outcomes and engagement, as students are more likely to be motivated by content tailored to their interests [1].

Teachers who work in primary or secondary schools deal with individual needs of each student. It is extremely difficult to ensure approach that all students can progress at their own pace, maximizing their potential and fostering a more engaging and effective learning environment.

AI-powered tools have the potential to make learning more interactive and engaging for students. Technologies such as immersive virtual reality (VR) and augmented reality (AR) can create highly engaging and dynamic learning experiences, not only for gifted students but for diverse learners also. For example, students can take virtual field trips to historical sites or explore complex scientific concepts in a 3D environment. AI can also facilitate flipped classroom models, where students review lecture materials at home through AI-driven platforms and use classroom time for interactive activities and discussions. Tools like "**Animated drawings**" and applications such as "**Hello History**" can bring lessons to life, making complex topics more accessible and enjoyable. These innovative approaches not only capture students' attention but also enhance their understanding and retention of the material.

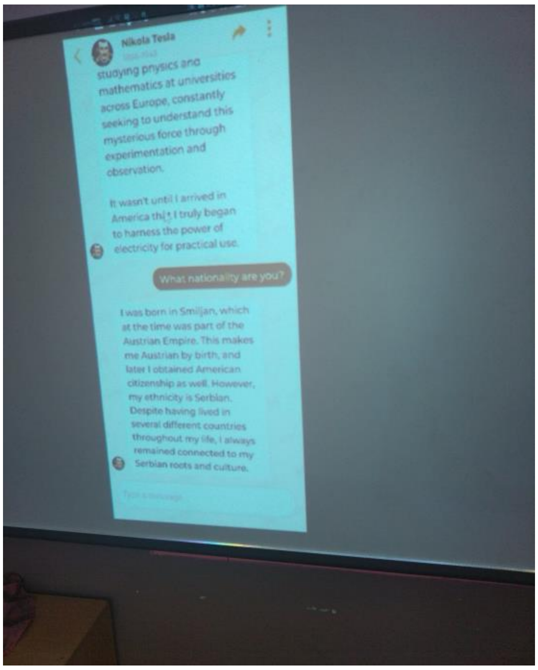

Figure 1. *Using app " Hello History"*

2.1. Students with special needs

AI can play a crucial role in supporting students with special educational needs and those from diverse backgrounds. For instance, **AI-driven tools** can provide personalized support for students with learning disabilities by offering customized exercises and feedback tailored to their unique needs. AI can also facilitate language translation and provide real-time subtitles, making learning more accessible for students who speak different languages.

Moreover, immersive technologies can be used to create interdisciplinary classes that cater to various learning preferences. Teachers can design inclusive educational materials using AI tools, ensuring that all students, regardless of their abilities or backgrounds, can participate fully and benefit from the lessons. By using AI, educators can create more inclusive classrooms that celebrate diversity and promote equity in education.

2.2. AI tools

When discussing AI tools in education, people often think of language models like **ChatGPT**. However, there are many other AI-based applications that are not large language models (LLMs) but still provide significant benefits. For instance:

EdTech Platforms: Adaptive learning platforms such as **MagicSchool** customize lessons based on student performance and learning pace.

AI driven tools like **Twee, Educaplay, Quizzes, Quizalize, Kwizzie** allow teachers to create quizzes that help students review key concepts and reinforce their learning. It is not obligatory to use AI support in this tools, but it significantly increases teachers' productivity and allows them to dedicate more time to developing lesson plans, engaging with students, and providing individualized support.

Content Creation: Tools like **Canva** and **Leonardo.AI**, powered by AI, help educators create visually appealing and interactive content for their classes.

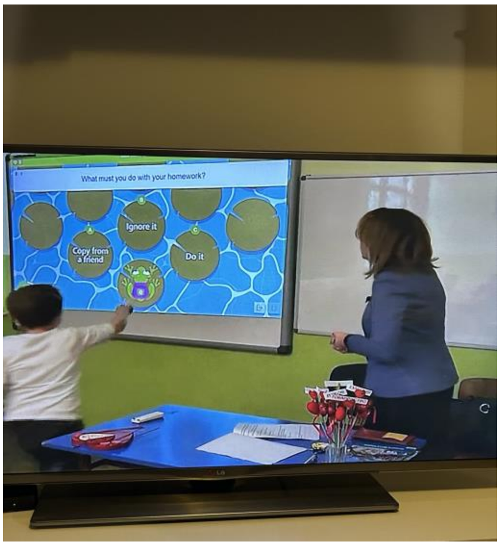

Figure 2. *Student is playing an AI game*

AI also offers numerous benefits for teachers, particularly in the domain of administrative tasks. By automating repetitive tasks, providing valuable insights through data analysis, and offering personalized support for students, AI allows teachers to focus more on what they do best: teaching and inspiring their students. This not only enhances the efficiency and effectiveness of the educational process but also contributes to a more engaging and supportive learning environment for all students.

2.3. AI in Academia

When it comes to teaching at the tertiary level, apart from the necessary subject-related knowledge and skills, the students are expected to develop certain academic skills, such as critical thinking, finding relevant and reliable sources, source-writing, academic writing, reflective writing, referencing, presenting, etc. [2]. While the newly emerged AI tools cannot (and should not) completely replace the students' ability to think cricitally, evaluate the sources they find, and reflect upon the content they read, they can facilitate and simplify the process of finding and analyzing literature.

For example, a tool called SciSpace has multiple functions. For one, it can create a relevant literature review about a certain topic; this is a similar function to the one of GoogleScholar or academic platforms such as ResearchGate or Academia, the main difference being that SciSpace filters the literature based on different criteria, so a researcher can sort the results by the number of citations, date published, or alphabetically. Moreover, the website has integrated tools such as citation generator, paraphraser, and AI detector. However, probably the most useful function for aspiring researchers is the tool for the analysis of the articles. By uploading an article, the user can choose which data they want extracted from the PDF: a TL;DR (short for: *too long, didn't read*) function which summarizes the whole paper, a summary of the abstract, conclusions, results, or methodology section and many more. This way, by uploading a greater number of files, one can compare and contrast the columns that are of importance for their research.

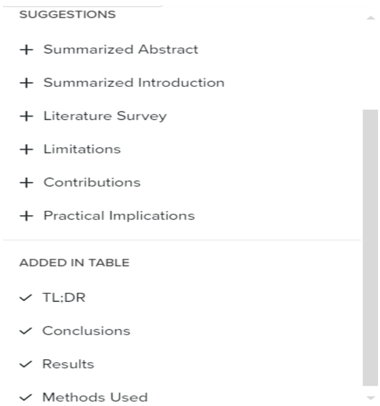

Figure 3. *SciSpace: Options 1*

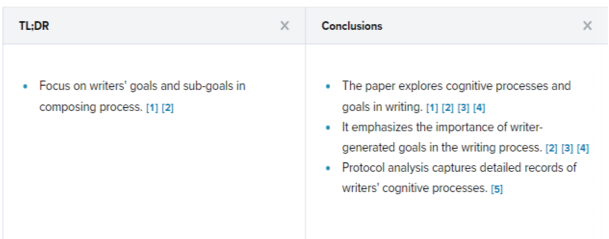

Figure 4. *SciSpace: Options 2*

These tools can drastically shorten the time needed for sorting out relevant sources from irrelevant ones. Furthermore, SciSpace can also help critically analyze a paper with the help of a function *Ask questions on a PDF*. Upon uploading a PDF, the AI will generate a number of questions related to this paper and motivate the researcher to think more thoroughly about its contents.

On the other hand, the development of Large Language Models (short LLMs) has made it incredibly easy to generate language content in the academic setting as well. Studies show that as much as 17% of peer reviewed articles are written by AI [3]. However, though this information is quite alarming, a greater threat to the academia might be that, as the same study shows, the reviewers actually prefer the AI-written papers to the ones written by humans (ibid.). Moreover, the relationship goes both ways: just like the reviewers prefer the AI-written papers, the researchers prefer the AI-written reviews to the ones written by humans. While more than half of the users found AI-generated feedback helpful or very helpful, a whooping 82.4% found the AI-feedback even more beneficial than human feedback [4]. On top of that, it seems that the AI can also be trained to spot errors in research papers. A group of researchers conducted a study in which they prompted the LLMs to review research papers and defined the instructions in detail [5]. Based on three different tasks including spotting various types of errors, the researchers conclude that, while the AI cannot just yet outperform humans in this field, it has a promising future as a reviewer tool.

Nonetheless, there seems to be a gray zone when speaking about AI-generated content. In order to be accessible to a wider audience, many papers are written in English by non-natives. For these purposes, some researchers will use various AI tools, such as Quillbot or Wordtune, or LLMs such as ChatGPT, to help them phrase their content in a proper way. While the content itself is written by the researchers, it is put through an AI filter and paraphrased. This rases a question of whether this AI-paraphrased content is also to be treated as AI-generated content? Moreover, some ethical concerns arise as well. For example, in order for the LLM to be able to write specific content, researchers have to feed it with information. This raises a concern of how ethical it is to enter the research data (be it only the research methodology, or a certain data corpus), since the AI uses these information to learn from them and might use them as an output for other users.

Instead of playing within the gray zone and risking plagiarism, LLMs can be used as a springboard for generating new ideas or refining the existing ones. For example, in the prompt, one can outline the main idea or the methodology of the research without revealing compromising data (such as data about the participants) and prompt the LLM to recomment strategies to refine the research questions to better align with the study's objectives or form hypotheses. Moreover, the LLM can give ideas about methods which would better suit the objective of the study and enhance the data analysis techniques. It can also be used as an interlocutor which would challenge the existing hypotheses by providing counter arguments or suggesting ways to strengthen the argumentation in the discussion section. If there is not a provided outline of the paper, it can also help by creating a structure and enhancing the writing flow. As long as it is used for brainstorming rather than generating the content that will be copied into the paper, it can be a great partner.

Last but not least, a challenge that the academia will inevitably face (and is already facing) is the topicality of the research. Due to the protocols, there is always a certain time gap between the time when the research is conducted and the date when it is published. However, the rapid development of the AI tools does not allow for a great time difference, since by the time the research is published, its findings might not be applicable anymore because the tools it referres to might be outdated. It is in this context and due to the pressure of topicality that even more researchers might resort to using AI tools for writing (parts of) their papers, though this seems to be a rather unstable approach. As Ethan Mollick notes, „Regardless of how good AI gets, the scientific publishing system was not made to support AI writers writing to AI reviews for AI opinions for papers later summarized by AI. The system is going to break." [6].

3. CONCLUSION

Despite the numerous advantages and conveniences that AI provides in our teaching profession, unfortunately, there are many abuses and ethical dilemmas. AI has become an indispensable part of all professions, not just teaching. Access to AI has been simplified and is available to students of all ages. Teachers have a moral and professional obligation to familiarize themselves with the possibilities of proper use of AI and guide students in the right direction. Considering the speed of technological development in the 21st century, students do not have well-developed critical thinking skills, and it is up to teachers to guide them on the difference between use and misuse and to help them develop the necessary digital skills.

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Regulating Artificial Intelligence for Higher Education

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Abstract: *Artificial Intelligence (AI) has paced its way into the area of education. This paper focuses on higher education, describing the current practice of teachers in the utilization of AI tools in the educational process. This shows that the usage of AI is left to the creativity of teachers, which entails their sole responsibility for the actualization of potential risks coming from the AI. From this starting point, the paper explains the need to regulate the process of design, development and the usage of AI in higher education. The focus of the paper is on the need to create the accountability framework, which will define the specific responsibilities of all the actors involved in the process of implementing AI in higher education.*

Keywords: *Artificial Intelligence; higher education; regulation; accountability*

1. INTRODUCTION

Artificial Intelligence (further in the text: AI) is a concept known for over 50 years, but the last decade is referred to as the AI renaissance [1]. The wide-ranging effects of AI are often discussed with regards to the industry requirements, and the impact it might have on the global economy. However, AI has the potential to impact society, affecting not only market flows and the race for new technologies, but also other areas which have the more direct effect to the well-being of the population. For example: labor market, environment, public sector… AI is treated as the pillar of the fourth industrial revolution, which is popularized through the term Industry 4.0 [2]. In this movement there are authors who believe that AI has already paced its way into the area of education, naming this process Education 4.0 [2]. Is it still early to acknowledge this kind of impact of AI? It is hard to answer this question, with not enough relevant research or empirical data to confirm or refute this notion, but we should not neglect that development and deployment of AI is a reality, and that there is already an ongoing debate on whether AI has the potential to replace the teachers [3].

The system of education is one of the most important components for the future progress of society. AI is still developing, and there is no final answer to what extent. Hence the impact AI might have on education is not to be neglected. So, should the implementation of AI to educational system be spontaneous, left to the opportunism of the moment? Or, can it be that we reached the point in which we need to plan, organize and regulate AI? If we strive to put AI into the service of social development, who should be accountable for the missuses? Should we focus on the developers of AI? Should accountability lie with the decision-makers who enabled the usage of AI in higher education? Did we identify those decision-makers? Is there a need to look for accountability further in the system? This paper is trying to offer some answers to these questions. The structure of the paper is as follows: part 2. of the paper describes current uses of AI in higher education as well as potential problems of this usage. Part 3. of the paper explains why regulation of AI is an issue of high relevance, especially for the system of higher education. In this part, the paper identifies some of the documents, such as guidelines or ethical codes, which have already been adopted and implemented. The paper, also, looks at the practices and adopted regulations for AI in the Republic of Serbia, and points out the issues identified in the system of higher education in this country. Part 4. of the paper focuses on the one specific matter that should be regulated through normative acts: the problem of accountability. The paper argues that there needs to be an accountability map, which would identify all the relevant actors who might affect the way AI is utilized in the system of higher education. The accountability of these actors must be subordinated to strict rules, if we are to have a strategically planned system of higher education for modern society. The part 4. of the paper concludes.

2. THE PRACTICE OF USING ARTIFICIAL INTELLIGENCE IN HIGHER EDUCATION

The relevant literature has identified educational processes in which AI might have adequate and effective usage. These processes are grouped into the following areas: school administration [4], teacher-student interaction, teaching methods and strategies, teaching content and students' assessment and monitoring [1]. AI may automate administrative tasks such as admissions, keeping track of attendance, timely homework delivery… This should add to efficiency and reduce potential human errors in processing data [4]. Potentially, AI might serve to personalize the learning process and adapt it to the specific needs and affinities of each student. AI can collect and analyze data that show the educational history, student's interests, subjects in which the student has best results, but also teaching units which the student mastered with difficulty. The gathered information should serve to create a path for student's advancement through studies, with regards to student's needs for specific learning content. Also, AI might suggest means of presenting teaching content, learning models, and the pace of teaching which would best accommodate the student's learning potential. This enables teachers to act as mentors, who guide students through their studies to reach students' competencies and learning outcomes in the most effective way. The usage of AI also enables the constant and rapid innovation of teaching materials, so that the learning content is not outdated. Also, the potential of AI is seen in aiding teachers to evaluate students, through constant monitoring and regular evaluation of students' progress [1]. AI is seen as a promise to relieve the teachers of their workload, so they can commit to a student-centered approach in learning. Since AI can analyze large amounts of data, the educational system can benefit from its predictive skills to detect which students might drop out. AI has the prospect of making the current learning systems more efficient [5].

However, AI must not be observed one-sided, with regards only to the benefits it offers. We must be aware of the risks it carries. The usage of AI implies that there is digital literacy among students, teachers and administrative staff. At this stage, there is a need to improve the knowledge needed to better apply AI [4]. Also, there is a need to provide equal opportunities, so we need to be aware that AI requires access to technology, which might create inequalities among students and lead to social division [6]. The usage of AI tools has already manifested bias in making automated decisions, which would go against the core values of higher education [7]. Since AI might process data about students to keep track of their progress and predict learning outcomes, data protection and privacy rights became the issues of high relevance [5].

There are growing concerns about the unethical usage of AI. AI tools are becoming easily accessible. The best example is ChatGPT, developed by Open AI in 2022, exceedingly popular among students. This trend has raised the question about steering the utilization of AI in the right direction. AI might generate text that can be simply copied to the students' or researchers' work, which imposes a particularly important issue on the implications AI might have on academic competency [8]. Generating text that the students and researchers might present as their own implies the need to rethink the development of their creativity, cognitive and logical skills [8]. Also, no less important is the question of maintaining academic integrity [9]. The harnessing of AI must be governed by ethical standards and rules which enable the fulfillment of higher education principles. There are blurred lines in the ethics of AI usage: when is AI simply a tool which helps students with their workload, and when does it become an instrument for plagiarism [9]?

The usage of Chat GPT and similar AI tools, also pose the very important question about long-term effects on developing the students' skills [4], especially in terms of critical thinking, because ChatGPT is not designed to deliver the true facts, but to give the impression of providing human-like text [10].

How do the ideas outlined in the previous section reflect in our system? In the Republic of Serbia, higher education system is regulated by the Law on Higher Education [11]. It is envisaged as an open environment for the implementation of new achievements in science and the creation of new knowledge. Also, study programs must reflect the social demand and be responsive and adaptive to the advancement in technology development. They should be designed to prepare the students for the labor market requirements of modern society. Thus, the system of higher education should not be isolated from the potential benefits brought by AI and should be prepared to mitigate the risks it bears.

There is exploratory research conducted among 103 teachers in Serbia, in Belgrade [12]. The data gathered was analyzed to gain information about teachers' knowledge of AI and their perceptions of AI application in higher education institutions. For this research, a survey with multiple-answer questions was designed. The answers were analyzed qualitatively, using the Likert scale. The authors of this research state that there should be a more thorough representative sample analysis, but it gives us a glimpse of the potential uses of AI by teachers in higher education institutions in Serbia.

The conducted research shows that the teachers in Serbia are aware of the possible advantages of AI inclusion in teaching process [12]. The usage of AI by teachers in Serbia is in line with the teaching processes suitable for AI implementation, as identified in the relevant literature [1]. For example, teachers find that AI might help them prepare materials for lectures or help them produce the best way to teach those materials. By using AI teachers engage students in the learning process, or they use AI to help them evaluate students' progress. But the problem is that the teachers' motivation to use AI depends more on the opportunities, rather than the challenges, presented by AI [12]. These findings suggest that the usage of AI in higher education is rudimentary, based on personal preferences of individual teachers. Also, even though during COVID 19 pandemic, the system of higher education was faced with the challenge of digitalization, there is still a need for digital literacy enhancement among teaching staff.

3. THE NEED FOR REGULATING ARTIFICIAL INTELLIGENCE

It is already recognized that AI is rapidly developing and that it has the potential for high impact on all aspects of society. Notions of sociotechnical systems in which human and technical resources coexist in a collaborative approach, are becoming increasingly relevant [13]. They suggest that for the future progress of any subsystem within the given social order (in this case the system of higher education) this interplay must be considered. AI is neither mere artifact nor traditional social system: technological properties, the usage of AI systems and the outcomes of this usage are still unpredictable [13]. So, we find ourselves before the question: should the system of higher education be short-sighted and isolated from the trend of AI exploitation? Or is it better to be prepared by recognizing the shortcomings of our resources, risks, and potential doubts?

At this point we already know that to promote the movement towards greater employment of AI in the higher education system, firstly we need to deal with digital illiteracy [12]. These are the basic requirements, and potentially they might absorb a lot of time and energy. But raising awareness of the importance of new technologies and learning new skills is a step forward to the innovation of the educational process. Bearing that in mind, organizing and managing human resources to be more adaptive to changes, has its rationale. Dealing with digital illiteracy and scarcity of AI technology expertise [12], are basic prerequisites for AI utilization. How to take one step further in this process?

The rapid development of AI tools, their accessibility and openness for usage in everyday activities, means that they can be substantial asset in the enhancement of the higher education quality. But to really benefit from this asset, we must utterly understand what the advantages it offers are and what are the risks it employs. The relevant literature, as shown in part 2. of this paper, is already informative of the prospective benefits of AI in higher education. But also, it may help us understand its downsides and the barriers our current system has that may prevent us from fully harnessing improvements AI offers.

The research conducted among teachers in Serbia [12], offers us a glimpse at what is the nature of AI usage. The utilization of AI in higher education in Serbia is currently unorganized and institutionally unplanned. The application of AI is not goal-oriented; rather it is spontaneous and without a clear vision of what should be the purpose of further exploitation of AI tools, or how it can help the process of higher education quality enhancement.

When AI is put in the context of higher education, it is mostly to emphasize the need to prepare the students for the changing future by incorporating studying AI in curriculums [6]. This is also the case in our country. The government is preparing The Strategy for Artificial Intelligence development in the Republic of Serbia for the period 2024 – 2030 [14]. The process of preparing this document included open debate and dialogue, and all the interested stakeholders had the opportunity to send suggestions on the document proposal, or to present them in public events organized by the government [15]. The document points to the need to innovate study programs, so they include learning about AI. The proposed Strategy also envisages the application of AI in scientific research and higher education, by using AI tools in teaching process and research, investing in proper equipment, organizing workshops and trainings which might enhance students' and teachers' AI literacy, supporting collaborative projects with companies that engage in AI development. The proposed strategy also suggests that there is a need for implementing a proper regulatory framework for further AI development [14].

The concerns that AI usage is raising, such as issues of equality, access, discrimination, loss of privacy, malicious use of AI, pedagogy, organizational structures, negative impact on quality of education [4], show that it is of the great importance to develop proper policy that will guide the process of AI inclusion into the higher education system [6].

On an international level, UNESCO developed guidelines for policy-makers, which call for ethical use of AI [4]. These guidelines focus on the need to educate both teachers and students about AI, to create lifelong learning which would generate knowledge for usage of AI tools through different generations. UNESO guidelines recognize the need for governments to implement regulatory frameworks which will ensure responsible development and use of AI in the education sector.

UNESCO, in cooperation with the Chinese Government, organized the International Conference on Artificial Intelligence and Education in Beijing in 2019, which resulted in adopting the

"Beijing Consensus on AI and Education" [16]. The Beijing Consensus offers policy recommendations which reflect a collective understanding of issues brought by AI.

The global community has already recognized the need to go one step further and to create an appropriate legal framework for designing, developing, and deploying AI [17]. There is already an ongoing debate on has the race to AI lead to race to AI regulation, with US, EU and China trying to take the lead in the field [18]. AI is a technology which surpasses national borders. This calls for a global commitment to find the appropriate hierarchy level or regulatory bodies to pass AI legislature. However, there is still no consensus on how to answer the challenge of AI regulating. Also, there is still no unified answer on where imperative norms should come into play, and to what extent more loose obligations should be the regulatory standard [18]. The challenges to regulating AI come from the very nature of the technology we wish to put in the regulatory brackets. AI is considered to be the "umbrella term" which consists of different applications which are constantly changing. Also, we may be faced with the so-called "AI-effect" which means that by habitual use and exposure new technologies over time lose their "intelligent" status [18]. This makes regulatory "capture" of AI difficult.

The nature of AI creates obstacles in predicting its further development. This feature demonstrates the high relevance of ethical norms or guidelines in context of regulating AI. They offer a route on which the development and usage of AI should be kept, but at the same time, they provide enough width for further research and growth. The Republic of Serbia has brought Ethical guidelines for the development, application, and use of reliable and responsible artificial intelligence (further in the text: Ethical guidelines) [19]. This document calls for reliable and accountable AI and determines certain standards that must be met as a basis for designing, development and utilization of AI systems. The standards should foster public trust in AI systems, and those are: explainability and verifiability, dignity, prohibition of damages and fairness. The goal of the Ethical guidelines is to allow science, especially in the field of AI, to develop and progress, but not to allow the endangerment and neglect of humankind. AI systems that are being developed must be in line with the well-being of humans, animals, and the environment. Ethical guidelines describe AI systems that can be used in higher education as high-risk systems. High-risk systems are not undesirable *per se,* but given the field which they might impact on, it is necessary to constantly monitor their effect and analyze their operation. Ethical guidelines recognize the need to further regulate AI, but that is yet to happen in our country [19].

What is the significance of the global movement for regulating AI and the introduction of Ethical guidelines for the system of higher education?

Regulation of AI should resolve the concerns AI raises, outlined in part 2. of this paper. But also, it should create a framework which would enable the institutionalized implementation of AI in higher education system. That means enabling structured, planned, goal-oriented approach, balanced with the resources that higher education currently has. Regulating AI in the context of higher education should encompass the path for introduction of well-planned and coherent learning models, in which all participants have clearly defined roles and levels of accountability.

4. THE PROBLEM OF ACCOUNTABILITY

Why should accountability have a central role in regulating AI? The simple answer is because of its significance for preserving the integrity of the system, and public trust. Put in context of higher education, which means attracting more students and ensuring modern, useful, and socially justifiable students' competencies.

The current practice of utilization AI tools in higher education demonstrates that the central role is based on teachers who are willing to use AI in their teaching process [12]. They may opt to use AI when they find it convenient. But if AI generates any risks, it is up to those teachers to mitigate or overcome them. From the legal perspective, this approach puts too much discretion in the hands of teachers, which is not guided by any rules or goals on the role of AI in the system of higher education. At the same time, the whole responsibility for framing the AI tools as reliable (when using them in teaching process) is also put on the individual teachers.

There are numerous examples where the question of accountability might come into play. AI might generate inaccurate teaching content. Although not from the field of higher education, the newspaper headlines already provide an illustrative example of this risk. This is a story of an American lawyer who used AI tools to prepare a legal brief for the court. AI created fake cases, which lead to court considering sanctioning the lawyer. But also, this example triggered the issue of whether the bar associations or the State should regulate the usage of AI by lawyers (from the loose obligation to notify the client to prohibition of such practice) [20]. The relevant literature also provides examples of AI generating biased and discriminatory decisions [7]. This would go against the core principles of higher education system which guarantees respect for human rights and civil liberties, including the prohibition of all forms of discrimination [11]. What if AI creates errors in analyzing data from monitoring students' progress, which results in false evaluation? The usage of AI is not restricted to teachers only. The students also use AI to help them with their tasks, such as making presentations or writing essays. This raises the question of plagiarism detection, and an even more important question on whether the utilization of AI helps students gain any knowledge or simply help them get their grades. Students must be educated about the boundaries in usage of AI: what constitutes ethical breaches? What is cheating with AI and why not do it? Also, they must be informed that unethical behavior must be sanctioned.

At the current state-of-the-art in Serbia, the responsibility to manage the risks lies on the teachers who are willing to use AI in teaching process [12]. If the usage is rudimentary, there is a great probability that the teacher is going to be able to control the process. However, the higher education system should not be based on probabilities. Also, what if we were to implement AI in the system of higher education on a bigger scale, with greater extent? The sole accountability of teacher might have deterrent effect. Also, would it be fair?

Generally speaking, accountability in AI relates to the expectation that designers, developers and users will comply with standards and legislation to ensure the proper functioning of AI during its lifecycle [13]. The current practice does not show how we can pinpoint the accountability for the actualization of the risks of AI utilization in higher education. At this point, we can only identify the teachers as the accountability backbone. But to have a coherent framework for planned application of AI tools, we need to move beyond individual responsibility to hold accountable all the relevant actors in the system [17].

Beijing Consensus on AI and Education [16] recognizes that AI might be used to serve different actors, such as students, teachers, parents, and communities. This recommendation serves to point out the idea that we need to create the accountability map. AI might have an impact on different groups, so the accountability for ethical and responsible use of AI cannot lie in the hand of the sole actor, who is the teacher. Accountability for AI needs to be mapped as a shared responsibility to accommodate all the interests involved in the educational process.

The Law on Higher Education in Serbia regulates different levels of decision-making in the system of higher education, which include: the Government, National Council for Higher Education, National accreditation body, University Conference, Authorities of higher education institutions, as well as teachers [11]. All these actors must find an adequate place in the accountability map for the ethical and responsible use of AI.

It is still unknown how AI will affect society [4]. That is why we need to make accountability stricter. We need to divide accountability to ensure all parts of the system are equally involved in harnessing benefits and mitigating the risks brought by AI. The process of designing shared responsibility must be based on a strategic approach. Firstly, it must consider many challenges brought by AI, identify the level of decision-making, which is best to address the challenge at issue, and align all the stakeholders' interests to serve the specific goal: enhancement of the quality of higher education. The UNESO guidelines propose that communities of expertise should be brought together to inform the key decisions in policy planning [4]. This might add to raising awareness that every actor in the higher education system has a specific role, and as such, must bear the portion of accountability for the ethical and responsible use of AI tools. Such practice would protect the rights of teachers and enable them to properly position the value of their pedagogical practices in the system infused by AI.

Currently, researchers and developers often design for teachers only at the end of the process [4]. This is a very important issue, because when developing AI tools for higher education the technology experts might transfer their own perception and knowledge on learning process [5]. This might lead to AI designs which are not in line with pedagogic principles, or they may emphasize the teaching practices which are outdated or not preferred by teachers, nor by the students. The development of AI tools must be put in the specific educational context, which supports new initiatives in developing the modern teaching environment [5]. This concern shows that the designers and developers of higher education AI systems must be included in the accountability map.

Policymakers should be aware that addressing the accountability of AI developers is another issue, which is very hard to link to the requirements of higher education system. Technological progress is in the hands of a few tech-giants. Companies strategically promote ethics as part of their public relations to delay or avoid binding regulation [17]. They do so because ethical rules and guidelines are not enforceable, so they are not bound by these rules. The regulatory framework must take a balanced approach to the competing interests at stake. Companies promote the rapid development of technology usually for the purpose of market domination and creating profit. Higher education is in the domain of public interest. But they are in the interplay which should be reflected in both ethical and legal norms that aim to regulate AI.

The issue of accountability for ensuring ethical and responsible development and utilization of AI tools must have its place in the regulatory framework designed for AI in higher education system. Mapping all the actors who must bear the responsibility for using AI to improve higher education needs to overcome the accountability gaps: a phenomenon in which when faced with distributed responsibility nobody feels obliged to prevent the risks. On the other hand, another problem may be the multiplication of those held responsible, which means overlapping of accountability schemes, or accountability surpluses [13]. In both cases the result is an inefficient regulation which lacks the capacity to introduce the novel requirements for an increase in quality of higher education, as presented by AI.

The described problems underline the idea that has already been identified by researchers tackling the usage of AI: "technological tide will wash over us" [21]. The appropriate answer to not having this scenario would be to create accountability framework which would disable the blame-shifting possibility [21]. This calls for good governance, with a task to ensure that all expectations about the benefits of AI are met [13]. Given the importance of higher education system, good governance should be provided through a formal framework – a normative act which puts all parts of the system into the service of reliable and responsible usage of AI.

5. CONCLUSION

The Ethical guidelines recognize AI systems in higher education as high-risk systems. High-risk profiling of higher education AI systems comes from the potential impact they might have on society. High-risk characteristic emphasizes the need for constant monitoring and analyzing of these systems [19]. Regulating AI for higher education might impose specific rules for monitoring processes. Also, analysis of AI systems and their outputs must balance the need for innovations with the set goals: integrity of higher education and quality enhancement. A well organized and structured accountability scheme adds to fostering trust in the usage of AI. Designing appropriate and applicable legal rules should have a more collaborative approach between all the relevant actors involved in the process from the development to the final stage of AI utilization. Starting a public dialogue may provide a forum for better understanding AI. This all must be in the service of creating a stable environment for the introduction of AI in higher education, where students are going to be protected from the potential risks and enabled to use all the advantages of this modern concept for further social development. Good regulation is needed to guide this process, thus focusing on the fullest exploitation of the strengths brought by AI.

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Learning Challenges and Performance in the Databases Course

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Abstract: *The Databases is a core course in computing disciplines since almost all systems require data storage component. Teaching a database course, in general, is a challenging task, due to several factors, such as increasing expectations of the job market, limited time frames of a regular semester system, to name a few. Nowadays, many organizations are turning to NoSQL databases as their preferred system of capturing and storing massive amounts of data, which is actually one of the many challenges and possible improvements in teaching. Therefore, it is likely that employees in all sizes of organizations will encounter NoSQL databases. At the Faculty of Technical Sciences in Čačak, relational databases are studied in the second year of studies, and the students enrolling in these studies have different prior knowledge in this field. This study examines the possibilities of teaching improvements to the Database course, such as the introduction of NoSQL databases, problem-based learning, solving practical problems, designing, gamification, etc., so that future database designers acquire the advanced level of knowledge required at the market. A survey of second-year students was conducted to determine their views and attitudes towards the Database course improvements.*

Keywords: *database; education; SQL tools; NoSQL*

1. INTRODUCTION

Over the last decade, databases have become a very important factor that has an impact on humans' lives, in almost all spheres of life. The traditional Database course teaches students about concepts and skills, such as entities, relationships, normalization, and data structuring, that are geared around relational databases. Standard Query Language is typically used to create tables and store data in databases. Students need to query data in order to build knowledge from them.

However, increasing demands of big data force companies to turn to NoSQL databases, as their preferred system, i.e. as one of the challenges and possible improvements in the sphere of business and education [1]. No-SQL, which is an acronym for Not Only SQL, databases refer to high-performance, non-relational data stores. Instead of joining tables of normalized data, NoSQL stores unstructured or semi-structured data [2]. Hence, it is almost inevitable for employees in organizations to encounter NoSQL databases. In order to meet the requirements of the market, students need to be introduced to this technology.

Our analysis related to the Databases course involves students enrolled in the second year at the University of Kragujevac, Faculty of Technical Sciences in Čačak. A survey was applied to the Databases course and the participation was optional and anonymous, in order to increase the freedom of the students responses.

In the first part of the semester, students learn about database fundamentals. The second part of semester is devoted to SQL and is applications. A survey was applied at the end of the semester, after the examination period, to all the 130 students that were enrolled in the course.

The goal was to analyze their perceptions related to the Databases course, their knowledge level, and attitude towards new materials and learning challenges, such as the introduction of NoSQL databases, solving practical problems in accordance with social needs, problem-based learning, designing, gamification, i.e. the integration of game elements into non-gaming environments in order to increase the engagement, motivation and performance of students in education, etc., which other authors have encountered in related work.

The rest of this paper is structured as follows: Section 'Related work' goes through different approaches faced by other professors, and proposes solutions to increase the efficiency, first of all of the database course, but also of other courses. Section 3 describes survey design and methodology used in the research. Section 4 discusses results obtained in the survey. Finally, in

Section 5, a conclusion and the future work are presented.

2. RELATED WORK

The application of the concept of education based on outcomes, as the main strategy for teaching reform was presented in the paper [3]. A series of reform measures and solutions from the aspects of formulating teaching goals, optimizing teaching content, innovation of teaching methods, optimization of experiment design, system innovation, evaluation, etc. was described. Outcome-based education is a type of educational mode that focuses on nurturing students' ability to solve practical problems according to social needs. Therefore, all aspects of this educational method are designed and implemented close to the students.

Through research [4], the authors argue that problem-based learning (PBL) provides a powerful framework for introducing database concepts to a wide range of students. Designing, i.e., database modeling, presents complex problems with multiple possible solutions. Database problems are necessarily interdisciplinary and involve both problem domain and technical expertise, supporting some real goals. Therefore, common problems in the database domain align with PBL definitions of good problems.

In [5], the authors deal with the term "Gamification", namely the integration of game elements into non-gaming environments, in order to increase student engagement, motivation, and performance in education on the computer science and software engineering study program. Namely, this view prompted the authors to create "QueryCompetition", a web system, that allows students to practice SQL in a competitive environment with the aim of obtaining empirical evidence on how elements of "Gamification", such as challenges, points, and leaderboards, integrated into this environment, affect student performance, motivation, and user experience. They conducted an experimental study with two groups of students in the Database course. One group used a gamified version of this system with access to points and leaderboards, while the other used a non-gamified version without access to the above elements. Quantitative and qualitative data were collected through tests and a survey. The results showed that there was a statistically significant improvement in student performance in the gamified group compared to the non-gamified group. In addition, higher motivation was observed in the gamified group. The results presented in this paper support the claim that the inclusion of challenges, points, and leaderboards, together with the competitive nature of the "QueryCompetition", positively affects student performance and motivation to practice SQL in their education and further career progression.

Through the conducted research [6] the authors came to the conclusion that dealing with psychological problems is essential for improving motivation, goodwill, and increasing skills and abilities, which can be correlated with students and their performance through education and their motivation. According to the authors of this paper, people belonging to all professions experience psychological problems in their personal and professional lives. The measures that should be implemented in providing solutions to psychological problems are: forming an effective social circle, working in a team, alleviating loneliness, strengthening cordiality and kindness in relationships, good information about work duties and responsibilities, good equipment in terms of methodologies and procedures, strengthening a constructive approach, receiving counseling and guidance, and creating a pleasant business and educational environment, which further leads to the improvement of personality traits and enrichment of living standards. The benefits of providing solutions to psychological problems lead to increased levels of motivation and concentration, improving one's career prospects, and increasing skills and abilities.

In his work [7], the author examines the process of transferring knowledge on the database in the higher education system, the current state, the form of organization of training, methods used, tools, organizational work, and their problems and shortcomings, and analyzes ways to overcome them. Through survey, students noted the problems in the database courses, such as more theory than practice, the old pedagogical technologies, limited database training, etc. The author suggests practice-oriented learning technologies in the classroom in order to overcome the mentioned problems.

The study presented in [8] explores and analyzes the learning tendencies of students enrolled in different lines of study related to the Databases course. Through a survey authors concluded that students prefer learning only the basic information that could help them achieve their goals: creating an application or using it at work. Authors in [9] conducted a systematic literature review by selecting research papers published between 1995 and 2021. They have also discussed how the developed teaching and learning assistant tools, methods, and database curricula have evolved over the years due to rapid change in database technology. The article also provides useful guidelines to the instructors, and discusses ideas to extend this research from several perspectives.

The authors in [1] propose the inclusion of essential knowledge about NoSQL in a traditional relational databases course. A NoSQL unit with an Excel-based NoSQL database example has been designed and introduced to business students. The authors state that the design and delivery of the NoSQL unit demonstrated that knowledge about NoSQL is practicable and very useful for business students. Teachers who wish to incorporate a small unit of NoSQL in their traditional database course for all business students can find this paper very useful, according to the authors.

3. SURVEY DESIGN AND METHODOLOGY

A questionnaire has been developed to propose online to students of the second year of academic studies at the Faculty of Technical Sciences in Čačak, University of Kragujevac. The questionnaire consisted of eight questions. The first three questions were related to higher school, the subject and the software tool used for databases, if any. The fourth question considered grade that was obtained after listening to the Database course. The next question was divided into eleven sub-questions that were related to the knowledge level of specified areas that were covered in the Database course. The students were asked to evaluate them using the one-to-five Likert type scale. In the next question, students have to choose one of the four statements that best describe their current readiness to work with databases. In addition, there was one open question to collect the students' opinion about the course in general. Questionnaire is given in Table 1.

Table 1. *Questionnaire: Improvement of teaching in the Databases course*

1. Choose your high school.	Grammar school
	Economic school
	Technical school
	Machine and transport school
	Catering school
	Other
2. Did you learn about databases in your high school?	
3. Which database tools you used in high school?	I didn't use any database tool
	MySQL
	Access
	phpMyadmin
	PostgreSQL
	APEX
	Some other tool
4. The grade I received in the course Databases is:	
5. On a scale from 1 (very poor) to 5 (very good), evaluate your KNOWLEDGE LEVEL for the specified areas that were worked on in the course Database.	
Modeling: Databases concepts	1 2 3 4 5
Modeling: Resolving M:M relationships	1 2 3 4 5
Relational model	1 2 3 4 5
Relational algebra	1 2 3 4 5
Normalization: I, II and III Normal Form	1 2 3 4 5
Entity-Relationship model to Relational model	1 2 3 4 5
SQL: Introduction	1 2 3 4 5
SQL: One table query	1 2 3 4 5
SQL: JOIN	1 2 3 4 5
SQL: Functions	1 2 3 4 5
SQL: Subqueries	1 2 3 4 5
6. Based on your previous experience in the Databases course, choose the statement that best describes your current readiness to work with databases.	I'm not sure I can design a database (even for a very simple example)
	I can design a simple database by myself, but it takes me a lot of time to do it.
	I can design databases for systems of medium difficulty, with someone's help
	I can independently design databases for complex systems
7. Do you think it is necessary to improve the Database course with the new areas such as NoSQL databases (currently in demand on the market)?	Yes
	No
	I don't know
8. If you have a suggestion on how to improve the Database course, you can write it in the field below.	

4. RESULT ANALSYS AND DISCUSSION

The questionnaire was administered online using JotForm[1] software. A total number of 93 students filled out the questionnaire. The data was electronically downloaded into the table, which eliminated the need for manual entry. The aims of the questionnaire were to find out if there is a relationship between students' prior knowledge in databases and their current knowledge level and to find out what the students' opinion is about the improvement of the Database course with the new areas, such as NoSQL databases. The "IBM SPSS Statistic 21" statistical package (evaluation version) was used for data analysis. Cronbach's reliability coefficient is (α = 0.745), which indicates an acceptable level of reliability of the used questionnaire. The contribution of individual statements was determined by analyzing the arithmetic mean, standard deviation, corrected total correlation coefficients, and Cronbach's alphas after deleting each of the questions at the level of the entire questionnaire.

After analyzing the obtained results, several conclusions can be drown.

Concerning prior education, the majority of students came from Technical school (60.2%) and Grammar school (20.4%). Over half of students (54.8%) worked with some database tool in high school. Out of the total number of respondents, 83.9% passed the exam, 9.7% failed the test, and 6.5% still didn't take the exam (Table 2). It should be noted that there are 130 students enrolled in the second year, and that 37 students didn't fill out the

[1] www.jotform.com

questionnaire, so the high percent of passing the exam is somewhat lower.

Table 2. *The grade I received in the Database course is:*

		Frequency	Percent
Valid	I didn't take the exam	6	6.5
	I didn't pass the exam	9	9.7
	6	12	12.9
	7	11	11.8
	8	23	24.7
	9	14	15.1
	10	18	19.4
	Total	93	100.0

One may conclude that students that have prior knowledge on databases should score better than those who listen about databases for the first time. However, application of the Pearson Chi-Square test (p=-0.282) shows a negative correlation between the variable "Did you learn about databases in your high school?" and "The grade I received in the course Databases is:". This could be explained by the fact that students who had databases in high school pay less attention to lessons because they think they already know material. Unlike them, students who learned about databases for the first time pay more attention during the class and make more efforts in order to master material more easily.

Table 3 summarizes results obtained from question 5. Analyses revealed that students, in their opinion, gained the highest level of knowledge in the areas *SQL: Introduction* (54.8%) *and SQL: One table query* (58.1%). On the other hand, they rated *Normalization* and *SQL subqueries* with the lowest marks concerning knowledge level, 11.8% and 10.8%, respectively.

Table 3. *KNOWLEDGE LEVEL for the specified areas (%)*

Subject area	Poor	Average	Good	Very good
Modeling: Databases concepts	2.2	19.4	36.6	41.9
Modeling: Resolving M:M relationships	1.1	24.7	30.1	44.1
Relational model	6.5	21.5	34.4	37.6
Relational algebra	4.3	21.5	40.9	33.3
Normalization: I, II, III NF	11.8	24.7	20.4	43.0
Entity-Relationship model to Relational model	4.3	21.5	31.2	43.0
SQL: Introduction	2.2	11.8	31.2	54.8
SQL: One table queries	2.2	9.7	30.1	58.1
SQL: JOIN	3.2	17.2	36.6	43.0
SQL: Functions	6.5	20.4	35.5	37.6
SQL: Subqueries	10.8	19.4	32.3	37.6

The first is due to its abstraction nature, because normal forms are learned on the entity-relationship models, not on tables themselves. As for the SQL subqueries area, it is the last lesson taught at the end of the semester when the number of students is significantly reduced. When taking the exam, for most students, creating a subquery is the most difficult task.

In the continuation of the analysis, the methods of descriptive statistics (more precisely, frequency table) are applied. Out of the total number of respondents, 59.1% think that they can design a database for a system of medium difficulty, with someone's help. However, there are still students (6.6%) who are not sure if they can design databases, even if it is for the very simple system.

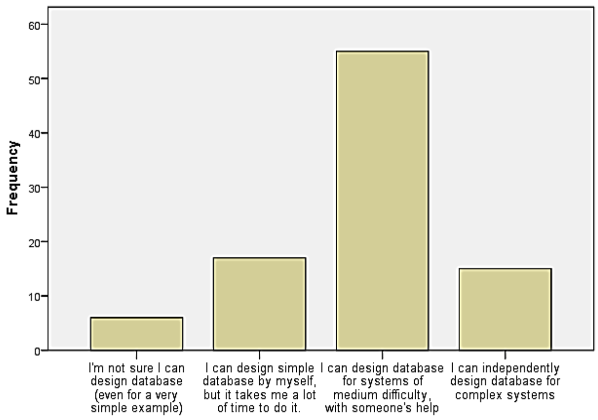

Figure 1. *Based on your previous experience in the Databases course, choose the statement that best describes your current readiness to work with databases.*

Finally, according to the analysis, the majority of students (66.7%) agree that the Database course should be improved in order to meet the needs of market demands, while 17.2% of students disagree. The rest of them (16.1%) are not sure about improvement. Tabe 4 shows distribution of answers for the improvement and the previous knowledge about databases. Pearson Chi-Square was p=0.205, which indicates dependents of two variables, i.e. students who had databases in high school seek to upgrade their knowledge. However, which is maybe more important, 57% of students who didn't learn about databases show a positive attitude about course improvement with new areas such as NoSQL databases.

Table 4. *Crosstabulation of variables: Did you learn about databases in your high school? * Do you think it is necessary to improve the Database course with the new areas, such as NoSQL databases (currently in demand on the market)?*

		Do you think it is necessary to improve the Database course with the new areas such as NoSQL databases (currently in demand on the market)?			Total
		Yes	No	I don't know	
Did you learn about databases in your high school?	Yes	38	7	6	51
	No	24	9	9	42
Total		62	16	15	93

5. CONCLUSION

Improving the quality of the educational process is one of the most important tasks. The need for research in the area of databases arose due to the growing demand for improving the knowledge of students, in order to meet the demands of the market. Since many companies use it to collect big data, NoSQL is quickly becoming an integral part of modern information systems [2].

Analysis of the results from the conducted survey shows that prior knowledge in databases has a partial influence on current students' knowledge level enrolled in the Database course. Analysis also reveals students' willingness to upgrade their knowledge level with new areas such as NoSQL databases.

Future work will focus on improving areas that students mark as the most difficult ones. Also, once the students learn how to query traditional databases, they will be introduced to a NoSQL database management system.

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Session 5:

Professional Development for the new Technological Environment

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The Analysis of IT Competencies in the Hospitality Related Study Programs in the Republic of Serbia

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Abstract: *Following the trends of modern tourism development and the expansion and adoption of new technologies, the hospitality industry is constantly improving its service, which is most commonly based on information technologies. The stated situation is noticeable in the two main segments of the hospitality industry – the hotel and restaurant industry and in most activities carried out before, during, and after the guest’s stay. Depending on the tasks performed, human resources in the hospitality industry must have adequate competencies to use the available IT. Thus, their adequate education is necessary. The subject of this paper is the analysis of IT competencies in the hospitality-related study programs in the Republic of Serbia. The aim is to determine the presence of IT courses (compulsory/elective) in hospitality study programs implemented at institutions of higher education in the Republic of Serbia. The study programs were analyzed according to the type and level of study and ownership type of the institutions that implement them. Study programs accredited during or after 2017, whose name directly refers to the hospitality industry, were included in the analysis.*

Keywords: *education; HEIs; curriculum; hospitality studies; competencies*

1. INTRODUCTION

The constant development of information technology (IT) necessitates a change in the way business is conducted in the hospitality industry. Changes are noticeable in both branches of hospitality:

- Hotel management (primarily focused on providing accommodation services) and
- Restaurant management (primarily focused on providing food and beverage services).

The introduction of new technologies and the necessity of obtaining skills to use them can be identified as future trends in human resource employment in tourism and hospitality. These primarily refer to "new working models, digitization, and robotization," as well as skills such as "management, analytical, digital marketing, and customer behavior analysis" [1]. Technology can have both positive and negative impacts on employment [1].

The existing curricula of hospitality-related higher education programs should be reformed to respond to the increasingly significant role that advanced technologies play in the hospitality industry. The inclination towards big data competence presents an example [2]. In the post-COVID-19 era, one of the focal points in adjusting the curricula of tourism and hospitality study programs in higher education should be technology. Thus, the focus is primarily on introducing artificial intelligence (AI), virtual reality (VR), and big data (BD) [3]. Modifications of the existing curricula, due to the influence of technological changes on education in hospitality, need to be implemented through mandatory cooperation between education and industry [4].

On the other hand, besides implementing IT into curricula, it's crucial to implement them into the teaching process [5]. Modern information and communication technology (ICT) has changed how students communicate with each other and their teachers [6]. There is undoubtedly a vigorous tendency to use ICT among students. This tendency should be utilized to enhance the teaching process while simultaneously introducing IT and ICT education so that students acquire proper competencies. There are two ways to achieve this:

- by introducing new IT subjects into study programs or
- by introducing IT competencies into existing subjects in study programs.

Serbia is an example of a country continuously striving for IT development through a comprehensive digitalization process. The strategic focus on technology and artificial intelligence is particularly noticeable [7, 8]. Thus, attention should also be directed towards educating future professionals, both managers and other employees in the field of IT.

In line with the above, the subject of this paper is the analysis of IT competencies in the hospitality-related study programs in the Republic of Serbia. The aim is to determine the presence of IT courses (both compulsory and elective) in hospitality study programs that are implemented at higher education institutions (HEI) in the Republic of Serbia.

2. METHODOLOGY

The analysis was conducted from March 5th to March 7th, 2024, following the example of other similar research studies [9, 10]. Table 1 represents the phases of the analysis.

Table 1. *The phases of the analysis*

Phase	Subphase
1 Identification of the study programs' sample	• Compilation of a list of study programs accredited in the Republic of Serbia from 2007 until the beginning of the analysis – March 2024 [11]. • Identification of study programs whose names directly suggest hospitality or one of its main segments – hotel and restaurant management. The potential presence of hospitality in particular modules of study programs not listed in [11] is not further considered. • Identification of study programs accredited in 2017 or later (option for enrollment in the first year of study for the academic year 2023/2024). • Identification of HEI study programs whose curricula are available on their official websites.
2 Analysis of the presence of IT subjects in the previously identified study programs	• Coding data about subjects in study programs using Microsoft® Excel® 2019. • Extraction of subjects whose names suggest they belong to the IT field in study programs. • Analysis of the presence of IT subjects in the curricula of selected hospitality study programs according to various criteria and comparison of the obtained results.

3. RESULTS AND DISCUSSION

A total of 14 hospitality study programs were analyzed. These study programs are implemented at two universities, two academies of professional studies, and four independent higher professional schools (see Table 2). We may conclude that the majority of HEIs offering hospitality study programs belong to the category of professional study institutions.

Table 2. *HEIs where hospitality programs are implemented*

University / Academy	Departments of University /Academy or independent HEI
Academy of Applied Studies Belgrade	• The College of Hotel Management Belgrade
Academy of Professional Studies Southern Serbia	• Department of the Leskovac Business School
„Singidunum" University	• Studies at the University, Belgrade • Higher Education Unit outside the seat of the institution without legal entity, Novi Sad • Higher Education Unit outside the seat of the institution without legal entity, Niš
The University of Kragujevac	• Faculty of Hotel Management and Tourism, Vrnjačka Banja
-	• Higher Business School of Professional Studies "Prof. dr Radomir Bojković", Kruševac
-	• Higher Education Technical School of Professional Studies, Novi Sad
-	• Higher Professional School of Organizational Sciences "EDUKA", Belgrade
-	• Higher School of Professional Studies for Management and Business Communication, Zemun

The structure of hospitality study programs is presented in Table 3. According to the criterion of the type of study, the majority belongs to the category of professional studies (8 study programs, 57.14%).

Table 3. *Structure of hospitality study programs*

Criteria	Categories	Number	Percentage
Level of study	Undergraduate	10	71.43
	Master	3	21.43
	PhD	1	7.14
Type of study	Professional	8	57.14
	Academic	6	42.86
Type of HEI ownership	State	8	57.14
	Private	6	42.86

The average hospitality study program in the Republic of Serbia is regarded as undergraduate professional studies implemented at a state HEI.

3.1. Level of study

Table 4 contains basic descriptive statistical data about the number of IT subjects present at different levels of study.

IT subjects are present in all study programs at all levels of study considered. The highest maximum number of IT subjects in a study program is recorded in the undergraduate study program, while the highest minimum number and mode are in the PhD study program. The average number of

IT subjects is the lowest in the master's study program.

Table 4. *Level of study – the number of IT subjects*

		U	M	D
All	Max	5	2	2
	Min	1	1	2
	Avg	2.00	1.33	2.00
	Mod	1	1	2
Compu-lsory	Max	2	0	0
	Min	1	0	0
	Avg	1.20	0.00	0.00
	Mod	1	0	0
Elective	Max	5	2	2
	Min	1	1	2
	Avg	0.80	1.33	2.00
	Mod	1	1	2
Notes: U – undergraduate study programs; M – master study programs; D – PhD study programs.				

Compulsory IT subjects are only present at the undergraduate level, specifically in all undergraduate study programs. There are no compulsory IT subjects at master's or PhD levels.

Elective IT subjects are present at all three study levels: a) all master and PhD study programs and b) three undergraduate study programs (33.33%). The highest average number, highest minimum number, and mode of elective IT subjects are at PhD level. The highest maximum number of elective IT subjects is at the undergraduate level.

The average number of compulsory subjects is higher than the average number of elective subjects in undergraduate studies. However, the maximum number of elective subjects in undergraduate studies is higher when compared to compulsory subjects – other indicators are identical.

Table 5 contains data on the percentage participation of compulsory and elective IT subjects in the total number of IT subjects at different levels of study.

Table 5. *Level of study - percentage participation of compulsory and elective IT subjects*

		U	M	D
Compu-lsory	Max	100.00	0.00	0.00
	Min	20.00	0.00	0.00
	Avg	80.33	0.00	0.00
	Mod	100.00	0.00	0.00
Elective	Max	80.00	100.00	100.00
	Min	0.00	100.00	100.00
	Avg	19.67	100.00	100.00
	Mod	0.00	100.00	100.00
Notes: U – undergraduate study programs; M – master study programs; D – PhD study programs				

Given that only elective IT subjects are offered, the average participation of elective subjects and other indicators (maximum, minimum, and mode) at master's and PhD levels is higher when compared to undergraduate studies, amounting to 100.00%. At the undergraduate level, indicators of the percentage participation of compulsory subjects are higher than those of the elective subjects.

3.2. Type of study

Table 6 contains data on the number of IT subjects in different types of study.

Table 6. *Type of study – the number of IT subjects*

		Professional	Academic
All	Max	4	5
	Min	1	1
	Avg	1.50	2.33
	Mod	1	1; 2
Compu-lsory	Max	2	1
	Min	0	0
	Avg	1.13	0.50
	Mod	1	0; 1
Elective	Max	2	4
	Min	0	0
	Avg	0.38	1.83
	Mod	0	2

IT subjects are present in all types of study programs considered. When comparing professional and academic studies, we conclude that the indicators mentioned in the previous table, except for the minimum (identical in both types of studies), are higher in academic studies.

Compulsory IT subjects are present in both types of studies, especially in the majority of professional study programs (7 study programs, i.e., 87.50%) and half of the academic study programs (3 study programs). Professional studies have higher maximums and averages, while the other indicators are consistent.

Elective IT subjects are present in both types of studies, namely: a) one-fifth of professional study programs (2 study programs); b) 83.33% of academic study programs (5 study programs). Academic studies have a higher average, maximum, and mode when compared to professional studies. The minimum is identical.

In professional studies, the average number and mode of compulsory subjects are higher when compared to elective subjects, while other indicators are identical. In academic studies, the average number, maximum number, and mode of elective subjects are higher when compared to compulsory subjects, while the minimum is the same.

Table 7 contains data on the percentage participation of compulsory and elective IT subjects in the total number of IT subjects in different types of study.

The average percentage of participation and mode of compulsory subjects are higher when compared to elective subjects in professional studies. The same indicators for the elective subjects' participation are higher than in compulsory subjects in the case of academic studies. Other indicators (maximum and minimum) are identical.

Table 7. *Types of study – percentage participation of compulsory and elective IT subjects*

		Professional	Academic
Compulsory	Max	100.00	100.00
	Min	0.00	0.00
	Avg	81.25	25.56
	Mod	100.00	0.00
Elective	Max	100.00	100.00
	Min	0.00	0.00
	Avg	18.75	74.44
	Mod	0.00	100.00

3.3. Ownership of the HEIs that implement the study programs

Table 8 contains data on the number of IT subjects observed from the perspective of ownership of the HEIs that implement the study programs.

Table 8. *Ownership of the HEIs that implement the study programs – the number of IT subjects*

		State	Private
All	Max	5	4
	Min	1	1
	Avg	2.00	1.83
	Mod	1	1
Compulsory	Max	2	2
	Min	0	0
	Avg	0.88	1.00
	Mod	1	1
Elective	Max	4	2
	Min	0	0
	Avg	1.13	0.83
	Mod	0	0

IT subjects are present in all study programs regardless of whether they are implemented at state or private HEIs. When comparing studies conducted at state and private HEIs, we conclude that the maximum and average number of IT subjects are higher in studies at state HEIs (other indicators are identical).

Compulsory IT subjects are present in studies conducted at both state and private HEIs. Compulsory IT subjects are present in most study programs both at state and private HEIs. However, a higher percentage of study programs conducted at private HEIs implement compulsory IT subjects (5 study programs, i.e., 83.33%) when compared to the study programs conducted at state HEIs (5 study programs, i.e., 62.50%). Study programs conducted at private HEIs display a higher average number of compulsory IT subjects, while the other indicators are identical.

Elective IT subjects are present in studies conducted at both state and private HEIs. Elective IT subjects are present in half of the study programs conducted at both state and private HEIs. Study programs conducted at state HEIs display a higher maximum and average number of elective IT subjects, while the other indicators are identical.

In study programs conducted at state HEIs, there is a higher maximum and average number of elective subjects compared to compulsory subjects, but the mode is descending (the minimum is identical). Study programs conducted at private HEIs have a higher average number and mode of compulsory subjects compared to elective subjects (other indicators are identical).

Table 9 contains data on the percentage participation of compulsory and elective IT subjects in the total number of IT subjects in study programs conducted at private/state HEIs.

Table 9. *Ownership of the HEIs that implement the study programs – percentage participation of compulsory and elective IT subjects*

		State	Private
Compulsory	Max	100.00	100.00
	Min	0.00	0.00
	Avg	52.50	63.89
	Mod	100.00	100.00
Elective	Max	100.00	100.00
	Min	0.00	0.00
	Avg	47.50	36.11
	Mod	0.00	0.00

The average percentage participation of compulsory subjects is higher when compared to elective subjects in study programs conducted at private HEIs, as the same participation indicator of elective subjects is higher than compulsory subjects in the case of study programs conducted at state HEIs. Other indicators are identical.

3.4. Undergraduate Academic Studies

Table 10 contains data on the number of IT subjects in undergraduate academic studies.

Table 10. *Undergraduate academic studies - number of IT subjects*

		A	S	P
All	Max	5	5	3
	Min	1	5	1
	Avg	3.00	5.00	2.00
	Mod	-	5	-
Compulsory	Max	1	1	1
	Min	1	1	1
	Avg	1.00	1.00	1.00
	Mod	1	1	1
Elective	Max	4	4	2
	Min	0	4	0
	Avg	2.00	4.00	1.00
	Mod	-	4	-

Notes: A – all study programs; S – study programs implemented at state HEIs; P – study programs implemented at private HEIs

IT subjects are present in all undergraduate academic study programs considered (3 study programs). The average number of IT subjects is 3.00, the maximum is 5, and the minimum is 1. The average, maximum, and minimum number of IT subjects are higher in study programs conducted at state HEIs (1 study program) when compared to those at private HEIs (2 study programs).

Compulsory IT subjects are present in all undergraduate academic study programs, whether conducted at private or state HEIs. Each of the study programs has one compulsory IT subject.

Elective IT subjects are present in 2 study programs of undergraduate academic studies (66.67%), i.e., in all study programs conducted at state HEIs (1 study program; 4 subjects) and in half of the study programs conducted at private HEIs. The average number of elective IT subjects is 2.00, the maximum is 4, and the minimum is 0. The average, maximum, and minimum number of elective IT subjects are higher in study programs conducted at state HEIs (1 study program) when compared to those at private HEIs (2 study programs).

Table 11 contains data on the percentage participation of compulsory and elective IT subjects in the total number of IT subjects in undergraduate academic studies.

Table 11. *Undergraduate academic studies – percentage participation of compulsory and elective IT subjects*

		A	S	P
Compu-lsory	Max	100.00	20.00	100.00
	Min	20.00	20.00	33.33
	Avg	51.11	20.00	66.67
	Mod	-	20.00	-
Elective	Max	80.00	80.00	66.67
	Min	0.00	80.00	33.33
	Avg	48.89	80.00	33.33
	Mod	-	80.00	-

Notes: A – all study programs; S – study programs implemented at state HEIs; P – study programs implemented at private HEIs

By comparing compulsory and elective IT subjects, we conclude that the average (51.11%), maximum (100.00%), and minimum percentage participation (20.00%) of compulsory IT subjects regarded in the total number of IT subjects in undergraduate academic study programs is higher. This ratio differs in study programs conducted at state and private HEIs. In study programs conducted at state HEIs, the percentage participation of elective subjects is higher when compared to the compulsory subjects. Study programs conducted at private HEIs display higher average and maximum percentage participation of compulsory subjects compared to elective subjects, while the minimum participation is identical.

Table 12 contains an overview of IT subjects in undergraduate academic study programs.

Table 12. *Undergraduate academic studies – IT subjects*

	State institutions	Private institutions
Compulsory courses	• Business Informatics	• Information Systems in Tourism and Hotel Management • Business Informatics
Elective courses	• Information Systems Development • Quantitative Software Analysis in Hotel Management and Tourism • Business Information Systems • Information and Communication Technologies in Hotel Management and Tourism	• Digital Marketing • Information Systems in Tourism and Hotel Management

Business Informatics plays a prominent role among compulsory IT subjects. Subjects related to Information Systems are the most prevalent among elective IT subjects.

3.5. Undergraduate Professional Studies

Table 13 contains data on the number of IT subjects in undergraduate professional studies.

Table 13. *Undergraduate professional studies – number of IT subjects*

		A	S	P
All	Max	4	2	4
	Min	1	1	1
	Avg	1.57	1.25	2.00
	Mod	1	1	1
Compu-lsory	Max	2	2	2
	Min	1	1	1
	Avg	1.29	1.25	1.33
	Mod	1	1	1
Elective	Max	2	0	2
	Min	0	0	0
	Avg	0.29	0.00	0.67
	Mod	0	0	0

Notes: A – all study programs; S – study programs implemented at state HEIs; P – study programs implemented at private HEIs

IT subjects are present in all study programs of undergraduate professional studies considered (7 study programs). The average number of IT subjects is 1.57, the maximum is 4, and the minimum is 1 (mode – 5 study programs, i.e., 71.42%). The average and maximum number of IT subjects are higher in study programs conducted at private HEIs when compared to those at state HEIs, while the minimum number and mode are identical.

Compulsory IT subjects are present in all study programs of undergraduate professional studies, whether conducted at private or state HEIs. The average number of IT compulsory subjects is 1.29, the maximum is 2, and the minimum is 1 (mode – 5 study programs, i.e., 71.42%). The average number of compulsory IT subjects is higher in study programs conducted at private HEIs when compared to those at state HEIs, while the other indicators (maximum, minimum, and mode) are identical.

Elective IT subjects are only present in 1 study program of undergraduate professional studies (14.29%; 2 subjects). This study program is conducted at a private HEI and represents one-third of such study programs. We conclude that there are no elective IT subjects in study programs conducted at state HEIs. The average number of elective IT subjects in undergraduate professional studies is 0.29, the maximum is 2, and the minimum is 0 (mode – 6 study programs, i.e., 85.71%).

Table 14 contains data on the percentage participation of compulsory and elective IT subjects in the total number of IT subjects in undergraduate professional studies.

Table 14. *Undergraduate professional studies – percentage participation of compulsory and elective IT subjects*

		A	S	P
Compu-lsory	Max	100.00	100.00	100.00
	Min	50.00	100.00	50.00
	Avg	92.86	100.00	83.33
	Mod	100.00	100.00	100.00
Elective	Max	50.00	0.00	50.00
	Min	0.00	0.00	0.00
	Avg	7.14	0.00	16.67
	Mod	0.00	0.00	0.00

Notes: A – all study programs; S – study programs implemented at state HEIs; P – study programs implemented at private HEIs

By comparing compulsory and elective IT subjects, we conclude that the average (92.86%), maximum (100.00%), and minimum percentage participation (50.00%), as well as the mode (100.00%), of compulsory IT subjects in the total number of IT subjects in undergraduate professional studies, are higher. This ratio differs in study programs conducted at state and private HEIs because there are no elective IT subjects in study programs conducted at state HEIs; all subjects are compulsory. This situation results in compulsory IT subjects displaying an average and minimum percentage participation of 100.00% in study programs conducted at state HEIs, which is higher participation when compared to study programs conducted at private HEIs (maximum and mode are identical). In study programs conducted at private HEIs, elective IT subjects display a maximum and average percentage participation higher than those in study programs conducted at state HEIs (minimum and mode are identical).

Table 15 presents a summary of IT subjects in undergraduate professional studies.

Table 15. *Undergraduate professional studies – IT subjects*

	State institutions	Private institutions
Compulsory courses	• Informatics in Hotel Management • Informatics • Information Systems in Tourism • Application of Information Technologies / Information and Communication Technologies	• Informatics in Business • Informatics and Mathematics in Hospitality • Business Informatics • Information Systems
E.C.	-	• Communication Technologies • E-business

Informatics is prevalent among compulsory IT subjects. In this category of IT subjects, subjects related to information systems are also noticeable.

3.6. Master Academic Studies

IT subjects are present in all master academic study programs considered (2 study programs). IT subjects are offered at private (1 study program) and state HEIs (1 study program). Each study program has one IT subject classified as elective. There are no compulsory IT subjects.

Table 16 provides a review of IT subjects in master academic studies.

Table 16. *Master academic studies – IT subjects*

	State	Private
C.C.	-	-
E.C.	• Internet Technology	• Intelligent Software Application in Tourism

3.7. Master Professional Studies

There is only one hospitality-related master professional study program at a state HEI. The only IT subject in this study program, classified as an elective. There are no compulsory IT subjects.

Table 17 provides a review of IT subjects in master professional studies.

Table 17. *Master professional studies – IT subjects*

	State	Private
C.C.	-	-
E.C.	• E-business in Hotel Management	-

3.8. PhD Academic Studies

There is only one hospitality-related PhD program at a state HEI. And there are 2 IT subjects, both classified as electives. There are no compulsory IT subjects.

Table 18 provides a review of IT subjects in PhD academic studies.

Table 18. *PhD academic studies – IT subjects*

	State	Private
C.C.	-	-
E.C.	• Intelligent Information Systems • Management of Tourism Resources through GIS	-

4. CONCLUSION

Regardless of the level and type of study and ownership of the institution that implements them, all hospitality study programs offer IT subjects. In terms of the level of study, master programs have the fewest IT subjects, while compulsory subjects are only present in undergraduate programs (all study programs), and compared to electives, they constitute the majority of IT subjects. Elective IT subjects are present in all master's and PhD study programs and one-third of undergraduate study programs.

Regarding the type of study, academic studies implement more IT subjects compared to professional studies. Compulsory subjects are present in the majority of professional and half of academic studies, while elective subjects are present in the majority of academic and one-fifth of professional studies. In academic studies, elective subjects constitute the majority of IT subjects. However, in professional studies, compulsory subjects comprise the majority of IT subjects.

On average, state studies implement more IT and elective IT subjects, while private studies implement more compulsory subjects. Compulsory subjects are present in the majority of state and private studies. However, the average number of compulsory subjects is higher in state ones. Elective subjects are present in half of the study programs – state and private. When we compare compulsory subjects to elective ones, they have a higher share in IT subjects in both state and private studies, but the share is higher in private ones.

We also examined individual undergraduate academic, undergraduate professional, master academic, master professional, and PhD academic studies at state and private HEIs. Undergraduate academic studies especially highlight Business Informatics (compulsory) and subjects in the sphere of Information Systems (elective), while undergraduate professional studies focus on Informatics (compulsory).

The proposal is that IT competencies are developed as subject and cross-subject competencies. The subjects should be divided into five groups:

- Informatics;
- E-business;
- IT and systems in hospitality;
- Digital marketing in hospitality;
- Robotics and artificial intelligence in hospitality.

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Trends and Development Challenges of Entrepreneurial Education in Serbia

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Abstract: *In the era of globalization and rapid technological changes, entrepreneurship emerges as a key factor in economic development and innovation. Entrepreneurial education, as a systematic preparation of individuals to be effectively implemented in systemic education and entrepreneurial ventures, represents a crucial component of this process. The field of entrepreneurial education faces numerous challenges that need to be recognized in all spheres of the educational system to ensure its effectiveness and relevance. The aim of this paper is to present the current state of entrepreneurial education in Serbia which was achieved through curriculum analysis at different levels of education.*

Keywords: *entrepreneurship; vocational schools; HEIs; curriculum; informal education.*

1. INTRODUCTION

Entrepreneurship, as the driving force of economic growth and innovation, represents an important aspect of modern society. The development of entrepreneurial spirit and skills is becoming more and more important in the context of a rapidly changing and technologically advanced world economy. In this sense, entrepreneurial education appears as a key element in enabling individuals to understand and effectively participate in this dynamic environment. In modern society, where entrepreneurial activity has become a key element of national and international economic strategies, the importance of entrepreneurial education cannot be overestimated. Entrepreneurship education plays a critical role not only in creating new entrepreneurs, but also in fostering innovative and creative thinking within existing organizations.

According to Schøtt, Kew, and Cheraghi, in traditional society young people were not encouraged to actively engage in the world of entrepreneurship [1]. It was believed that through work experience one gains maturity and knowledge and that through work young people can develop entrepreneurial characteristics and become entrepreneurs. Education and the immediate environment did not influence the encouragement of young people to develop their entrepreneurial potential and become entrepreneurs, what more the environment that includes family and other informal actors who can help young people to raise funds and start their entrepreneurial idea did the exact opposite and disincentivized young people by refusing to help them. One of the main reasons is the fact that they did not want to invest in people without experience. Even today, this represents one of the main problems in the process of developing youth entrepreneurship and a stumbling block at the very beginning of the development of an entrepreneurial idea, although the situation is changing for the better and there are changes in the norms and value system in which young people who decide on entrepreneurship are supported and they see as an extremely valuable part of society [2]. Entrepreneurial potential is seen today as a phenomenon that should be nurtured and encouraged through the education system and socialization as well as through training programs and trainings. Young people are supported more and more in their entrepreneurial endeavors, both emotionally and financially, and successful young entrepreneurs become so-called Community stars [1]. Many researches today deal with young people and their entrepreneurial potential, intentions and competencies that they can improve through various education programs and trainings [3]. Beginning entrepreneurs are much younger today than in previous generations [1]. Solomon [4] states in his research that there is a great need for the development of entrepreneurship education throughout the world. Authors Aronsson and Birch [5] believe that it is necessary to create entrepreneurship programs that have the capacity to adapt the curriculum and incorporate into it the development of entrepreneurial competencies in the domain of sales, management and product development. In his research [6], Jones comes to the conclusion that entrepreneurship education may not statistically contribute directly to the opening of a greater number of new businesses, but he believes that entrepreneurship education is very important for the development of specific skills that are crucial for the development of future academic citizens, in a way that modern society expects them.

The main goal of this paper was an overview of the state of the entrepreneurial education in Serbia which was achieved through the search of Serbian HEI's for entrepreneurship related study programs. Paper also gives an insight into the state of entrepreneurial education in secondary education, as well as the legislation overview from the mentioned domain.

2. ENTREPRENEURIAL EDUCATION CHALLENGES IN SERBIA

The definitions of entrepreneur and entrepreneurship are numerous and varied – there is no single and generally accepted definition, but each of them to a certain extent refers to knowledge, skills and competencies related to business, proactivity, productivity and innovation with the prism of creativity. It is important to point out the difference between the terms "entrepreneur" and "acting entrepreneurially", because in the first case it is about any natural or legal person who starts an independent business, and in the second about the coherence of knowledge, skills, attitudes or the ability to recognize opportunities, that is, chances in the environment and their implementation for the benefit of future, or current business.

When defining the concept of entrepreneurship education, it is very important to mention the evolution of the same concept with reference to the Republic of Serbia, as one of the countries where the evolution has become more frequent. So, in Serbia, the development of entrepreneurial education followed global trends, with an increasing number of programs and initiatives at all levels of education. However, there are still challenges regarding the quality and relevance of the program, as well as regarding the integration of entrepreneurship education into the country's broader development strategy.

Contemporary entrepreneurial education is a dynamic field that is constantly developing and adapting to the changing needs of the market and society. Global trends are shaping the way entrepreneurship is taught and practiced, opening up new opportunities and challenges for educators, students, and entrepreneurs [7].

Although global trends significantly influence the development of entrepreneurial education, local initiatives and approaches play a key role in adapting these trends to the specific needs and context of Serbia. Some of the key aspects of local tendencies in entrepreneurship education are [8]:

- Cooperation between educational institutions and the economy;
- Focus on the development of the entrepreneurial ecosystem;
- Promoting entrepreneurship among young people;
- Utilization of local resources and potential;
- Adapting to the needs of different target groups.

The lack of resources is one of the key challenges in the implementation of entrepreneurial education in Serbia. This problem manifests itself on several levels [9] and affects the quality and availability of programs, as well as their effectiveness in fostering entrepreneurial spirit and skills. Those levels are created according to the following hierarchical diagonal method (from the most important missing resource):

- Financial resources, which are reflected as limited financial support and lack of financial incentives;
- Human resources, which are reflected in the lack of qualified lecturers and the lack of mentors and advisors;
- Material resources, which are reflected in the lack of modern equipment and materials and the lack of space for work and cooperation;
- Institutional resources, which are reflected in the form of lack of support from educational institutions and lack of cooperation with the economy (dual education).

Resistance to the traditional education system represents a significant challenge in the implementation of entrepreneurial education in Serbia. This resistance manifests itself in different ways and makes it difficult to integrate entrepreneurial principles and skills into existing educational structures [10]. Some of the crucial ways of resistance manifestation are:

- Focus on theory and not on practice;
- Lack of flexibility;
- Resistance to changes;
- Lack of support;
- Lack of awareness of the importance of entrepreneurship.

Overcoming these challenges requires a strategic approach that includes [10]:

- Education and training of teachers;
- Promotion of entrepreneurship;
- Cooperation with the economy;
- Flexibility and innovation.

3. ENTREPRENEURIAL EDUCATION TRENDS IN SERBIA

The systematic design of entrepreneurial education in Serbia is regulated by a series of documents that have been adopted in recent years.

The umbrella law of the education system in the Republic of Serbia is the Law on the Basics of the Education System [18]. It sets the foundations of the system of preschool, primary and secondary education and upbringing, namely: principles, goals and standards of education and upbringing, methods and conditions for carrying out activities of preschool upbringing and education, primary and secondary education and upbringing, types of education and upbringing programs, establishment, organization, financing and supervision of the work of institutions, as well as other issues of importance for education and upbringing.

Each form of entrepreneurial education has its advantages and disadvantages, and it cannot be claimed that one is the best. Their combination can be the optimal solution, and continuous entrepreneurial education during the lifelong educational system becomes a necessity to stay on the market. Entrepreneurial education should not be limited only to young people, but should also include older generations who want additional knowledge and business excellence. Awareness of the importance of entrepreneurship and education is already included in this model, and the key challenge remains to make this a widely accepted way of thinking and seeing the world.

3.1. Vocational Secondary Schools

The Law on Secondary Education and Upbringing [19] in Article 11, which refers to the content of the school curriculum, states that it contains "programs and activities that develop problem-solving abilities, communication, teamwork, self-initiative and encouragement of the entrepreneurial spirit", as well as a program of career guidance and counseling.

In Serbia in 2005, an analysis by the Ministry of Education and Sports in the Government of the Republic of Serbia determined that, in addition to good initiatives at the national, regional and local levels, a comprehensive plan for the thorough and adequate implementation of entrepreneurship in education is still missing [11].

The following is a collaboration of the most commonly applied pilot programs at universities in the global world, with an aspect on consolidation with teaching and educational processes of entrepreneurial education:

- Student Entrepreneurship Program [12],
- Secondary Vocational Education Reform Program [13],
- Junior Achievement Young Enterprise [14],
- GTZ project for professional education in the period from 2020-2012 [15].

The expected outcomes of this and other general and cross-curricular competencies are currently defined only at the basic level. Concrete outcomes for entrepreneurship and entrepreneurial orientation are as follows:

- The student understands the importance of personal initiative and shows proactivity in getting to know the characteristics of the labor market (requirements of jobs, way of working of institutions, positioning in the business world).
- Understands the principles of the functioning of the labor market and understands the need for continuous training in accordance with the development of the market and the demands of employers.
- He is able to identify and adequately present his skills and abilities (strengths); knows how to write a CV and motivation letter.
- He knows how to express and defend his ideas, as well as to influence others through the skills of public speaking, negotiation and conflict resolution.
- Has the ability to set realistic goals, assess and accept risks; plans and manages resources (knowledge and skills, time, money, technologies and other resources) with a focus on achieving goals.
- Knows how to communicate with employers; knows how to negotiate; he is ready for practice and volunteering while respecting the agreement [20].

3.1.1. Entrepreneurship as a subject

Within the first phase of the Secondary Vocational Education Reform Program (2003-2005), which was financed from CARDS EU funds, new and refined old curricula were developed for 20 sample profiles in 50 sample schools from five areas of work (agriculture and food processing, health and social protection, construction and geodesy, mechanical and electrical engineering). As an important novelty and as an integral part of these 20 sample profiles, the subject of entrepreneurship was developed and introduced into the curricula. The course program itself is adapted to the field of work and to each of the educational profiles within which it is realized [19].

The first teacher training included 15 entrepreneurship teachers from agricultural schools, who, with the support of experts from the Secondary Vocational Education Reform Program, continued to train future entrepreneurship teachers through six regional seminars lasting two days each.

The second phase of the Vocational Education Reform Program was implemented from December 2005 to May 2008. Similar to the first phase, the project was implemented through several key areas with the aim of implementing new vocational education strategies based on partnership with the economy, professional development of employees in education, implementation of new teaching programs, provision of quality training for adults, constant innovations in teaching process and modernized school infrastructure. 22 pilot schools were included in the second phase of the reform process.

According to Ministry of Education, Science and Technological Development data, secondary vocational schools are in the 2013/14 school year. had 287 profiles classified into 15 sectors, of which 166 were four-year profiles (42 experimental), and 121 were three-year profiles (9 experimental). This means that today, if we take into account the 19 sample profiles that were translated into the regular system by 2013/14 the subject entrepreneurship is implemented in 70 educational profiles, it is on the list of compulsory subjects with a fund of 62-64 hours per year and is implemented in the final year of schooling with the insistence that active teaching methods are used in its implementation.

3.2. Higher Education

When it comes to higher education, the reform that began in the early 2000s led to a series of changes in the structure of studies, changes in subject content, rationalization of study plans and programs, greater mobility, etc., which contributed to certain positive changes in many areas of higher education.

Following the new paradigms of education, it is worrisome that in higher education in Serbia, according to Paunovic, it is evident "a very small number of private and state faculties (mostly economic, business or management-oriented faculties) that deal with this issue and that offer their students the opportunity to they learn something more about entrepreneurship. In the minority there are also faculties where entrepreneurship has the status of a special subject, and in the majority of faculties where certain segments of entrepreneurship are studied within other subjects" [16].

And in the Education Development Strategy itself until 2020, the models just mentioned are stated:

- "Continuous development of measures leading to increased employment"
- Introduction of research elements and contents that encourage entrepreneurship,
- All higher education institutions should train students for the development of innovation and entrepreneurship;
- "Entrepreneurial University"
- Encouraging the creation of business incubators in higher education institutions,
- The use of multidisciplinary approaches in the process of creating entrepreneurial spirit and skills [17].

By analyzing the accredited study programs of the first, second and third degree (Table 1), we came to the conclusion that entrepreneurship appears in the names of 27 study programs, 19 academic higher education institution and 31 educational and scientific disciplines.

3.3. Informal education

Entrepreneurship cannot be adequately explored through a single perspective approach, and learning about it is not limited to formal educational institutions. It goes beyond those frameworks with its complexity and includes different forms of learning, including non-formal and informal education.

Informal and informal education are often intertwined, but in this context we will treat them as similar because individuals in both varieties show self-initiative in learning. This can be achieved through various educational centers and cultural and educational institutions. In Serbia, there are 108 such centers [21]. Many of them are focused on teaching foreign languages or computer science, but there are also those that offer broader programs, such as the Academy Education Center in Čačak. In addition to providing language and IT courses, this center also offers training in modern business, retraining, preparation for university studies and development of intellectual skills. However, there are few centers that offer specific courses on entrepreneurship.

Table 1. *Higher education institutions, study programs and courses from the field of entrepreneruship*

HEI	Course	Study program	Year	Status	YA
Faculty of Economics UNIKG	Entrepreneurship management	BAS Economics and Business Management (Module 1 Management and Modul 2 Marketing, Tourism and Hotel Management)	3	C/E	2020
Faculty of Economics UNIBG	Entrepreneurship and Small Business Management	BAS (240 ESPB) Economics, Business Management BAS (180 ESPB) Economics, Business Management and Statistics	3	C	2020
Faculty of Economics in Subotica, UNINS	Entrepreneurship	BAS Economics study program BAS Business Informatics	4	E	2023
Faculty of Technical Sciences in Čačak, UNIKG	Entrepreneurial innovation Basics of entrepreneurship Economics of entrepreneurship	BAS Entrepreneurial Management	1 2	E C	2009 2014
	Entrepreneurial Management	MAS Entrepreneurial Management	1	C	2021
University of Belgrade	Entrepreneurship	MAS Entrepreneurial Management - TEMPUS	1	C/E	2011
College of Business Economics and Entrepreneurship Belgrade	Entrepreneurship	BAS Business Economics and Entrepreneurship	3	C	2012 2015
		MAS Business Economics and Entrepreneurship	1		2012 2015
College of Business Economics and Entrepreneurship Belgrade, Čačak	Entrepreneurship	BAS Business Economics and Entrepreneurship	3	C	2012 2015
		MAS Business Economics and Entrepreneurship	1		2012 2015

HEI	Course	Study program	Year	Status	YA
Belgrade Academy of Business and Art Vocational Studies in Čačak	Entrepreneurship	BAS Management	2	E	2021
Faculty of Economics in Čačak, University of Priština	Entrepreneurship	BAS Business Economy	4	C	2021
Union Nikola Tesla University, Belgrade	Basics of entrepreneurship	BAS Entrepreneurial business	2	C	2016 2023
	Entrepreneurial Management		3	C	
	Innovation and entrepreneurship	BAS Real estate management	4	E	
	Management of entrepreneurship				
Union Nikola Tesla University, Belgrade - studies at the university	Entrepreneurship and Creativity	MAS Management and Entrepreneurship	1	C	2016 2023
Union Nikola Tesla University, Belgrade, Faculty of Entrepreneurial Business without legal personality	Basic of entrepreneurship	BAS Entrepreneurial business	2	C	2011
	Entrepreneurial management				
	Innovation and entrepreneurship		3		
Union Nikola Tesla University, Belgrade, Faculty of Entrepreneurial Business without legal personality	Entrepreneurship and Creativity	MAS Management and Entrepreneurship	1	C	2011
Faculty of Organizational Sciences "Eduka" Vocational School of Entrepreneurship, Belgrade	Entrepreneurship	BVS Entrepreneurship management	2	C	2012 2020
Technical College of Vocational Studies Aranđelovac	Entrepreneurship	BVS Applied economy and entrepreneurship	2	C	2017
Higher School of Economics of Vocational Studies Peć, Department Peć - Leposavić	Entrepreneurship	BVS Business of small and medium enterprises	2	E	2017
				C	2024
College of Business Economics and Entrepreneurship Belgrade - Jagodina	Entrepreneurship	BAS Business Economics and Entrepreneurship	3	C	2013 2015 2022
College of Business Economics and Entrepreneurship Belgrade - Loznica	Entrepreneurship	BAS Business Economics and Entrepreneurship	3	C	2013 2015 2022
College of Applied Vocational Studies, Vranje	Entrepreneurial economy	BVS Entrepreneurial Management	3	C	2015
	Entrepreneurship		3		2022
	International entrepreneurship	MVS International economy and entrepreneurship	1		2019
Faculty of Technical Sciences in Novi Sad, University of Novi Sad	Entrepreneurial Management	DAS Industrial Engineering / Engineering Management	2	E	2012

4. CONCLUSION

Taking into account the fact that the current efforts towards the integration and implementation of entrepreneurial education in the Republic of Serbia are at a very good level, there are nonetheless significant shortcomings that hinder the full potential of this discipline. Despite the effective implementation of entrepreneurship in the names of study programs at higher education institutions, there is a lack of integration of entrepreneurship and its competencies into the comprehensive educational system. Furthermore, the traditional education system, which has not yet been fully inhibited, often poses a problem for the innovative methods and applications that could enable a dynamic trend and development of entrepreneurial skills among students and participants. Moreover, the lack of effective training for educational staff in entrepreneurship orientation further raises concerns regarding the creation of adequate educational and teaching content, primarily, and then the environment that could potentially motivate, enhance, and raise young people's awareness of the importance of applying entrepreneurial activities in the Republic of Serbia.

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Understanding and Addressing Motivational Challenges Among University Students

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Abstract: *This paper explores the intricate dynamics surrounding the motivation and perspectives of university students born after the mid-1990s (Generation Z). It brings to light the generation gap and the clash between the expectations of educators and the realities of changing student interests. The paper uncovers a new paradigm where many students lack intrinsic motivation, struggle with study commitment, and prefer easy solutions, often relying on readily available information without critical evaluation. If left unaddressed, these trends pose profound challenges to the educational system, potentially leading to a society reliant on information consumerism. Additionally, the paper examines the role of educators in adapting to these changes, emphasizing the need for a holistic approach to education beyond mere knowledge transfer. Strategies to address these challenges are discussed, highlighting the importance of redefining the role of educators, cultivating intrinsic motivation and critical thinking skills, and fostering a more dynamic, effective, and supportive learning environment aided by student selection based on a genuine interest in study subjects and motivation to study.*

Keywords: *motivation; generation z; information consumerism; holistic approach;* student-centered learning

1. INTRODUCTION

Engaging students in their studies and encouraging active class participation is an enduring challenge for educators worldwide. This challenge has become even more complex in recent years due to societal shifts and evolving student preferences, particularly among Generation Z born after the mid-1990s. The educational landscape is now characterized by a generation gap, where the expectations of teachers and school programs often clash with students' changing interests and behaviors. A new paradigm is emerging, with many students lacking intrinsic motivation, perseverance, and the ability to commit to rigorous academic pursuits. This paper delves into these challenges, providing insights into the motivations and perspectives of modern students and proposing strategies to mitigate their impact on the quality of education and the development of students as independent thinkers.

1.1. The New Paradigm: Lack of Intrinsic Motivation and a Preference for Easy Solutions

A concerning trend within this generation is the apparent lack of intrinsic motivation among many students [1, 2, 3]. Many students prefer easy solutions and shortcuts, seeking quick fixes rather than investing time and effort in deep learning. Students skip classes, don't turn in assignments on time, come to exams entirely unprepared, or do not show up, seem unmotivated, and remain passive in the classroom. This phenomenon is exacerbated by the proliferation of technology, which provides instantaneous answers to virtually any question. As a result, students may rely on platforms like ChatGPT or Gemini for answers without critically evaluating the information or engaging in independent problem-solving.

The generation gap between educators and students is evident in various aspects of academic life. Traditional teaching methods and course structures may fail to resonate with modern students' preferences and learning styles, who are digital natives accustomed to instant access to information and rapid gratification. This misalignment in expectations can lead to disengagement and apathy toward learning as students struggle to find relevance and meaning in their academic pursuits. The consequences of this shift in student behavior are far-reaching and demand immediate attention. A decline in intrinsic motivation and critical thinking skills jeopardizes education quality and undermines students' development as independent, lifelong learners. Moreover, an overreliance on external sources of information without proper evaluation fosters a culture of superficial understanding and mechanical memorization, rather than deep comprehension and analytical thinking. If left unaddressed, these trends threaten to erode the foundations of academia and perpetuate a cycle of intellectual passivity [1, 3].

In addition to these general considerations, according to several studies, this "astounding" level of disengagement was found to be (post)pandemic-related stress, depression, exhaustion, and trauma. It was found that three-quarters of college students experienced disruptions in the home, and over 90 percent of surveyed students reported that they or their families or close friends had difficulty coping with various stressors [2].

Two years of distance learning was traumatic and has damaged not only students' mental health but also their social skills and ability to adapt to traditional academic expectations [3]. Most four-year universities act as if nothing has changed and consider four or five courses a semester and all the projects and exam pre-conditions as an average load. As a result, many students suffer from cognitive overload and experience no sense of connection and urgency, view their schoolwork as futile, and feel powerless and lost [2].

Student needs and curriculum priorities constantly change, and teachers must ensure that presented content is relevant and practical. AI-led education analytics can help identify critical trends, extract key markers, and help teachers develop the most effective content that drives digital transformation.

2. WHO ARE THESE GEN-Z STUDENTS?

To effectively address motivational challenges, it is imperative to understand the perspectives and motivations of modern students. For many students born after 1995, life is characterized by a constant influx of information and stimuli, facilitated by technology and social media [4, 5]. These students spend more time on their devices than in real interactions, typically communicating with images, videos, or short cryptic messages with peers whom they do not anyhow feel close with. While technology offers unparalleled connectivity and convenience, it also poses significant challenges to forming meaningful relationships and navigating the complexities of growing up into healthy individuals within society, as they are almost entirely disconnected from normal relationships. Students may struggle to establish genuine connections with their peers and mentors. The reliance on virtual interactions and social media platforms often fosters superficial relationships, devoid of the depth and intimacy essential for emotional well-being. Moreover, constant exposure to curated images and idealized lifestyles on social media can exacerbate feelings of inadequacy and isolation, further perpetuating emotional distancing.

This generation values autonomy, creativity, and instant gratification, is eager for money, and often prioritizes (digital) experiences over material possessions. However, contrary to stereotypes of hedonism, many students also harbor a deep-seated desire for purpose, meaning, and personal fulfillment. On the other hand, they are easily distracted, are not competitive, tolerate less risk, and avoid failure in real life, making them less prone to experimenting. As such, they seem several years younger and less mature, are not very familiar with norms and expectations of (higher) education, have less life experience, require more guidance in both school-related and personal matters, and require more frequent, short and to the point feedback [6]. Consequently, they will hesitate to ask questions or talk in the class, to avoid saying the wrong thing. In addition, Gen Z students have much less reading experience and lack sustained concentration, making them (almost) unable to process traditional textbooks with hundreds of pages of engineering fundamentals. They prefer e-textbooks with short chapters, interactive figures and online courses on Coursera-like platforms with built-in quizzes and YouTube videos. In essence, they want flexible learning opportunities, a mix of independent and group work and instant gratification to keep them involved.

The updated European Digital Competence Framework DigComp 2.0 considers the knowledge, skills and values needed by 21st-century citizens and presents a matrix for understanding the core competencies required to adapt to and actively participate in the digital world. This includes both the positive side of modern technologies and the numerous negative phenomena such as misinformation and digital bullying [7]. Understanding these underlying considerations and motivations is crucial for educators seeking to connect effectively with and engage modern students.

3. STEPS TOWARDS A SOLUTION

Addressing university students' motivational challenges requires a multifaceted approach integrating pedagogical innovation, student support services, and community engagement. Educators should adapt their teaching methods and align with modern students' preferences and learning styles, incorporating technology and real-world applications to enhance relevance and engagement [8]. Innovative teaching methods such as experiential learning opportunities, project-based assignments, and collaborative activities must cater to modern students' diverse learning styles and preferences to enhance student engagement and motivation. Additionally, fostering a supportive learning environment that encourages risk-taking, experimentation, and collaboration can help cultivate intrinsic motivation and resilience in students. Furthermore, leveraging technology and multimedia resources can help make learning more interactive, dynamic, and accessible.

Universities can play a pivotal role by [3, 9]:

- **Providing strong academic advising:** Advisors can help students define clear goals, explore career options, and select courses that align with their interests.
- **Promoting active learning:** Engaging teaching methods that encourage participation, problem-solving, and real-world applications can rekindle student interest.
- **Developing time management resources:** Workshops and resources on effective time management strategies can equip students with the tools to juggle their commitments.
- **Developing a sense of community:** Creating opportunities for social interaction, peer support groups and mentorship programs can reduce feelings of isolation and increase a stronger sense of belonging.
- **Promoting mental health awareness:** Universities can offer accessible mental health services and programs to help students cope with personal challenges and maintain well-being.

Students also have a significant role to play in maintaining motivation. Here are some strategies they can adopt [10, 11]:

- **Setting SMART goals:** Specific, Measurable, Achievable, Relevant, and Time-bound goals provide a clear roadmap and a sense of accomplishment.
- **Developing effective study habits:** Creating a dedicated study space, establishing regular routines, and utilizing time management techniques can enhance focus and productivity.
- **Building a solid support system:** Connecting with peers, professors, or mentors can offer guidance, encouragement, and a sense of accountability.
- **Practicing self-care:** Prioritizing adequate sleep, healthy eating habits, regular exercise and sport can improve overall well-being and boost motivation.
- **Recognizing and celebrating achievements:** Acknowledging progress, no matter how small, can be a powerful motivator.

Understanding and addressing motivational challenges among university students is crucial for fostering academic success and personal growth. By employing a combination of institutional support and individual strategies, students can navigate this critical period with a renewed sense of purpose and direction.

3.1. The importance of student-centered learning

Central to addressing motivational challenges is student-centered learning, wherein the focus shifts from the teacher as the only source of knowledge to an active participant of students in the learning process [9]. This approach emphasizes personalized learning pathways, self-directed inquiry, and critical thinking skills, empowering students to take ownership of their education and lifelong learning. Empowering students is igniting the flame of self-determination within them, fostering a spirit that embraces learning for the present and a lifetime.

Considering these dynamic changes, educators' roles are adapting to better align with the needs and expectations of modern students. Rather than focusing solely on transmitting knowledge, educators should adopt a broader approach to education, emphasizing mentorship, guidance, and personal development [9]. This entails creating a supportive learning environment where students take ownership of their learning and are empowered to explore their interests and passions. Furthermore, efforts should be made to promote critical thinking skills and information literacy, equipping students with the tools to evaluate the validity and reliability of sources independently. This entails incorporating media literacy education into the curriculum and allowing students to practice discernment and analysis in various contexts.

Beyond the classroom, collaboration between educators, parents, and policymakers is essential to address the systemic factors contributing to the decline in student motivation and academic performance. This may involve reevaluating educational policies, investing in teacher training programs, and advocating for holistic approaches to student development that prioritize academic achievement, social-emotional learning, and personal growth.

3.2. Personal connection with students

One important motivation booster is promoting your course and building a personal connection with students [3]. Students take courses for many reasons, including filling a schedule gap or balancing challenging courses with easier ones. Educators must explain why their course is relevant and valuable and why attendance and participation in course activities are important.

It is essential to monitor student engagement throughout the semester through surveys, group discussions, and one-on-one conversations, and consequently, to have an honest debate about the problems of disinterest with students, asking them what is going on and helping them to articulate their feelings and fears. This involves building personal relationships and connections with individual students and proactively reaching out to disengaged students, not reprimanding them but finding out what's going on and how you can help. This implies rejecting pedagogy that contributes to student alienation. In particular, teachers need to give unmotivated or alienated students a perspective: instead of letting them fail, they need to work with them one-on-one to develop a plan to help them succeed. Suppose students must complete a research project at the end of the semester. In that case, it is essential to define milestones and steps and interact with students individually as they move through each stage [3].

One of the ways of activating students is to treat them as co-teachers and give them active roles and responsibilities in the delivery of classes: to initiate lessons, lead class discussions, and work with student teams to develop exciting classroom activities. Due to their reduced cognitive capacities, many students disengage with the Socratic questioning approach and with lectures without pauses. Team-based activities and active learning strategies work better, including inquiry, problem-solving, case studies, and debate. Going a step further, it is also essential to encourage students to work together and build strong and supportive relationships, which promotes collaborative active learning and can bridge a gap and alleviate emotional distance between students.

To engage students effectively, consider treating them as co-teachers, granting them active roles in class delivery. This can involve initiating lessons, leading discussions, and collaborating on exciting classroom activities with student teams. Traditional lectures often fail to captivate all students, particularly those with reduced cognitive capacities, who may disengage without interactive elements like pauses and Socratic questioning. Opting for team-based activities and active learning strategies, such as inquiry, problem-solving, case studies, and debates, proves more effective in fostering engagement and comprehension. Additionally, fostering collaborative relationships among students is crucial. Encouraging them to work together promotes active learning and helps bridge gaps and alleviate emotional distance, ultimately enhancing the learning environment for all.

3.3. Coping with emotional distancing in the digital age

Universities and educators play a pivotal role in facilitating emotional growth and connection among students. Beyond academic instruction, universities serve as communities where students form lasting friendships, discover their identities, and develop crucial social and emotional skills. Therefore, it is incumbent upon universities to prioritize the following initiatives to counteract emotional distancing [3, 10, 12]:

1. **Promoting Offline Interactions:** It is paramount to encourage face-to-face interactions and create opportunities for students to engage in meaningful dialogue and shared experiences. Universities can organize social events, group activities, and collaborative projects that foster genuine connections and camaraderie among students.
2. **Fostering Emotional Intelligence:** Integrating emotional intelligence training into the curriculum can help students recognize and manage their emotions effectively [11]. Through workshops, seminars, and counseling services, universities can empower students to cultivate empathy, resilience, and self-awareness—essential qualities for navigating interpersonal relationships.
3. **Creating Supportive Environments:** Establishing a supportive and inclusive campus culture is essential for nurturing emotional well-being. Universities should prioritize mental health resources, counseling services, and peer support networks to ensure students feel valued, heard, and supported in times of need.
4. **Role Modeling Healthy Behaviors:** Educators play a crucial role as mentors and role models in students' lives. By demonstrating healthy communication, empathy, and conflict-resolution skills, teachers can set a positive example for students and cultivate a culture of respect, compassion, and authenticity within the classroom and beyond.
5. **Embracing Diversity and Inclusion:** Promoting diversity and inclusion initiatives fosters a sense of belonging and acceptance among students from various backgrounds. Encouraging open discussions and promoting cultural competency can further enhance understanding and empathy among students, reducing emotional distance and promoting a sense of unity.

In conclusion, addressing emotional distancing in the digital age requires a concerted effort from universities and educators to prioritize students' emotional well-being and interpersonal connections. By promoting offline interactions, fostering emotional intelligence, creating supportive environments, and role-modeling healthy behaviors, universities can empower students to navigate the complexities of growing up and develop into emotionally resilient and socially connected individuals within society.

3.4 Student admission: selecting students based on their academic capabilities and motivation

It would be unfair to say that only educators and universities should adapt to new student generations. Societies still need sound engineers, doctors, scientists, and specialists in many other disciplines, and becoming one still requires hard work, commitment, and ownership. Besides general end-exam results, we believe universities should also introduce a student admission process that considers students' motivation, interest in a particular study, and willingness to commit their time and effort. Too often have we seen students engaged in, e.g., information technology studies not because they are interested in these topics but because their parents or themselves believe that it offers them an excellent financial future, despite any genuine interest and knowledge in these topics. These students are unable or unwilling to answer study requirements and disturb other students and their learning process due to their disengagement and attitude.

In other words, besides the point that educators and universities should adapt to new students, selecting the right students who can withstand the university requirements is equally valid. Besides entrance exams, Universities can consider student's motivation, interest, and commitment in a few ways to create a well-rounded admissions process [13]:

1 **Personal statements and essays:** these can be prompts that ask students to describe their academic goals, why they're interested in a specific program, or challenges they've overcome.

2 **Letters of recommendation:** teachers and mentors can write about a student's work ethic, passion for a subject, and initiative in class.

3 **Portfolios:** portfolios can showcase a student's talent and dedication to artistic or creative fields.

4 **Interviews:** motivated students will be able to articulate their goals clearly, demonstrate their knowledge of the field, and ask insightful questions about the program. Interviewers can assess students' communication skills, enthusiasm, and study commitment and how they overcome challenges: explore how students have dealt with academic or personal difficulties, showcasing their resilience and dedication.

5 **Extracurricular activities:** participation in clubs, projects, or internships related to the field of study can demonstrate a student's passion and initiative.

6 **Incorporating technology** can also enhance student engagement and participation. Utilizing interactive multimedia resources, online platforms for collaboration, and educational applications can provide students with additional avenues to participate in their learning process and stay motivated.

4. CONCLUSION

Motivating students at universities in the 21st century presents a complex and multifaceted challenge, exacerbated by the generation gap and shifting paradigms in education. It requires a nuanced understanding of student's perspectives, motivations, and preferences. The employment world is currently definitely changing because of the influence of digitalization. By embracing innovative teaching methods, fostering a supportive learning environment, and redefining the role of educators, universities can create an engaging educational experience that resonates with modern students and empowers them to become active participants in their learning. Ultimately, by prioritizing intrinsic motivation, personal development, critical thinking skills, and student-centered learning, educators can empower students to thrive academically and prepare them to navigate an increasingly complex and dynamic world, ensuring their success as young humans. Educators can enable students to excel academically and navigate the world's ever-evolving complexities by focusing on intrinsic motivation, personal growth, honing critical thinking abilities, and adopting student-centered teaching approaches. This ensures their readiness to succeed as individuals in today's dynamic society.

The critical developmental tasks of adolescent adulthood — breaking away from the parental home, achieving a degree of emotional and financial independence, forming an identity and a sense of direction, and building more intimate interpersonal relationships — have become more difficult not only because of the lockdown and the shift to remote learning but also because of a cultural environment in which identity options have increased. The script of young adulthood has become more diverse and is far more confusing and complex today than when I was growing up. It's no wonder many students feel lost without a clearly defined roadmap or model.

The usual coping mechanisms— for young adults - playing video games, social media, drugs and alcohol, and, of course, actively participating in the online digital world— can be profoundly inappropriate and counterproductive in some instances by promoting self-isolation, fueling social anxiety, internalizing external judgments, and clouding a sense of priorities. We may react to student disengagement with annoyance, frustration, and even anger. We should not do that. Instead, please take action to re-engage your students and put them back on the path to success.

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Prerequisites for Higher Quality Education: Teachers' Attitudes on the Application of Artificial Intelligence Tools in Teaching

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Abstract: *This paper presents research on the impact of artificial intelligence (AI) on improving the quality of education. The focus of the research is teachers' views on the application of AI tools in primary and secondary education. The application of advanced technologies such as AI opens up new opportunities, potentials, and challenges in education. With the help of AI, which simulates human intelligence in making inferences or predictions, computer systems can provide personalized guidance, support, or feedback to students and teachers in the educational process. The paper aims to identify the prerequisites for quality education, analyze teachers' views on the application of AI tools in the teaching process, and highlight the perceived advantages of the application. Successful integration of AI tools depends on teachers' positive attitudes, technological literacy, and readiness for change. The study concludes that adequate training and support for teachers, together with transparency and understanding of potential risks, can significantly contribute to the successful implementation of AI technology in education.*

Keywords: *AI tools; teaching; teachers' attitudes; education*

1. INTRODUCTION

In the field of education, artificial intelligence (AI) is used in teaching, administration, and research. In modern research, the positive effects of using AI in the field of teaching practice are observed, and they can be seen through the reduction of teaching duties, faster completion of activities, opportunities for profiling, and predicting student needs and evaluating student work.

This type of learning removed the gap between real life and technological ubiquity and an educational system in which it was not affirmed to a sufficient extent.

Western intelligence affects the quality of education. Adequate training and support for teachers, along with transparency and understanding of potential risks, can significantly contribute to the successful implementation of AI technology in education.

Artificial intelligence can be used in education in many ways, including:

- automatic generation of learning programs;
- helping students to understand complex topics;
- visualization of data and concepts;
- automatic text recognition and classification;
- helping students acquire new technology skills;
- analysis of students and prediction of success;
- personalization of content and lessons;
- automatic knowledge testing;
- analysis of speech and language for better understanding of students;
- simultaneous translation of speech and text;
- autonomous learning for individualized education;
- automatic correction of grammatical errors;
- generation of questionnaires and tests, etc.

Artificial intelligence helps students get the most out of their education. Systems based on AI can provide individualized support to students with different levels of knowledge. Technology provides personalized assistance, allowing students to work on their weaknesses and strengthen their skills [1]. Artificial intelligence helps teachers educate children more effectively. Teachers can use technology to monitor student progress and identify problem areas. In addition, AI allows them to plan and conduct lessons more easily.

The model for improving the teaching process is "understanding the needs of students", or more precisely "identifying areas where AI can help improve the learning experience". Applications of AI in education should enable more purposeful, dynamic, and interesting learning. It is precisely AI that offers the possibility of improving educational systems in a way that was not possible until now [2].

2. PREREQUISITES FOR HIGHER QUALITY EDUCATION

Availability of learning materials has always been a problem, but AI now provides access to educational content to people around the world, thereby making education more accessible.

Artificial intelligence will make education more efficient, accessible and adaptable. Education systems around the world are beginning to adapt to AI technology, enabling students and teachers to reach their full potential.

Artificial intelligence can be applied in education in different ways. It can be used to improve educational programs and curricula and to help improve the quality of teaching. In addition, it can also help improve learning tools, such as games, simulations, and interactive applications, and be useful in distance education, providing personalized support to students and thus contributing to their greater interest in learning and a better understanding of the material. Artificial intelligence can improve the quality of education, which will lead to better educational outcomes, and can make it accessible to all, which will ultimately lead to a better society [3, 4].

School teachers can participate in the development of AI in several ways. First, they can use various AI tools and platforms to improve their teaching methods and increase student productivity. Teachers will also be able to help develop tools and procedures for adapting AI algorithms that can adapt education to students to achieve the best results. Finally, teachers can get involved in training and educating students about AI to help them acquire the necessary skills to help them achieve their educational goals [5, 6].

3. METHODOLOGY

Using a mixed research design, our study included a sample of N=140 primary and secondary school teachers. The questionnaire was developed by combining an adapted attitudes scale and a set of original questions designed by the authors. The instrument consisted of two parts: (I) Demographic data of the sample (5 questions) and (II) Questions related to teachers' views on the application of AI tools (10 questions). In the second part, a scale is adapted for Al.

The questions compiled by the researchers were related to the application of AI in teaching, i.e. for solving tasks from teaching subjects, the types of tasks for which it is mainly used, and assessment. The data was collected by surveying teachers online, during the month of May 2024.

Teachers from the elementary school in Ivanjica, the secondary technical school in Ivanjica, and the secondary electrical engineering and construction school in Jagodina participated in the survey.

In the first part of the questionnaire, respondents were asked to provide demographic information, including gender, smartphone ownership, and how often they use their smartphones. The sample consisted of 20% men and 80% women. In terms of smartphone ownership, 79% own smartphones while 21% do not (Fig. 1).

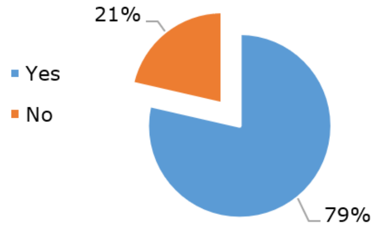

Figure 1. *Possession smartphone*

Respondents declared that 35% use a smartphone for 1 to 2 hours a day, 45% use a smartphone for 2 to 5 hours a day, while 20% of respondents use a smartphone for more than 5 hours during the day (Fig. 2).

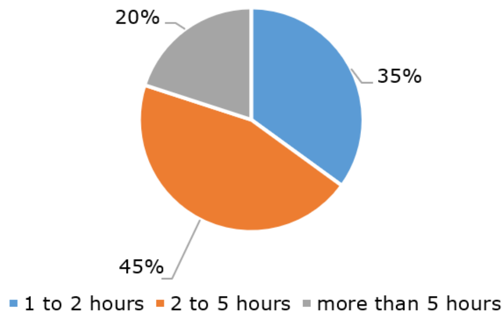

Figure 2. *Usage mobile phone*

4. RESULTS AND DISCUSSION

The main part of the questionnaire investigated the attitudes of teachers in primary and secondary education about the application of AI tools in teaching.

4.1 Results

Respondents most often used laptops, followed by mobile phones, personal computers, and tablets. Other devices were mentioned much less frequently (Fig. 3).

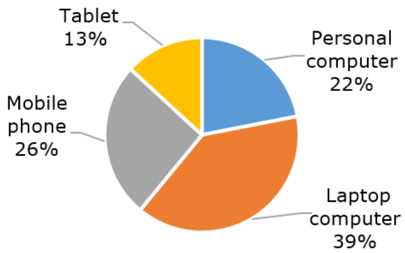

Figure 3. *Most commonly used devices*

Teachers rated their competence in using computers for applying AI tools in the classroom as follows: very low - 27%, low - 54%, weak - 17%, high - 2%, and very high - 0%. This indicates that most teachers feel inadequately prepared to integrate AI tools into their teaching practices (Fig. 4).

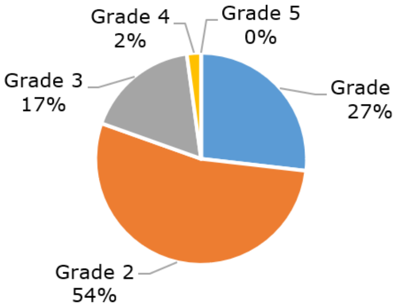

Figure 4. *Competency level for using computers to apply AI tools (1 – very low, 2 – low, 3 – weak, 4 – high, 5 – very high)*

Teachers also evaluated their competence in using different devices for applying artificial intelligence tools in teaching. The results were as follows: very low - 15%, low - 42%, weak - 41%, high - 2%, and very high - 0%. These ratings suggest that a significant majority of teachers feel underprepared to effectively use AI tools in their teaching, with almost none feeling highly competent (Fig. 5).

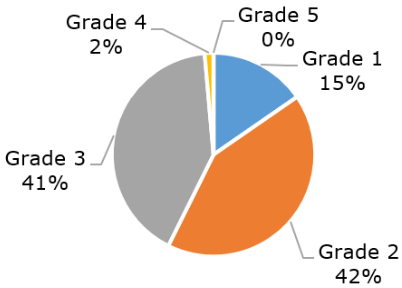

Figure 5. *Competency level for using all devices and applying AI tools (1 – very low, 2 – low, 3 – weak, 4 – high, 5 – very high)*

Teachers' experience with using AI tools is mostly limited, with the following ratings: very low - 20%, low - 37%, weak - 42%, high - 1%, and very high - 0%. This indicates that almost all teachers have minimal experience with AI tools, highlighting a significant area for potential growth and professional development (Fig. 6).

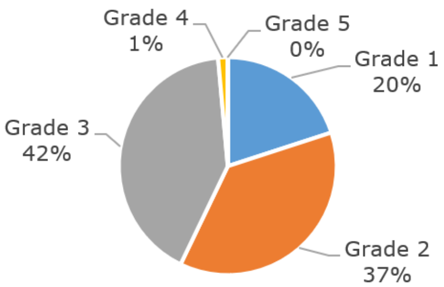

Figure 6. *Experience using AI tools* (1 – very low, 2 – low, 3 – weak, 4 – high, 5 – very high)

To the question What AI tool have you used so far, it was possible to choose more than one answer:

1) Tools for writing and creating text (e.g. Quillbot, Grammarly,...)
2) Learning Analytics (eg Brightspace by D2L, Blackboard Analytics, Tableau for Learning Analytics)
3) Automated grading (eg Gradescope, Turnitin, Crowdmark)
4) Artificial assistants (eg SIRI, Hello Google, Cognii, Century Tech)
5) Virtual assistants (eg IBM Watson Assistant, Squirrel AI, Jill Watson)
6) Intelligent tutoring systems (eg Blippar, Thinkster Math, Carnegie Learning, Age of Learning, Amira Learning, Cognitive Tutor, Jill Watson, DreamBox, Knewton, Carnegie Learning)
7) Natural language processing (e.g. Google Cloud Natural Language API, IBM Watson Natural Language Understanding, Amazon Comprehend)
8) Smart content creation (eg Canva, Articulate 360, Quillionz)
9) Personalized learning (eg DreamBox, Knewton, Smart Sparrow)
10) Predictive modeling (eg Civitas Learning, Learning Analytics and Prediction (LeaP), D2L Insights)
11) Speech recognition (e.g. Nuance)
12) Customized learning (eg McGraw-Hill ALEKS, Duolingo, DreamBox)
13) Augmented and virtual reality (eg Oculus VR for Education, Google Expeditions, zSpace)
14) Learning foreign languages (eg Duolingo, Blue Canoe)
15) Chat-bot (eg Chat GPT)
16) Other.

More than half of the surveyed teachers are most familiar with chatbots. One-quarter of respondents are aware of smart content creation. Other tools are still not available to teaching staff (Table 1).

Table 1. *The most frequently used AI tools*

AI tool	**Percentage**
Intelligent systems for teaching	4%
Natural language processing	6%
Smart content creation	25%
Learning foreign languages	12%
Chatbot	53%

When asked if they were trained to use AI tools in teaching, the respondents' answers were as follows: Yes - 10%, No, but I plan - 54%, and No and I don't plan - 36%. This indicates that only a small percentage of teachers are currently trained in the use of AI tools, while the majority plan to be trained. However, a significant part of teachers do not intend to be trained, which could be an obstacle to the wider application of AI tools in education (Fig. 7).

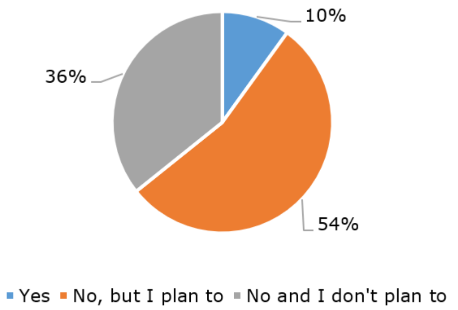

Figure 7. *Training in the use of AI tools in teaching*

The proposal would be for such training to be offered to schools as a mandatory form of professional development. Teachers would have a different attitude in that case.

Table 2 shows the methods teachers would prefer for training sessions in acquiring knowledge and skills for using AI tools in education.

Table 2. *The way to acquire and improve your knowledge for using AI tools in teaching*

The way to acquire and improve your knowledge for using AI tools in teaching	Percentage
Through seminars	12%
Through the forum	3%
I do my research	22%
I did not acquire the appropriate knowledge	80%

To the question What in your opinion and current practice, advantages of using artificial intelligence tools in teaching, it was possible choose more than one answer:

1) Positive influence on the level of knowledge and engagement of students
2) Interest in learning
3) Development of problem-solving strategies
4) A more pleasant atmosphere when studying and checking students' knowledge
5) The method of examining and learning new material is adapted to the interests and abilities of students"
6) More objective assessment

The results of research on the advantages and disadvantages of using tool A are given in Fig. 8 and Fig. 9).

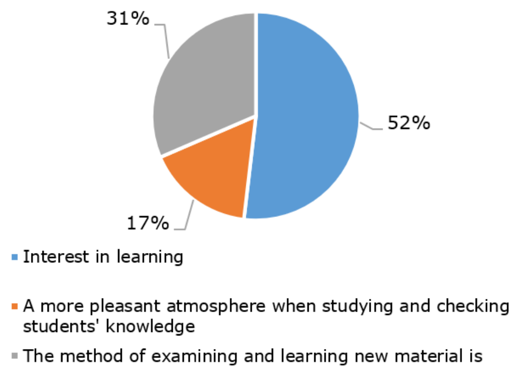

Figure 8. *Advantages of using AI tools in teaching*

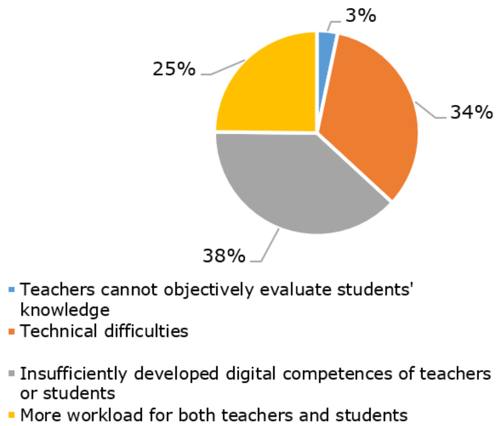

Figure 9. *Disadvantages of using AI tools in teaching*

To the question "Which are, in your opinion and current practice, the disadvantages of using AI tools in teaching", it was possible to choose more answers:

1) Excessive consumption of time
2) Teachers cannot objectively evaluate students' knowledge
3) It is difficult to establish a balance between student independence and providing support
4) Technical difficulties
5) Insufficiently developed digital competencies of teachers or students
6) More workload for both teachers and students
7) Other.

As disadvantages of using artificial intelligence tools in teaching, teachers report insufficiently developed digital competencies of teachers or students. Such conclusions build on the previous answers related to competencies. Also, teachers report heavy burdens with new technologies.

Insights into each of the following AI claims are detailed in Tables 3–6 (note: 1 – I do not agree at all, 2 – I do not agree, 3 – I neither agree nor disagree, 4 – I agree, 5 – I completely agree):

- Knowing the processes through which deep learning enables AI to perform voice recognition tasks (Table 3)
- I understand why AI needs large amounts of data (Table 4)
- I understand how computers process an image for visual recognition (Table 5)
- I understand how artificial assistants like SIRI or Hello Google manage human-computer interaction (Table 6).

Table 3. *Knowing the processes through which deep learning enables AI to perform voice recognition tasks*

Grade	Percentage
Grade 1	9%
Grade 2	26%
Grade 3	58%
Grade 4	7%
Grade 5	0%

With knowledge of the processes through which deep learning enables AI to perform voice recognition tasks, the majority of respondents neither agree nor disagree. Very few respondents agree with this statement.

Table 4. *I understand why AI needs large amounts of data*

Grade	Percentage
Grade 1	4%
Grade 2	6%
Grade 3	25%
Grade 4	12%
Grade 5	53%

Table 5. *I understand how computers process an image for visual recognition*

Grade	Percentage
Grade 1	36%
Grade 2	10%
Grade 3	36%
Grade 4	18%
Grade 5	0%

How artificial assistants like SIRI or Hello Google manage the interaction between man and computer, the largest number of respondents neither agree nor disagree with the uninformed.

Table 6. *I understand how artificial assistants like SIRI or Hello Google manage human-computer interaction*

Grade	Percentage
Grade 1	7%
Grade 2	14%
Grade 3	70%
Grade 4	9%
Grade 5	0%

4.2. Discussion

Teachers' views on the application of AI tools in primary and secondary education

The findings of this study shed light on the attitudes and preparedness of teachers in primary and secondary education regarding the application of AI tools in teaching.

First, regarding the devices used for teaching, respondents mainly rely on laptops, followed by mobile phones, personal computers and tablets. This suggests that teachers use familiar technology in their teaching practices, albeit with limited integration of newer devices.

However, despite the prevalent use of technology, teachers rate their competence in using computers to implement AI tools relatively low, with the majority falling to low to weak levels of competence. This points to a gap between device familiarity and the ability to effectively use AI tools in the classroom.

The level of competence in using all devices to implement AI tools was rated at a modest level of 3. This indicates a consistent perception among teachers that they lack a higher level of competence in using AI tools across devices.

When it comes to experience with AI tools, most teachers are most familiar with chatbots, followed by smart content creation. However, awareness and use of other AI tools remain relatively low, indicating a need for further training and exposure in this area.

The introduction of technology into education is nothing new, but the speed with which AI is being integrated into the teaching process represents a significant step forward. AI tools offer the potential to personalize learning, automate administrative tasks, and improve access to educational resources [7]. However, as these tools are introduced into primary and secondary schools, teachers' attitudes become a key factor in their successful implementation. This chapter explores teachers' attitudes toward the application of AI tools in education, analyzing the benefits, challenges and obstacles these tools bring.

Advantages of applying AI tools in education

In terms of training, it is apparent that very few teachers have received formal training in the use of AI tools, with more than half of respondents reporting no training at all. This highlights a potential reluctance among teachers to embrace new technologies or a lack of opportunities for professional development in this area.

Proposing mandatory training for teachers in the application of artificial intelligence tools could potentially change attitudes toward the adoption of technology in education. By providing structured training opportunities, teachers can feel more empowered and confident in integrating AI tools into their teaching practices.

Many educators recognize the numerous benefits that AI tools can bring to the educational process [8]:

- *Personalization of learning*: AI enables the creation of individualized lesson plans that are adapted to the needs and pace of each student. This can significantly improve student engagement and their ability to absorb the material.
- *Automate administrative tasks*: AI-based tools can automate routine tasks such as test grading, score analysis, and homework administration, allowing teachers to focus more on interacting with students.
- *Improving access to educational resources*: AI can help organize and search large amounts of educational materials, making it easier for students and teachers to access relevant information.

Challenges and obstacles

While the benefits of AI tools in education can be significant, educators face some challenges and obstacles:

- *Technological literacy*: Many teachers may lack the knowledge and skills to effectively use AI tools. This requires additional training and professional development.
- *Data privacy and security*: Using AI tools often involves collecting and processing large amounts of data about students. This raises questions about the privacy and security of that data.
- *Resistance to change*: Some teachers may be skeptical of new technologies and resistant to changes in traditional teaching methods. This can be a barrier to the widespread adoption of AI tools.
- *Ethics and bias*: AI systems can be subject to biases present in the data they are trained on. Teachers must be aware of these risks and able to recognize and address potential problems.

Teachers' attitudes towards AI tools

Research shows that teachers' attitudes toward AI tools vary, but several key themes frequently emerge:

Positive Attitudes: Teachers familiar with AI technologies often express positive attitudes, recognizing the potential benefits of personalizing learning and reducing administrative burdens.

Skepticism and concern: Some educators express skepticism about the effectiveness of AI tools, worrying about their reliability, bias, and impact on the teacher's role in the educational process.

Need for support: Many teachers emphasize the need for continuous training and support to feel competent and confident enough to use AI tools in the classroom.

The introduction of AI tools into primary and secondary education has the potential to transform the educational process, but the attitudes of teachers play a key role in this transformation. While many educators recognize the benefits that AI can bring, they also face significant challenges. Understanding and addressing these challenges, through adequate training, support, and transparency, are key steps toward successfully integrating AI tools into education [9]. Only by actively involving teachers and taking into account their views and experiences can AI become a useful tool that improves the educational process and contributes to better outcomes for all students.

The role of teachers in the digital age

From the analysis of the questionnaire, it can be concluded that the use of AI supports and facilitates the work of teachers, such as ChatGPT, influencing the improvement of the educational process in various aspects. So, for example, these tools are used in the evaluation of students, in the processing of student data to determine habits and patterns, and to identify students who are at risk of failing.

The application of AI can help teachers by saving time, improving the quality of work, and contributing to the personalization of experiences. A very important segment is the professional development of teachers in this field. Older teachers are not sufficiently familiar with AI.

To use technology in education in a way that contributes to changing and transforming the teaching process, it is necessary to develop the competencies of students (and teachers) for the age in which we live, including for the application of AI.

AI can help teachers design lessons, assignments, grading criteria, and so on. Teachers should be enabled to follow new technology, apply new tools, that their students already use (albeit for other purposes), and become role models for them.

The digital age has revolutionized many aspects of life, including education. Technological advances have transformed traditional methods of learning and teaching, enabling access to information and resources. In this changing environment, the role of the teacher is becoming more and more complex and important. In this chapter, we will explore how the role of the teacher is changing and adapting in the digital age, and what key competencies are needed to successfully perform this job.

Transformation of the traditional role of the teacher

Traditionally, teachers were the primary sources of knowledge and information, imparting material through lectures and text materials. In the digital age, this model is changing as students now have access to a vast wealth of information through the Internet, educational applications, and digital tools [3]. Teachers are no longer the only sources of knowledge, but become guides and mentors who help students navigate through an information-rich world.

One of the key aspects of a teacher's role in the digital age is the possession of digital literacy and technological competence. That includes:

Use of digital tools and platforms: Teachers must be adept at using a variety of digital tools to create interactive and engaging lessons. This can include the use of virtual reality tools, interactive whiteboards, collaboration applications, and many others [3].

Understanding Online Security: In the digital world, security is critical. Teachers must educate students about safe Internet use, privacy protection, and recognizing misinformation.

Integrating technology into the curriculum: Technology should be integrated into the curriculum in a way that enriches learning. This requires creativity and innovation in the design of lessons that use technology to improve student understanding and engagement.

There are specific types of training programs that could help teachers become more proficient in using AI tools: seminars, conferences, expert meetings in the field of artificial intelligence. The introduction of AI into the education system opens up the possibility of creating a dynamic and adaptive environment for learning and teaching, only if it is used responsibly with finding solutions to the risks and problems that AI brings.

In order to strengthen the teaching staff in education for this process, it is necessary to have more educational contents where the essential aspects of the application of artificial intelligence in education are shown.

Online and hybrid learning

The COVID-19 pandemic has accelerated the adoption of online and hybrid learning models. Teachers had to quickly adapt their teaching methods to maintain continuity of education. This experience showed the importance of flexibility and willingness to learn new technologies. In the future, a combination of online and traditional learning is likely to become the norm, and teachers will play a key role in ensuring that this transition is smooth and effective.

Digital tools enable the personalization of learning like never before. Teachers can now use analytics tools to track student progress and tailor instruction to individual needs. This is particularly useful for identifying students who need extra support or those who are more advanced and need more challenging tasks.

Developing critical thinking and digital ethics

In the era of information overload, teachers have a key role in developing students' critical thinking. They must teach students how to assess the credibility of sources, recognize bias, and understand the context of information. In addition, digital ethics is becoming increasingly important, and teachers need to promote responsible and ethical behavior online.

The study assessed teachers' understanding of various artificial intelligence concepts, such as deep learning processes, the need for large data sets, image processing for visual recognition, and the functioning of artificial assistants. The results indicate a mixed level of understanding of these concepts, with room for improvement in certain areas.

The findings point to the need for targeted professional development programs aimed at strengthening teachers' competence and confidence in the effective use of AI tools in teaching. In addition, efforts should be made to solve problems and provide support to overcome barriers to the integration of technology in education.

Accessibility of AI tools

When a new tool appears, not only a digital one, you should always investigate what benefits its use brings. The same is the case with artificial intelligence. Artificial intelligence tools can help teachers in professional development, researching new teaching methods, getting new ideas for the implementation of teaching as well as achieving educational outcomes and goals, on better monitoring of student achievements, as well as behavior, disruptive factors and in general on the overall life of a class for teaching time

A common method of monitoring the teaching process is recording with a video camera and analyzing the recordings after the implementation. However, today's recording technology makes it possible to recognize and mark each face, recognize behavior, activity levels, and collect various meta data about a person and a group.

Artificial intelligence is a great tool, but it is just that: only a tool in the hands of an expert or a learner. Like any tool, if used critically and purposefully, beneficial results are obtained

Artificial intelligence can also be put to good use for teaching planning, for example looking for inspiration or ideas. In a "conversation" with artificial intelligence, we can get a kind of idea. Such a "conversation" can be even more successful if we introduce the ideas we describe to artificial intelligence in cooperation with colleagues, because more people have more useful and original ideas. Ideas can be implemented in a single query to artificial intelligence or make several independent queries that can then be compared, analyzed, critically reviewed, summarized and create something entirely new and different.

Specific areas for future research, such as studies to assess the long-term impact of AI tools in education: The role of artificial intelligence in improving teaching; Artificial intelligence and education in the future; The importance of deep learning in education; Checking knowledge with the help of Western intelligence; Use of artificial intelligence platforms and tools. Creating educational content and teaching materials using artificial intelligence. Although the work of teachers is most often considered through work with students in the classroom, it is much more complex, and requires comprehensive preparation for the implementation of the teaching process. Preparation for teaching is a complex job, especially if we follow the requirements of modern education, teachers gain through their professional development.

Artificial intelligence can help in the preparation of teaching materials. It is important to adhere to ethical guidelines and key requirements for the reliable use of artificial intelligence. By using artificial intelligence tools to help in the creation of learning and teaching materials, teachers can get numerous ideas and help on how to create them and thus shorten the time for their creation in order to be adapted to all students.

5. CONCLUSION

This research paper provides a deeper insight into the attitudes and readiness of teachers in primary and secondary education regarding the application of AI tools in teaching. The results indicate the existence of challenges in the process of integrating AI technologies into the teaching process. Although technology is present in education, teachers show low confidence in using AI tools, as well as a lack of formal training in this area. There is significant scope for improving the digital skills of teachers and students, as well as for the development of educational programs that would support the implementation of AI technologies in teaching. Further research and development of training initiatives could contribute to improving the acceptance and success of using AI tools in education.

Many educators recognize the numerous benefits that AI tools can bring to the educational process:

- Personalization of learning
- Automation of administrative tasks
- Improving access to educational resources.

While the benefits of AI tools in education can be significant, educators face some challenges and obstacles:

- Technological literacy
- Data privacy and security
- Resistance to change
- Ethics and bias.

Teachers should be enabled to follow new technology, apply new tools, that their students already use (albeit for other purposes), and become role models for them.

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Digital Competences in Preschool Education

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Abstract: *Digital technologies have become an integral part of all segments of life and work, making elementary literacy unthinkable without digital literacy. Children of preschool age show the need and interest in using digital technologies and the Internet, applications for communication, entertainment and learning. In doing so, it is important to pay attention to the safe use of digital technologies and to protect children from various and diverse possibilities of abuse on the Internet. That is why it is necessary to develop the culture of using digital technologies and digital competence already at preschool age. Parents, and especially educators, have a primary role in the development of preschool children's digital competences. Therefore, educators must possess appropriate digital competences: general and specific, related to the profession they are engaged in. Preschool teachers acquire these competences during their initial education, and later through continuous professional development. This paper includes and processes digital competences in preschool education through the digital competences of preschool children and digital competences of preschool teachers.*

Keywords: *digital literacy; digital competences; digital culture; preschool teacher; preschool education*

1. INTRODUCTION

In the modern world, digital technology and the Internet occupy a significant place in people's lives, both in the professional, as well as in the private and social segments. Digital devices and the global computer network have led to the fact that without them it is impossible to imagine any serious work, as well as everyday life on this planet. Life without computers and the Internet becomes unimaginable. From year to year, the age limit of users of modern technology is decreasing. While growing up, children spend more and more time at the computer, most often playing or "surfing" on the Internet, getting to know different contents and information. Bearing in mind the fact that computers and the Internet have become part of our everyday life, which they largely mark the most important period of human development - childhood, the question is rightly raised as to what their influence is on the psycho-physical development of children and on their safety.

Modern technology plays an increasingly important role in children's lives. It shapes and influences all their daily activities: "the way they spend their free time, communicate, play and socialize with their peers, learn and gain new experiences" [1]. Children in the 21st century are active users of technology, more so than previous generations. This increase in use has led to much attention being paid to the effects of technology use and how it affects children's brains, socio-emotional, cognitive and physical development. The general, daily, mandatory and often multi-hour use of new technologies requires that full attention be paid to its impact on children's life and development. In the last few years, the more massive use of computers and the Internet has led to the innovation of educational technology in all educational institutions, including kindergartens. Children's environment, ways of life, aspirations, interests, growing up conditions are much different compared to those twenty years ago. Today, children are exposed to various multimedia contents that are easily accessible to them.

The advantages of new technologies are numerous. They have the potential to enrich every aspect of human life if handled wisely. New tools and applications are emerging that facilitate learning, such as virtual reality, augmented reality, and hologram projection of teaching topics can soon be expected. These new approaches have the potential to make even complex things easy to understand. However, aspects of the use of new technologies can also be harmful, especially if they are not clearly visible. These consequences of the use of digital technologies are usually indirect, hard to see and/or slow to develop and therefore represent new and additional challenges in upbringing and education. [2]. Digital technology and the Internet can be used in a preschool institution as a tool for planning and documenting, record keeping, professional development, communication with colleagues, parents and the local community, promotion of activities of the preschool institution, application in immediate educational work for learning initial mathematical concepts, foreign language, getting to know the environment, dramatic, musical, artistic, physical activities, speech development...

Digital technology offers countless opportunities to preschool children, but it is possible to use them adequately only if there are developed appropriate digital competences.

This paper deals with digital competences in preschool education, through digital competence of preschool teachers and digital competence of preschool children.

2. DIGITAL COMPETENCES IN PRESCHOOL EDUCATION

The digital transformation of society has led to the fact that the traditional understanding of literacy is changing and that people today are expected to be digitally literate as well. Being literate, nowadays, doesn't just mean being able to read, write and count anymore. A literate person today must possess functional knowledge and be able to use it in solving various problems from everyday life. Digital literacy framework updates from DigiComp 1.0 which proposes three proficiency levels, to DigiComp 2.1 with eight proficiency levels with systematical definitions and examples of use [3]. A literate person, in addition to his native language, must know at least one world language and possess appropriate social and digital skills. Technological and social development caused an increase in the scope of knowledge and skills that represent literacy, and the development of digital technologies led to the emergence of a new, so-called digital literacy. Digital literacy is one of the eight key competences of education and is defined as "the ability to critically and safely use digital technology at work, in free time and in communication" [4]. There are many definitions of digital literacy, such as: “an emergent literacy from other literacies and, as such, is greater than the sum of the other literacies, which include information literacy, media literacy, Internet literacy, and computer or ICT literacy (i.e. hardware and software knowledge and skills)” [5] or according to Kenya’s Basic Education Curriculum Framework, digital literacy encompasses traditional literacies and computer literacy [4].

In addition to this term, the term digital competence is also in use. Very often, these two terms are used as synonyms, even in some important documents, such as programmatic and strategic frameworks of educational policies [6]. Digital literacy [4] is the ability to: (1) access, (2) manage, (3) understand, (4) integrate, (5) communicate, (6) evaluate and (7) create information safely and appropriately through digital technologies for employment, decent jobs and entrepreneurship. It includes competences that are variously referred to as computer literacy, ICT literacy, information literacy and media literacy.

A large number of documents from the field of educational policies use the term competence as a synonym for literacy. Digital competence can be defined through five domains [7]: (1) information and data, (2) communication and collaboration, (3) digital content creation, (4) security, and (5) problem solving.

"Competence represents a combination of knowledge, skills and attitudes necessary for each individual to achieve personal development and active participate in society" [1].

Digital competence is of indisputable importance for functioning in modern society, and it is also a significant factor in the process of lifelong learning.

The acquisition of digital competence is also prescribed by the legal framework within the system of compulsory education [8].

Preschool upbringing and education is the first level in the educational system and as such, represents the basis for the development of digital competences.

Digital education of teachers and students, that is, teachers and children of preschool age, represents one of two complementary areas of educational policy, while the other is the pedagogical application of digital technologies in order to improve teaching and learning. [9].

Preschool age is characterized by rapid acquisition of knowledge, children at this age are curious, and digital technology provides children with interesting content, and they easily and quickly master the skills of handling digital devices and using various applications. However, entering the digital world brings with it various risks for which children are not sufficiently prepared and for which parents, if they control them, or preschool teachers can prepare them. In any case, both of them are factors of building and developing the culture of using digital technology, which should be developed through systematic education of: (1) educators, (2) parents and (3) children. In doing so, educators have the role of introducing children, and, if necessary, their parents, to practice correct and meaningful use of digital technology. The integration of digital technology into the educational system and direct work with children, along with the development of digital competences, must also be supported by strengthening the digital capacities of educational institutions at all levels. [9].

As the development of digital technology takes place very quickly, the necessity of continuous improvement of digital competences through the harmonization of skills necessary for the 21st century and teaching and learning programs is emphasized. When we are talking about digital competences in preschool upbringing and education, two complementary spheres are distinguished within this field [10]: (1) digital competence of preschool teachers and (2) digital competence of preschool children. Basics of the preschool education program - Years of Ascension define the key, and among them, the digital competences of preschool children, as well as their teachers.

3. PRESCHOOL TEACHERS' DIGITAL COMPETENCE

Preschool teachers, like other professionals involved in the upbringing and education of children, are expected to continuously improve professionally and to use the achievements of modern technology in their work. The professional role of educators in preschool age is realized through four areas [10]: (1) direct work with children, (2) program development, (3) professional development and (4) professional public action. Digital technology is integrated into all areas of his professional activity.

A preschool teacher, who uses digital technology in his work and wants to keep up with the demands of modern times, must, in addition to professional and pedagogical competences, also possess digital competence, which implies [10]: (1) efficient use of digital resources for the needs of education and upbringing, (2) planning and creating an authentic and stimulating digital learning environment that respects the diversity of children and contributes to their direct interaction, (3) communication and collaboration with children, parents and the wider community, (4) modern approaches in monitoring children's progress and personal development in the process lifelong learning, (5) documenting, (6) supporting children who need additional educational support, using the potential of digital technologies, (7) searching and finding digital content on the Internet, (8) creating digital content for learning and (9) security - responsible use of digital resources with maximum attention focused on the safety of children in the digital environment.

Preschool teachers' digital competences could be divided in two main groups [11]: general digital competences and specific digital competences. The general digital competences, according to [11], include (1) safe and responsible behavior in digital environment, (2) digital resources and (3) solving problems in the digital environment. The specific digital competences refer to professional role of preschool teacher and refer to [11]: (1) use of digital technologies in the immediate working with children, (2), using digital technologies to develop preschool programs, (3) using digital technologies for professional development and (4) professional public action using digital technologies. This framework defines seven areas of digital competence of preschool educators, within which the knowledge, skills and values they demonstrate are clearly distinguished and indicate appropriate competence.

Safe and responsible behavior in digital environment means protection of personal data and privacy, protection and storage of data and digital devices and protection of health and well-being. The field of digital resources includes internet search, evaluation and selection of digital content, customization and creation of digital content and digital content management, protection and sharing. The next digital competence refer to solving technical problems, recognition of own needs, possibilities and limitations in digital environment. A competent educator uses digital technologies in direct work with children and also in planning and documenting own work. Professional development of preschool teachers takes place through communication, cooperation, improvement of digital and pedagogical skills in a digital environment. Professional public action of preschool education is performed in representation of children's rights, promoting the value of upbringing and education with accent on importance of the teacher's profession by using of digital technologies.

Educators, through their direct work, should introduce children to the proper use of digital technology and, at the same time, use it themselves adequately in the realization of the educational process.

Research conducted in 2020 on a sample of 1560 respondents (educators, professional associates and directors), which dealt with the readiness of preschool institutions and practitioners to use digital technology, showed that about 40% never use digital tools and technologies to support children's play and researching or documenting activities in the educational group [12, 13]. The same survey indicates that more than 50% of respondents believe that their institution is not adequately equipped with digital devices, and almost the same number is of the opinion that the existing equipment is not used for the development of children's and educators' competences. More than 75% of those surveyed, to a greater or lesser extent, express the opinion that digital technologies are useful in working with children of preschool age and that the use of certain digital tools is stimulating for children's development and learning.

Educators acquire digital competences through their education for the profession they will be engaged in, but also through continuous professional development during work. Whether and in what way they will integrate digital technology in direct work with children, develop and improve their digital competences, depends a lot on their attitudes and readiness to use digital technology. In addition, a significant factor that encourages the development of digital competences of educators is the equipment and availability of devices and digital technology in institutions and the space where the educational process takes place.

4. PRESCHOOL CHILDREN’S DIGITAL COMPETENCE

Digital competence belongs to one of the key competences for lifelong learning in preschool education and is developed through the meaningful use of digital technologies as tools that enables children to [10]: (1) access information, (2) express and present in the function of play and research and (3) documenting various activities. Digital competence implies the development of an adequate relationship and a culture of using digital technologies. Preschool children’s digital competences are difficult to explore, so there is a need to make interview with preschool teachers to explore this field. According to [14], digital competent preschoolers have to: (1) become familiar with digital technology, (2) dare to try digital technology, (3) use digital technology, (4) have a critical approach toward digital technology, (5) have ethical media competence, (6) have problem-solving skills, (7) be a producer, not just a consumer of digital technology. Their teachers assumed they have to demonstrate use of digital technology and help children to become familiar with use and potential risks. Teachers understood the importance of early digital education and think that “is a challenging idea which cannot be separated from children’s other competences” [14]. Children should dare to try, without fear of making mistakes, while learning some new skill.

How the digital competence of a preschool child will be formed, depends on four groups of factors "Fig. 1”: (1) family and family environment, (2) immediate experience, (3) kindergarten environment and (4) interaction with peers.

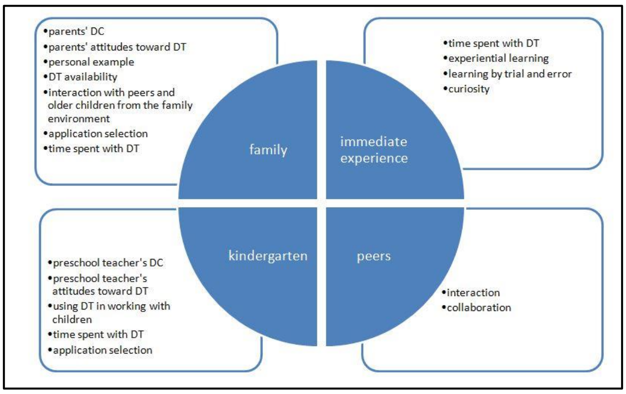

Figure 1. *Preschool children's digital competence determine factors (DT - digital technology, DC - digital competence)*

Parents with their attitudes about digital technology and their digital competences are the primary factor, because their example is the first that the child will follow. The family presents the first role model and is the source of the first immediate experiences. The availability of digital applications, an adequate selection of digital content, and the time spent with digital devices and technologies are very important. Children can be significantly influenced by example, especially older children from the family or immediate family environment, because children learn by model and imitating subjects from their immediate environment. Kindergarten teachers influence through their digital competences, their attitudes towards digital technology, their choice of applications and content, as well as the use of digital technology in direct work with children. If educators do not use digital technology and do not possess appropriate digital competence, it will negatively affect the development of this competence in children. “The availability of digital technologies in kindergarten is extremely important for the development of children’s digital competences" [12, 13].

The development of digital competences is influenced by interaction and collaboration with peers in kindergarten, as well as direct personal experience. Children use different apps and devices depending on their age. The most used devices are smart phones, tablets, and more recently smart toys and robots. Children around the age of five usually play games or use devices to communicate, watch cartoons or listen to music [15].

5. CONCLUSION

Kindergarten is a place where children spend a large part of their time, and it should be a safe and inspiring space for children to play, learn and grow. Through play and cooperation with peers, children acquire appropriate competences for life, develop creativity, independence and self-confidence, master knowledge and skills, and acquire competences for lifelong learning.

Children are guaranteed by law the right to master appropriate digital literacy skills in the digital age, that is, to acquire the culture of using digital technologies within educational institutions (kindergarten, school). Digital technology has become an integral part of their life, work and learning. In addition to the opportunities that digital technology and the Internet provide for the development and education of children, there are also many security risks, some of which are similar to risks in the real world, and some of which are specific only to the digital environment. For this reason, it is necessary to develop digital competences, which can only be acquired with the active participation of all those who influence the upbringing and education of the child. Rational and meaningful use of digital technologies in preschool institutions helps the development of children's digital competences.

Children can develop these competences adequately only if they have digitally competent parents and educators in their environment, with knowledge and attitudes about the use of digital technology and all the advantages and disadvantages of its use. In doing so, the primary role of families and kindergartens remains to take care of children's well-being and their safety in the real and in the digital environment.

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Patentability of AI-Related Inventions in Practice of the European Patent Office and the Intellectual Property Office of the Republic of Serbia

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Abstract: Current rapid development of Artificial Intelligence (AI) technologies posed many questions both for national and international patent system. One of them relates to the matter of patentable inventions and exceptions to patentability, and the other relates to evaluation of novelty and inventive step as patentability criteria. Current patent legislation cannot deal with these arising problems related to AI inventions in each case. Therefore, it is necessary to discuss, propose and implement new solutions to national patent laws and international treaties in order to overcome above mentioned problems and to harmonize work both of national and regional patent offices. It also expected that both policymakers and stakeholders take part in this process. In this paper is given an overview of current situation in this field, especially at the European Patent Office and the Intellectual Property Office of the Republic of Serbia.

Keywords: *patentability; invention; patent; artificial intelligence; AI*

1. INTRODUCTION

We are all witnessing rapid development of AI technologies. It is obvious that current advances in AI already strongly affect our life and work. One of areas being mostly influenced by this course of events is the innovation space. Using of AI technologies in the development of new inventions is growing rapidly, while AI becomes more and more autonomous.

Contemporary intellectual property legislation is not suitable for dealing with these arising problems. Therefore, it is necessary to look for new solutions. In this paper is given an overview of current situation in field of inventions and patents, especially at the European Patent Office and the Intellectual Property Office of the Republic of Serbia.

It should be stressed that we are addressing to ways to protect both AI-related inventions and inventions that involve use of AI by patent. On the other hand, we shall just briefly discuss the problem of protection of inventions created by AI as an inventor, because it is very complex topic and much more space is needed for its detailed elaboration.

1.1. Definitions relating to AI

According to [1], artificial intelligence (AI) refers to the branch of computer science and engineering that focuses on creating systems capable of performing tasks that typically require human intelligence, such as understanding natural language, recognizing images, making decisions and learning from data. Next important expression is machine learning (ML), which is defined as a subset of AI that specializes in developing algorithms and models, allowing computers to learn from data and improve their performance on specific tasks without explicit programming. Nowadays the most advanced AI systems are based on ML algorithms, as mentioned in [1].

By the term "architecture" is generally meant the overall design or general framework of an AI system, whereas "AI algorithm" is the set of instructions guiding the AI system to learn from data to perform a specific task. Finally, the term "AI model" refers to a specific implementation of an algorithm trained on data, as stated in [1].

2. CURRENT PATENT LEGISLATION

In this paper we focus both on the patent legislation of the European Patent Office (EPO) – the European Patent Convention (EPC), which can be found in [2] and the Patent Law of the Republic of Serbia, which can be found in [3]. It should be stressed that RS has been the one of the EPC contracting state since 2010.

2.1. The European Patent Convention

According to the Article 52 paragraph 1 of the EPC European patents shall be granted for any inventions, in all fields of technology, provided that they are new, involve an inventive step and are susceptible of industrial application, as stated in [2]. But some technical creations are not considered to be patentable inventions. Namely, according to Article 52 paragraph 2 of the EPC discoveries, scientific theories and mathematical methods, aesthetic creations, schemes, rules and methods for performing mental acts, playing games or doing business, and programs for computers and presentations of information are not regarded as inventions within meaning of the previous paragraph, as stated in [2].

2.2. The Patent Law of the Republic of Serbia

According to the Article 7 of the Patent Law of the RS (PLRS), a patent is a right granted for an invention in any field of technology, which is new, involves an inventive step and is susceptible of industrial utilization. It is obvious that this definition of patentable invention is very similar to the one from the EPC, as stated in [3]. The reason for it is that the RS had to harmonize its patent legislation with the EPC before joining the EPO.

Therefore, the list of technical creations that are not considered to be patentable inventions is practically the same and it contains the following: discoveries, scientific theories and mathematical methods, esthetic creations, schemes, rules and methods for performing mental acts, playing games or doing business, computer programs, and presentation of information.

2.3. Examination of AI-Related Patent Applications at the EPO

As one of the five biggest patent offices in the world, the EPO has to deal with constantly increasing number of AI-related patent applications, although it is notable that these belong to different technical fields: digital communication, medical technology, computer technology, energy, transport, measurement, biotechnology, etc, as mentioned in [4].

Since AI and ML as such are considered mathematical/algorithmic concepts at the EPO, it was the reason for development of its specific patent application examination approach that is known as "The two-hurdle approach", as explained in [5]. The mentioned approach contains two steps. In the first step it is checked if the subject-matter of application, which is defined in claims, can be considered to be a patentable invention in the terms of Article 52 paragraph 1 of the EPC. But this hurdle is very easy to overcome – it is enough that the claim contains any technical means in order to be classified as so called "mixed type invention" and to enter the next phase of examination; otherwise, the application shall be rejected.

The second step is far more complex. Namely, it is implemented on the claims comprising both technical and non-technical features, as described in [5]. Firstly, all features contributing to the technical character are being considered for assessment of inventive step. It is also checked if mathematical method contributes to the technical character of the invention.

According to the mentioned approach there are two types of contribution to the technical character of invention: the first one is by its application to a field of technology, and the second one is by being adapted to a specific technical implementation, as elaborated in [5].

For example, a mathematical method may contribute to producing a technical effect that serves a technical purpose, by its application to a field of technology and/or by being adapted to a specific technical implementation.

Since AI central fields are considered to be AI algorithms, models and architectures and implementation thereof, claims directed to a specific technical implementation could be:

- AI algorithm specially adapted for that implementation,
- AI design motivated by technical considerations of the internal functioning of the computer.

Even mathematical features can contribute to the technical character by a "specific" technical implementation motivated by technical considerations of the internal functioning of the computer system or network.

Regarding technical application, it is checked if AI and ML contribute to the technical character of the invention. Also, mathematical features can contribute to technical character by producing a technical effect serving a technical purpose, as described in [5].

Therefore, it is examined if the claim specifies explicitly or implicitly how the output of the mathematical method is used and is this use technical or the result thereof is of direct technical relevance. The purpose should be specific, but not generic and the claim should be functionally limited to its purpose.

In order to clarify the above mentioned we shall provide some examples of AI technical and non-technical application fields. Examples of the AI technical application fields are image processing, speech processing, control of different devices (such as machines, turbines, motors, vehicles, etc.). Examples of the AI non-technical application fields are determining price of a service, management of usage of beds in hospitals, positioning of products in supermarkets, etc.

To conclude, the EPO approach is based on the consideration that the AI and ML as such are considered mathematical/algorithmic concepts. A contribution of AI/ML to the solution of a technical problem can be in form of a technical implementation and/or a technical application to a field of technology. As a result, examination of patent applications is based on the above mentioned "two-hurdle" approach, as stated in [5].

2.4. Examination of AI-Related Patent Applications at the IPO

During the examination in the Patent Sector, it is obvious that patent applications in AI field are very complex and difficult to be drafted for applicants; they are also complex for examination, because of changing the novel technology in very rapid way. In accordance with that it is important to follow the examples from the bigger IP offices, such as the EPO, and also to implement the PLRS when examining such applications in the IPO. The first problem for inventors and applicants is drafting the proper patent application. The question is why? The reason is that it is difficult to draft application in sense of the PLRS and to follow all regulations which are mostly comprehensive. The first problem is lack of sufficient disclosure of invention (article 82 of the PLRS), especially in terms of mentioning insufficient number of steps/phases of method/process or parameters of same method/process. Also, there is a problem with mixed patent claims category that are not divided into independent claims for method, then system claims and so on (claims for computer programs, computer program product claims, signal claims, use of claims, etc.). However, all independent claims can be followed with numerous dependent claims for each category, which is always recommended.

For AI inventions, the most important is always patent claim for method that is followed by system claims. It is recommended to use precisely defined phases and/or steps of method claims (of AI algorithm). Meanwhile all patent claims must be supported by description of invention; if it is not case, then it can be problem with application and the PLRS according to article 83 of the PLRS. Sometimes although patent applications relate to inventions that are patentable, they lack of (or comprises non-) technical characteristics, lack of technical means or technical effect of such inventions.

The patent applicants usually believe that it is assumed that the invention is carried out on a computer, some system or device that they do not specify at all, and this is where the problem arises, which they become well aware of only when they receive a negative search report, or a partial search report, or the statement of inability to prepare a search report. Especially when it comes to the premature publication of a patent application in the Intellectual Property Gazette (IPG), their hands are tied, because they cannot withdraw an application that has already been published anymore. In some cases, it is better to withdraw patent application before publication and draft a new upgraded and amended patent application instead of continuing procedure with patent application lacking of important technical characteristics, technical means and technical effect.

Artificial intelligence, neural networks, deep learning, machine learning, etc. are being grouped in so-called Computer Implemented Inventions (CIIs), as AI is one part of such group of new technologies which are growing every day in number of patent applications worldwide.

During development of AI inventions and before drafting patent applications, the most of the applicants do not search patent documents through free patent search (for example, in free of charge patent databases, such as: ESPACENET (see [7]), Patentscope (see [8]), LENS.org (see [9]), national register of patents in the Republic of Serbia (see [10]). Especially, both nationally or internationally published patent applications and granted patents with their patent claims and categories of claims are contained in such patent databases. They are free for search and can be very helpful for applicants. Sometimes it is possible to follow the order of presentation of patent applications, see their drawings as examples, especially algorithms for method claims with phases indicated. Problem can arise when applicant do not include technical parameters which are important for better understanding of invention and their disclosure in such a way that it defines invention; instead, applicants just mention in their applications that is only included such words as artificial intelligence, intelligent device, smart device, deep learning, machine learning, neural network, quantum computing and etc. Of course, this is not enough in sense of patentability or inventive step for a subject matter of such patent application.

Almost every of the above-mentioned patent applications contained in the mentioned patent databases include such previously mentioned expressions in Title of Invention or in the Abstract, which is easier for patent search.

2.5. The DABUS case

One of the most famous worldwide patent cases is the one where Stephen Thaler, from St. Charles, Missouri, US, listed "DABUS invention which was autonomously generated as artificial intelligence" as inventor, as mentioned in [11]; he also listed it as an applicant together with himself in some countries (for example, in Israel), as shown in [12], [13]. Several decisions have been made in this case. For example, CIPC (the South African IP office) granted the first patent for AI invention worldwide (ZA 2001/03242) on July 28th 2021.

DABUS means "Device for Autonomous Bootstrapping of Unified Sentience", as stated in [14]. Thaler also filled patent applications with several countries and regional patent offices, such as USPTO, EPO, UKPTO, DPMA Germany, New Zealand, Taiwan R.O.C., India, South Korea, Israel and Australia. In all of the previously mentioned countries patent was rejected and mainly on finding that a natural person must be listed as inventor with its own address of living place or must have legal capacity, as mentioned in [11]. In some countries IPO offices do not carry out substantive examination, but only formality examination instead; in such cases patent could be granted without substantive examination.

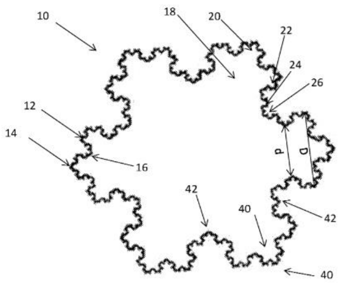

Figure 1. *Drawing from the one of the DABUS patent applications (WO 2020079499 A1)*

Title of this AI invention was "Food container" and the applications are still pending in jurisdictions in some countries after the EPO's Board of Appeals rejection decision.

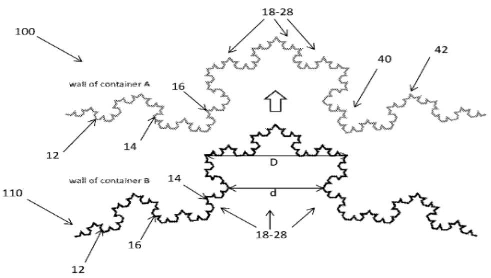

Figure 2. *Another drawing from the one of the DABUS patent applications (WO 2020079499 A1)*

Nowadays a variety of different solutions to the problem of protection of AI generated inventions has been considered under the auspices of the World Intellectual Property Organization (WIPO). Currently they can be divided into the following groups, as suggested in [15]:

- Preserve the status quo and continue to recognize human inventors only,
- Revise patent laws to allow an AI system to be named as an inventor or co-inventor,
- Revise patent laws to require a legal person to be named as a proxy for the AI (co-)inventor, while recording the inventive contribution of an AI system,
- Establish a sui generis IP law for AI-generated inventions.

The discussion on this issue is ongoing and the most appropriate policy setting is still to be found and accepted by policymakers.

2.6. Research in the ESPACENET database

The search in the ESPACENET database, mentioned as [7], wherein keywords such as the previously mentioned expressions for AI and in combination with "RS" as country code for patent documents published in the Republic of Serbia, and "G" (Physics) and "H" (Electricity) sections of the International Patent Classification (IPC; see [16]), were used as search criteria, resulted in 76 patent documents (i.e. published patent applications or granted patents). Fifty of them were filled by foreign applicants and only 26 (twenty-six) by Serbian applicants. A number of granted European patents that entered into the Register of Patents of the Republic of Serbia thus becoming RS patents were 47, but none of the European patent applications. On the other hand, only 3 patent applications filled in accordance with the Patent Cooperation Treaty (PCT) of the WIPO were published. The rest were the published patent documents of Serbian applicants.

Table 1. *Results of the search in Espacenet database*

Kind of patent documents	Total number of published RS patent documents	Number of RS patents
Patent documents of Serbian applicants	26	2
Patent applications filled in accordance with PCT	3	-
Granted EP patents that entered in the Registry of Patents	47	47
Total	**76**	**49**

Referring specifically to the patent documents of Serbian applicants, it was found that only 2 (two) of total of 26 (twenty-six) thereof were granted (i.e. registered) patents (RS B documents), while the rest of them (twenty-four documents) were either published patent applications (RS A documents) or they are still undergoing the process of substantive examination after being published in the IPG.

It should be stressed that the granted EP patents that entered in the Registry of Patents had been previously examined and granted by the EPO and within period of three months had been applied for entering in the Registry of Patents, i.e. they had been validated as patents in the Republic of Serbia as one of the EPO contracting states.

When analysing the granted EP patents in this research, it has been found that each granted EP patent that had been validated in the Republic of

Serbia has got claims for method (or computer implemented method). In some cases, system claims, apparatus claims, computer program claims, computer program product claims, computer readable medium or data carrier claims also have been added to the mentioned claims for method.

This research also confirms that a number of AI-related patent applications and patents worldwide are significantly bigger than the one in the Republic of Serbia, where number thereof is still small. In order to overcome this problem, it is necessary to improve interactions between relevant institutions such as universities, research institutions, IP offices and significant AI companies, and to prioritize and provide best practices and solutions for all in order to increase use and recognize new technologies as priority for all of us.

3. CONCLUSION

Current rapid development of AI (Artificial Intelligence) technologies posed many questions both for national and international patent systems. Therefore, both national and regional patent offices meet the challenge regarding examination of AI-related patent applications, whose number is constantly growing. The EPO developed its own approach for examination of these applications that is known as "two-hurdle approach". The first hurdle relates that presence of any technical means in the claim. Since AI and ML as such are considered mathematical/algorithmic concepts, the second hurdle relates to the evaluation if such mathematical method may contribute to producing a technical effect that serves a technical purpose, by its application to a field of technology and/or by being adapted to a specific technical implementation. It should be noted that during examination of the patent applications filled by Serbian applicants typically arises a problem relating to insufficient disclosure of the invention, due to the fact that applicants believe that is understood that any AI invention is carried out on a computer; also, patent applications are often missing technical parameters and phases of the computer implemented inventions to be executed on computer. Such defects cannot be corrected subsequently, which is why such patent applications are rejected. In the future, it will be critical problem to express such new technologies as AI in proper way that they can be protected by Intellectual Property rights such as patents, industrial design, copyright, topography of semiconductor products, trade secrets, etc. Currently a variety of different solutions to the problem of protection of AI generated inventions has been considered. The discussion on this issue is ongoing and the most appropriate policy setting is still to be found and accepted by policymakers. Furthermore, it is noteworthy mentioning that a number of AI-related patent applications and patents worldwide are significantly bigger than the one in the Republic of Serbia, where number thereof is still small. In order to overcome this problem, it is necessary to improve interactions between relevant institutions, and to prioritize and provide best practices and solutions for all in order to increase use and recognize new technologies as priority, to be able to keep up with the latest developments in this field.

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The Impact of the KVINK Innovation Incubator on the Development of the Startup Ecosystem at the Faculty of Mechanical and Civil Engineering in Kraljevo

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Abstract: *Innovation incubators play a crucial role in enhancing the innovation ecosystem by not only supporting the development of new products, technologies, and services but also through providing guidance, support, and resources through the innovation process. Innovation incubators perform such a role by enabling interdisciplinary collaborations through networking and connections to resources as well as by providing mentor programs for acquiring entrepreneurial skills and experience. Therefore, innovation incubators are an essential part of university infrastructure that helps sustain not only individual startup development but also the creation of a robust innovation ecosystem fostering further economic growth and progress. This study analyzes the impact of the innovation incubator on the development of the startup ecosystem at the Faculty of Mechanical and Civil Engineering (FMCE) in Kraljevo. Through a descriptive approach to research, data from the Kvink innovation incubator were analyzed to determine the support provided by the incubator in forming startup teams, developing innovative projects, and promoting entrepreneurial spirit among students and researchers. The results of the study indicate a significant positive impact of the innovation incubator on the development of the startup ecosystem at FMC. Also, some success factors were identified and challenges were revealed for more sustainable development of the entrepreneurial culture within the faculty.*

Keywords: *Kvink innovation incubator; startup ecosystem; Faculty of Mechanical and Civil engineering; entrepreneurship*

1. INTRODUCTION

Innovation, startups, and entrepreneurship are key factors for economic growth and the development of modern societies. Innovations enable the development of new technologies and products that directly contribute economies' competitiveness and prosperity. The startup ecosystem, as a network of actors including entrepreneurs, investors, incubators, accelerators, universities, and the government, plays a central role in creating a favorable environment for the growth and development of new firms [1]. Key components of the startup ecosystem include access to capital, mentorship, regulatory frameworks, and support infrastructure for entrepreneurship. Startups, as innovative business entities with the potential for rapid and significant growth, often face numerous challenges in the early stages of their development [2]. Support for startups can be organized through various systems, including business innovation incubators, science and technology parks, and innovation incubators within research organizations [3].

Innovation incubators established within research organizations play a crucial role in supporting startups, especially in the early stages of their development. They provide direct support to students and faculty through access to mentors, funding, and resources such as workspace and technological infrastructure, which significantly increases the chances of success for innovative ideas [4]. Additionally, incubators play a key role in bridging the gap between academic research and the market, allowing students and professors to turn their research results into commercial products and services, thus contributing to economic development [1, 5, 6, 7;]. They help overcome barriers such as lack of business knowledge and market access, thus increasing the chances of forming successful startups [4, 8]. They provide access to technology, markets, capital and mentorship, all of which contribute to increased innovation and entrepreneurship. According to data from the Startup Scanner [2], incubators significantly contribute to the development of the entrepreneurial ecosystem through networking, access to capital, and promoting entrepreneurial spirit among young people.

The Ministry of Science, Technological Development, and Innovation of the Republic of Serbia has recognized these needs and launched an initiative to establish innovation incubators in scientific research organizations (SRO), aiming to create conditions for the direct commercialization of research results and support the development of innovative projects. Under the Program for the Formation and Development of Innovation Incubators in SRO, funds were approved for the establishment of an innovation incubator at the Faculty of Mechanical and Civil Engineering in Kraljevo (FMCE). The project will be implemented over 12 months, with its primary goal being the promotion of innovative entrepreneurship and the development of entrepreneurial spirit among students and employees in research organizations, as well as providing support to anyone with innovative ideas and the desire to bring them to market. The project is being implemented in cooperation with the Science and Technology Park in Čačak and with the support of other members of Serbia's innovation ecosystem.

Startups face numerous and specific challenges, such as a lack of business knowledge among students, limited access to funding, and a lack of mentoring support. These challenges limit the potential to develop innovations and entrepreneurial ventures [9]. A common strategy universities use to overcome these obstacles is the establishment or use of incubators, centralized facilities that provide access to university support and resources [10, 11]. Access to technology and infrastructure is also limited, as startups often lack the necessary laboratories, equipment, and software to develop and test innovations. Networking and market access are additional challenges since many startups do not have the network of contacts that are essential for growth and expansion. Balancing academic obligations with entrepreneurship is complex because students, professors and researchers often have commitments that make it difficult to dedicate themselves to developing new ideas. This is particularly challenging for forming spin-off companies, where the support and active participation of professors and researchers are crucial for success. Additionally, startups face regulatory and legal issues that can be obstacles to growth, including intellectual property protection and business contracts. Finally, developing a sustainable business model and scaling up the business are key challenges for the long-term success of startups. Innovation incubators play a crucial role in overcoming these challenges by providing comprehensive support, including mentorship, access to financial resources, and key resources, thereby reducing the risk of failure and increasing the chances of success for new firms.

The Faculty of Mechanical and Civil Engineering in Kraljevo faces additional challenges due to the lack of previous experience in developing a start-up ecosystem. The establishment of KVINK, an innovation incubator represents the first step in addressing these challenges and creating a sustainable entrepreneurial environment. Before the establishment of KVINK, the FMCE did not have a developed entrepreneurial ecosystem, which limited the opportunities for the commercialization of research results and the development of new business initiatives.

The aim of this paper is to analyze the impact of the KVINK innovation incubator on the development of the startup ecosystem at the Faculty of Mechanical and Civil Engineering in Kraljevo, through an evaluation of the support provided to students, professors and researchers. The focus is on how the incubator helps form startup teams, develop innovative ideas, and promote entrepreneurial spirit. This paper will also identify key success factors and challenges in the sustainable development of an entrepreneurial culture at the faculty, with a special focus on initiatives and programs that have facilitated the formation of startup teams and the development of innovative ideas. We will examine the specific measures and activities that contributed to KVINK's success and identify obstacles that need to be overcome for further development.

2. LITERATURE REVIEW

Higher education institutions play a key role in promoting entrepreneurship among students. By introducing entrepreneurial programs and courses, universities can significantly contribute to creating new entrepreneurs and enhancing economic development. According to Doddamani [12], higher education institutions should promote entrepreneurial capacities among students. He emphasized the importance of creativity, innovation, and entrepreneurship as key components of the educational system. According to Jeyalakshmi and Meenakumari [13], the role of higher education institutions in promoting entrepreneurship is multifaceted. They not only provide education and training but also create an environment that fosters innovation and the development of new business ideas. Through various academic programs, research, and extracurricular activities, universities help students acquire the necessary skills and knowledge for entrepreneurship. Through university incubators, students and employees at scientific research organizations receive support for turning their research findings into market-relevant products and services, facilitating their transition from academia to the business world.

University innovation incubators are specialized institutions that provide support to students and academic staff in developing innovative ideas and entrepreneurial projects. They create a positive environment that encourages creativity and innovation, enabling the development of ideas with high potential for success [4, 14]. University business incubators (UBI) provide access to mentors, funding, and infrastructure, which are crucial for innovation development.

Incubators play a significant role in the academic community, where universities and other public research organizations are the main sources of innovation. Grimaldi and Grandi [5] emphasized that UBIs provide support for new knowledge-based ventures, focusing on the transfer of scientific and technological knowledge from universities to companies. This not only enables the commercialization of public research results and also contributes to economic and social well-being and regional development. In developed countries, universities and companies often collaborate because firms need external sources of knowledge to enhance their human resources and research laboratories. The modern development of new products and services requires creative sources beyond the companies themselves, including collaboration with customers, suppliers, research institutes, and even competing firms [15].

Bigliardi, Galati, and Verbano [6] highlighted that academic spin-off companies have significant potential to exploit technological knowledge acquired at universities. The process of forming spin-off companies is complex and involves transforming a research idea into a marketable product. University technology business incubators (UTBI) represent a modern tool for enterprise development that uses a combination of support, including shared office services, business assistance, access to capital and business networks. Mian [16] asserted that UTBIs provide a nurturing environment for developing new technology firms through a combination of necessary university and typical incubator services.

University support for spin-off companies can significantly increase their chances of success. Factors such as financial support, competent staff in technology transfer offices, transparency and clarity of support policies, and access to qualified entrepreneurial skills are crucial for the success of these companies [6]. According to Mian [16] UTBIs provide support through various stages of startup development, from the initial idea to commercialization.

However, academic spin-off companies face numerous challenges, including the founders' need for autonomy, leadership, personal responsibility, risk-taking, and preference for various organizational structures. Additionally, new technology-based firms (NTBFs) often face a lack of resources, uncertainty in the technology development process, market acceptance, and limited entrepreneurial knowledge and skills [7].

Government support and its institutions play a crucial role in the startup formation process and its further development. According to Vekić and Borocki [17] governments should recognize innovative startups and help them grow, actively influencing the development and strengthening of economic activity in the country. Support through a network of institutions, including laws, policies, and regulations, is essential for this complex process.

The Startup Scanner 2024 report highlights that Serbia's support for startups is crucial for their further growth. The Innovation Fund plays a central role in this process by providing financial support, mentorship, and networking with investors, enabling startups to turn their innovative products and technologies into successful global businesses. The Fund is recognized as an indispensable partner and support for innovation development, as confirmed through numerous successful projects and programs supporting startups [2].

Despite challenges such as financial instability and insufficient connections with universities, incubators in Serbia manage to contribute to the development of the entrepreneurial ecosystem by strengthening mentorship programs and connecting with industry. These activities significantly reduce risks and increase the chances of success for new firms [18].

Academic spin-off companies contribute to technology transfer by transferring technology from their parent organizations to themselves and then to customers, significantly enhancing the industrial application of scientific knowledge [6]. The role of educational institutions in entrepreneurship is crucial for the direct contribution to the quantity and quality of new startups, which indirectly contributes to the economy. According to Guerrero, Urbano, and Gajon [1], strengthening entrepreneurial culture and education within universities can further improve the performance of incubators and the success of startup companies.

Examples of successful university incubators include programs such as MIT Media Lab and Stanford StartX, which have successfully integrated academic research resources with the business world, and created innovative entrepreneurial ecosystems [9]. These incubators have contributed to the development of numerous startups that have achieved significant commercial success and have impacted regional economic development.

3. METHODOLOGY

In this research, a descriptive approach is used to analyze the data collected through surveys and interviews. This approach allows for a detailed understanding of the role and impact of KVINK on the development of the startup ecosystem at the Faculty of Mechanical and Civil Engineering in Kraljevo. Qualitative analysis provides deeper insight into the participants' experiences and perceptions.

Data were collected through surveys and interviews with FMCE students and faculty members. The surveys were designed to include questions about the availability of resources, quality of mentorship support, access to funding, and impact of the incubator on the development of innovative ideas. The interviews provided a deeper insight into the individual experiences of the participants.

Surveys were conducted among 50 students and 20 professors and researchers. The survey questions combined of open-ended and closed-ended questions, allowing for the collection of both quantitative and qualitative data. The surveys took between 5 and 10 minutes per respondent.

Interviews were conducted with key participants in the incubator, including students who actively participated in the incubator's programs and professors and researchers who used the incubator's resources for their projects. The interviews lasted between 20 and 30 minutes and were semi-structured, allowing for flexibility and adaptation during the conversations.

The selected students were those who participated in KVINK programs and those who used its resources. The goal of this study was to obtain a representative sample of students from different years of study and departments.

Selected professors and researchers were those who used KVINK's resources for their research projects or were involved in mentoring students. The goal was to gather diverse experiences and perspectives from faculty members.

In addition to surveys and interviews, documentation related to KVINK's activities and results was also analyzed. This documentation includes project reports, program evaluations, and training records, which allow for a comprehensive understanding of the incubator's work and its impact on the startup ecosystem.

The Faculty of Mechanical and Civil Engineering in Kraljevo has a long tradition of providing education in technical sciences, but it previously did not have a developed entrepreneurial ecosystem. The formation of KVINK represents the first step toward creating a sustainable entrepreneurial environment that will enable students, professors and researchers to develop their business ideas and commercialize their research results. In the first phase of the project, KVINK employees participated in training organized by the Science and Technology Park Čačak, with the aim of strengthening their internal capacities. This training enabled employees to improve their skills and competencies to provide the highest quality support to the incubator participants.

4. ANALYSIS AND RESULTS

The KVINK innovation incubator provides various support for the process of forming startup teams, including mentoring assistance, access to funding and infrastructural resources such as office space and laboratories. Data collected from surveys and interviews clearly show that access to mentors and funds are key factors for the success of business ventures.

The survey results indicate that 75% of students and 80% of professors are very satisfied with the availability of office space and resources in the incubator. Additionally, 72% of students and 90% of professors expressed satisfaction with the availability of laboratories and technological equipment. The use of the 3D workshop recorded a high level of satisfaction, with 70% of students stating that they regularly used it and found it extremely useful.

The quality of mentoring support has proven to be a crucial factor for the success of startups, which is consistent with findings in the literature [7]. According to the surveys, 90% of students and 30% of professors stated that they frequently used the mentoring services of the incubator. Of these, 78% expressed high satisfaction with the quality of the mentoring support. Students particularly emphasized the importance of practical advice and support in developing business models, aligning with Grimaldi and Grandi's [5] findings on the importance of mentoring programs in innovation development.

The introduction of the Innovation Fund significantly helped participants become familiar with funding opportunities. Before using the incubator's services, only 5% of students and 80% of professors were familiar with the Fund, but after using the incubator's services, this percentage increased to 85% for students and 90% for professors. The allocation of innovation vouchers enabled the realization of several innovative projects. Specifically, 60% of the professors used innovation vouchers, and 80% of them stated that the vouchers were crucial for transitioning from the conceptual phase to the practical implementation of projects.

The incubator has significantly influenced the development of participants' innovative ideas. According to the surveys, 85% of students and 80% of professors believe that the incubator helped them develop their business ideas. About 75% of students stated that activities such as startup weekends and competitions were key to forming their teams. One student team participated in the Serbian-French Innovation Forum and won first place, demonstrating the concrete value of these initiatives.

Most of the surveyed students (90%) and professors (72%) were not familiar with the startup concept before the existence of the incubator, further emphasizing the importance of KVINK's presence and activities in the educational and entrepreneurial ecosystem. Activities of the incubator, such as training, mentoring, and networking events, provide students with the opportunity to connect with experienced entrepreneurs and members of the innovation community and receive valuable advice for developing their projects. The participants emphasized that these activities significantly impacted their motivation and confidence in developing their innovative ideas.

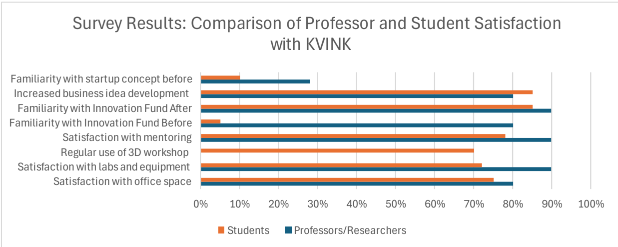

Figure 1. *Survey and Interview Results: Comparison of Professor and Student Responses on Satisfaction with Resources and Services of the KVINK Innovation Incubator*

KVINK strives to provide continuous support through networking with industry experts and potential investors. Mentoring programs and networking events enable students and researchers to connect with industry experts, receive valuable advice, and establish contacts that are crucial for realizing their innovative ideas. These programs contribute to the development of entrepreneurial skills and the creation of a support network necessary for the long-term success of startups.

KVINK provides access to the key resources necessary to successfully develop of innovative ideas and startups. This access includes not only physical resources such as office space and laboratories but also intellectual resources such as the knowledge and experience of mentors, access to research materials and technologies. The survey participants highlighted that these resources enabled the faster and more efficient realization of their business ideas.

The training and mentoring programs offered by KVINK have significantly impacted the development of entrepreneurial skills among students and professors. Through these programs, participants have acquired valuable skills in project management, teamwork, financial planning, marketing, and sales. These skills are crucial for successfully running startups and increasing the chances of long-term success.

KVINK has proven to be a key player in promoting entrepreneurial spirit among students and researchers. Most students and professors had no prior knowledge of startups before the incubator was established at FMG, further emphasizing the significance of KVINK in educational and entrepreneurial environments.

This transformation has been enabled through the strategic support of the incubator and the engagement of all relevant stakeholders in the process. KVINK has created a platform that allows students, professors, and researchers to develop their innovative ideas and apply research results for commercial purposes, significantly contributing to the development of the entrepreneurial ecosystem at the Faculty of Mechanical and Civil Engineering in Kraljevo.

5. DISCUSSION

The results of this research show that the key success factors for KVINK are access to mentors, networking with other members of the innovation ecosystem, financial support, and infrastructural resources. These circumstances enable students and professors to work on their business ideas and apply research results for commercial purposes, which aligns with Grimaldi and Grandi [5], who emphasize the importance of university business incubators in supporting innovative ventures. Kazhenov [8] highlighted the importance of strengthening entrepreneurial culture and education within universities, which further enhances the performance of incubators and the success of startup companies. Jeyalakshmi and Meenakumari [13] stated that entrepreneurial education not only helps create new jobs but also fosters innovative thinking and serves as a stabilizer for society, thereby enhancing the entrepreneurial spirit among students. Doddamani [12] also emphasized that higher education institutions can significantly contribute to reducing poverty and increasing employment through entrepreneurial education, enabling students to develop the necessary skills to start their own businesses, which are supported through incubators that provide the necessary infrastructure and support. According to Grimaldi and Grandi [5], university business incubators (UBI) provide essential support for knowledge-based ventures, focusing on the transfer of scientific and technological knowledge from academia to business entities. Similarly, the KVINK incubator facilitates knowledge and technology transfer, which has improved innovation and entrepreneurship at the Faculty of Mechanical and Civil Engineering in Kraljevo.

The KVINK incubator also contributes to promoting entrepreneurial spirit among students, professors and researchers. According to the findings of this research, 78% of students and 72% of professors and researchers were not familiar with the concept of startups before the incubator existed. The incubator's activities, such as training, mentoring, and networking events, significantly impacted the participants their motivation and confidence in developing their innovative ideas. These results are consistent with of Guerrero et al. [1], which highlighted the importance of strengthening entrepreneurial culture and education within universities.

Financial support has also been identified as a key factor. The introduction of the Innovation Fund significantly increased participants' awareness of funding opportunities, as confirmed by the rise in the number of innovation voucher users. Before using the incubator's services, only 5% of students and 80% of professors were familiar with the Fund, but after using the incubator's services, this percentage increased to 85% for students and 90% for professors and researchers. This aligns with findings from the Startup Scanner 2024, which emphasizes the importance of information availability about funding for startup success.

Mentoring support is also a crucial element of success. Soetanto and Jack [7] stated that access to mentors and industry networks is vital for startup success, which aligns with the findings of this research. In our study, 78% of respondents expressed high satisfaction with the quality of mentoring support, indicating that KVINK successfully provides the necessary guidance and support to overcome these challenges.

Support from the university, the innovation community, and the local community is crucial for KVINK's success. The university provides infrastructure and resources, the innovation community offers its network of resources and mentors, and the local community helps with networking and finding financial support. This collaboration enables the incubator to provide comprehensive support to students and professors, creating a sustainable entrepreneurial ecosystem [1, 5, 7, 9]. Additionally, Guerrero et al. [1] emphasize the importance of institutional support and industry connections for the success of university incubators.

However, significant challenges exist in sustainable development of the startup ecosystem. The major obstacles are the lack of clear internal regulations, limited resources, and financial unsustainability of the incubator. There is also a need for further development of mentoring programs and increased access to capital for startups. One of the key challenges is the formation of academic teams to commercialize their scientific research, as there are currently no spin-off companies at the faculty. Bigliardi, Galati, and Verbano [6] pointed out that academic spin-off companies face specific challenges in the context of technology transfer and the commercialization of research results.

We recommend further institutional support for developing of incubator programs, strengthening cooperation among universities, the government, and industry, and improving mentoring programs. Additionally, it is necessary to secure additional funds for financing startups and developing innovative projects. Vekić and Borocki [17] highlighted the importance of government support for the development of innovative startups, which is crucial for strengthening economic activity and achieving long term success.

6. CONCLUSION

The KVINK innovation incubator has a significant impact on developing of the startup ecosystem at the Faculty of Mechanical and Civil Engineering in Kraljevo. By providing support in forming startup teams, developing innovative ideas, and promoting an entrepreneurial spirit, the incubator contributes to creating a sustainable entrepreneurial environment. Activities such as training, mentorship, and networking events offer students the opportunity to connect with experienced experts and receive valuable advice for developing their projects.

Future research should focus on the long-term effects of innovation incubators on the development of regional economies and the possibilities for improving incubator activities. It is proposed to develop new initiatives and programs that will further support entrepreneurial activities at the faculty. Special attention should be given to strengthening mentoring programs for academic staff, which will enable continuous improvement of their entrepreneurial skills and abilities, as well as the commercialization of their scientific results.

Additionally, it is important to secure additional funds to finance startups and develop innovative projects. Institutional support, strengthening cooperation between universities, the government, and industry, as well as enhancing mentoring programs are key factors for success. These activities will not only increase the capacity for innovation within the university but also significantly contribute to the economic development of the region.

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APPENDIX A

Appendix A includes the survey used to collect data from students, researchers, and professors at the Faculty of Mechanical and Civil Engineering in Kraljevo, regarding their experiences with the KVINK Innovation Incubator.

Survey questions:

1. General Information:
   - 1.1. Your role:
     - Student
     - Professor
     - Researcher
   - 1.2. If you are a student, please indicate your year of study: ___
   - 1.3. If you are a professor, please indicate your position: ___
   - 1.4. Number of years at the institution:
     - Less than 1 year
     - 1-3 years
     - 4-6 years
     - More than 6 years
2. Availability of Resources:
   - 2.1. How satisfied are you with office space availability in the incubator? (1 - Very Dissatisfied, 5 - Very Satisfied):
     - 1
     - 2
     - 3
     - 4
     - 5
   - 2.2. How satisfied are you with the availability of laboratories and technological equipment? (1 - Very Dissatisfied, 5 - Very Satisfied):
     - 1
     - 2
     - 3
     - 4
     - 5
   - 2.3. Have you used the 3D workshop?
     - Yes
     - No
3. Quality of Mentoring Support:
   - 3.1. How often do you use mentoring services in the incubator:
     - Never
     - Rarely
     - Occasionally
     - Often
     - Very Often
   - 3.2. How satisfied are you with the quality of mentoring support? (1 - Very Dissatisfied, 5 - Very Satisfied):
     - 1
     - 2
     - 3
     - 4
     - 5
   - 3.3. Which aspects of mentoring support have been most helpful to you?
4. Access to Funding:
   - 4.1. Were you aware of the Innovation Fund before using the incubator services?
     - Yes
     - No
   - 4.2. How satisfied are you with the availability of information on funding opportunities? (1 - Very Dissatisfied, 5 - Very Satisfied):
     - 1
     - 2
     - 3
     - 4
     - 5
   - 4.3. Did you use innovation vouchers? If so, how helpful were they in developing your project?
5. Impact of the Incubator:
   - 5.1. How much did the incubator help develop your business/research ideas? (1 - Not at all, 5 - A great deal)?
     - 1
     - 2
     - 3
     - 4
     - 5
   - 5.2. Did activities such as startup weekends and competitions help you form a team?
   - 5.3. What are the key benefits of using the incubator for you?
6. Additional Suggestions:
   - 6.1. Do you have any additional suggestions or comments regarding the work of the KVINK incubator?

APPENDIX B

Appendix A includes the interview questions used to collect data from students, researchers, and professors at the Faculty of Mechanical and Civil Engineering in Kraljevo, regarding their experiences with the KVINK Innovation Incubator.

1. General Information:
   - 1.1. Could you tell us more about yourself? (Year of study/Position, number of years at the institution)
   - 1.2. How long have you been involved in KVINK incubator activities?
2. Availability of Resources:
   - 2.1. How do you evaluate office space availability in the incubator?
   - 2.2. Have you used the laboratories and technological equipment of the incubator? If so, how would you evaluate their availability and quality?
   - 2.3. How often do you use the 3D workshop and other specialized resources of the incubator?
3. Quality of Mentoring Support:
   - 3.1. How often do you use/provide mentoring support through the incubator?

   3.2. How do you evaluate the quality of mentoring support you received/provided?
   3.3. Could you describe any particularly helpful experience or advice you received/provided as a mentor Could you tell us more about yourself? (Year of study/Position, number of years at the institution)
4. Access to Funding:
   4.1. Were you familiar with the Innovation Fund before using the incubator's services?
   4.2. How useful was the information on funding opportunities you received at the incubator?
   4.3. Did you use innovation vouchers? If so, how did they help you in developing your project?
5. Impact of the Incubator on Development:
   5.1. How did the incubator impact the development of your business/research ideas?
   5.2. Did the incubator's activities help you form a startup/research team?
   5.3. What are the key benefits of using the incubator for your work?
6. Challenges and Recommendations:
   6.1. What challenges did you face while using the incubator's resources?
   6.2. Do you have any recommendations for improving the work of the incubator?

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Empowering Student Entrepreneurship Education: The Role of Academic Innovation Incubators

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Abstract: *In today's rapidly evolving landscape of technology and innovation, the role of academic institutions extends beyond traditional education. Universities and faculties are becoming hubs of entrepreneurial activity, fostering cultures of innovation and creativity. Entrepreneurial education, especially at technical faculties, is a driving force for improving the skills needed to launch startups and innovative businesses that lead to the creation of new value, the commercialization of inventions and the creation of new jobs. By the end of 2023, with the support of the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, fourteen innovation incubators have been established at faculties and institutes throughout Serbia. These innovative incubators provide a supportive environment that improves the entrepreneurial potential of students, equipping them with the skills and resources needed to develop innovative ideas and start business ventures. One such incubator is the Innovative incubator of Faculty of Technical Sciences in Čačak, which has shown significant progress in its first six months. This paper explores the importance of academic innovation incubators in empowering student entrepreneurship education, highlighting their role and impact.*

Keywords: *entrepreneurship; entrepreneurship education; innovative incubators; student's startup teams; Innovative incubator of Faculty of Technical Sciences in Čačak;*

1. INTRODUCTION

In a period of crisis and comprehensive economic changes, entrepreneurship emerges as a key driver of the transformation of the current economic system and the creation of conditions for the development of a modern economy. According to Schumpeter, entrepreneurship is viewed from the point of view of entrepreneurs who represent innovators which create conditions for gaining profit by creating temporary monopolies through organizational and technological innovations [1]. Modern economies are marked by process which Schumpeter later defined as "creative destruction" [2]. Today, modern entrepreneurship implies three observations: entrepreneurship as business management, entrepreneurship in the sense of entrepreneurial behavior as opportunistic behavior driven by value and value acquisition, and entrepreneurship as self-employment through business ownership that includes significant elements of risk, management and reward [3]. In developed countries many entrepreneurs founded their companies at universities. Entrepreneurship education is crucial for student entrepreneurs to gain resources and improve knowledge, enhance their innovative capabilities and skills, and develop an entrepreneurial mindset. Entrepreneurship education encompasses both the development of general competencies and the enhancement of specialized professional skills. By stimulating entrepreneurship and innovation among students at faculties through the activities of newly established innovative incubators, we can have a great impact on our changing society and economy.

With an increase of government support, the recent period has shown a slight but encouraging increase in interest in technology and startup entrepreneurship and the commercialization of inventions stemming from academia.

2. ENTREPRENEURSHIP EDUCATION AT ACADEMIC INSTITUTION

While general education focuses on the overall development of students, entrepreneurial education lays on the foundation for the overall improvement of students' entrepreneurial ability. From observation to participation, the social learning network provides multi-level learning channels for student entrepreneurs to continuously improve their skills in learning and practice [4].

Entrepreneurship education can change a student's attitudes toward entrepreneurship by fostering a culture of innovation, skills development and entrepreneurship and reducing environmental uncertainties. It enhances student's perception, enabling them to consistently improve and accumulate new knowledge, which in turn shapes their innovative abilities and personalities.

The two most used terms in this field are *enterprise education* focusing more on personal development and abilities, and *entrepreneurship education* which is defined as education which focus on the specific context of setting up a venture and becoming self-employed. In Sweden and the Balkans, the term *entrepreneurial learning* is used as an equivalent to enterprise education and this sometimes causes confusion since it is the same term used in the research domain of entrepreneurial learning, which is about studying how entrepreneurs learn outside of the educational domain [5].

Entrepreneurship education might enhance the confidence of the students that he will be able to solve new and unexpected problems that could lead to establishing innovative ventures. A supportive environment that promotes entrepreneurship and innovations among students can increase student's motivation and knowledge of entrepreneurship which can help them to start their business venture or to become more suitable on the labor market.

Due to their inherent nature, large organizations like universities are not typically the most entrepreneurial institutions. There are certain barriers that prevent entrepreneurship education from being applied at the required level at universities and colleges. The reasons for it could be [6]:

- The impersonal nature of relationships;
- The hierarchical structure and many levels of approval;
- The need for control and the resultant adherence to rules and procedures;
- The conservatism of the corporate culture;
- The time dimension and the need for immediate results;
- The lack of entrepreneurial talent;
- Inappropriate compensation methods.

Students' perspectives on their entrepreneurship education are closely linked to their views on innovation, entrepreneurship and attitude towards risk, so universities hold the primary responsibility of fostering innovation through entrepreneurship education. There is a positive relationship between the educational processes and technological innovation and development [7].

Cultivating innovative awareness and abilities is key to students' engagement in innovation activities, which are further shaped by their motivation and support given by different institutions. There are important indications that entrepreneurship educational programs positively influence entrepreneurial goals, enhance the appeal of accessing various resources and connections, and increase participation in entrepreneurship competitions [8].

The motivation of entrepreneurial students could be numerous, but some of the main tendencies can be highlighted [9]:

- The willingness and involvement to be useful for society, to change things, "to make a difference in the world" and to participate in a more sustainable world by answering citizens and end-users needs, especially disabled people or elderly;
- To have a creative and stimulating job;
- Working for themselves, gain financial freedom and earn a living from their passions;
- Create more links and interactions between students and within the communities.

According to Startup Scanner 2024 - comprehensive annual research about innovative entrepreneurship and domestic innovative startup ecosystem in Serbia, 10,4% of startup founders got the idea for launching a startup and gathering a team during their university studies [10].

It should be noted that in Serbia the majority of higher education institutions are to a certain extent engaged in a multitude of different entrepreneurial activities but this does not imply that all these academic institutions can be specifically considered as entrepreneurial institutions. Measuring the quality of entrepreneurial activities at universities against the financial resources generated from such activities, it can be noticed that not all higher education institutions in Serbia are equally successful - entrepreneurial activity depends on the entrepreneurial knowledge, skills and capacities of employees at higher education institutions [11].

3. ACADEMIC INNOVATIVE INCUBATOR'S ROLE IN ENTREPRENEUSHIP EDUCATION

Universities must evolve beyond their traditional roles in teaching and research to actively contribute as creators and disseminators of entrepreneurial knowledge. They should actively contribute as both producers and disseminators of knowledge in entrepreneurial endeavors. The concept of academic innovation incubators is gaining more and more importance. Academic innovative incubator targeted resources and services to support the early-stage ideas of students and entrepreneurs. This approach contrasts with traditional incubation models which support established firms, whether startups or more developed companies. By fostering these business ideas, this pre-incubation and incubation centers can play a crucial role in accelerating the development and success of new ventures among students.

Entrepreneurship can be learned through experience and the sharing of knowledge, yet promoting it is no simple task. Core elements of entrepreneurship — such as searching for new opportunities, building trust and creating networks and projects are often challenging to be properly understood and turned into practical guidelines. Currently, many students aspire to join the "labor market" immediately after graduation. However, adopting an entrepreneurial mindset can improve student's skills and expectations about the future. This change in perspective requires environment that support the development of entrepreneurial thinking and business skill improving [12].

This is where academic innovation incubators can come out as center that is empowering student entrepreneurship education processes, regardless of how multi-faceted they might be. It becomes critically important in the rapidly changing technological landscape of today. Academic innovation incubators narrow the gap between theoretical knowledge and practical application by providing an incubation environment for students to experiment, innovate, and bring their ideas to market. It combines unique values, including team engagement, learning from experience and access to the networks in special industry circles.

The most vital feature of an academic innovation incubator is experiential learning - students are not just the passive recipients of information, they go through high engagement in problem-solving, critical thinking, improving creativity and management of projects. This kind of experience is invaluable, as it prepares them to face the real-world challenges they might face as entrepreneurs. Academic incubators foster the culture of collaboration and teamwork, so students from different backgrounds can work together on developing innovative ideas and bring to team different approach, skills and points of view. This interdisciplinary approach not only enhances the entrepreneur learning experience but also leads to more innovative solutions.

In this way, academic innovation incubators foster better ways to develop and improve a student's entrepreneurial mindset. Students learn to identify opportunities, calculate risks, and fight failures using practical skills which are fundamental requirements for the modern entrepreneurship. The incubators also function as a play-pen for failure, which is a critical element of learning. Students are often encouraged to try out things and learn from their misjudgments without much fear of significant repercussions. That is learning through an iterative process of trial and error, which is critical to innovation.

In addition to the development of technical skills, academic innovation incubators are business sense training centers. Participating in activities such as entrepreneurial courses, workshops, pitch competitions and startup bootcamps, students are expected to learn market research methodology, develop business models, learn how to manage their finances, talk with customers and intellectual property rights. This approach ensures that students are able to handle the complexity starting and managing business. Also, these activities build an energetic entrepreneurial community that supports and sustains new ventures. Incubators also ensure that students are connected to potential investors, which give them a chance to pitch their ideas that can lead to funding.

Research indicates that innovation incubators support existing teachers, researchers, and academic staff or faculty management. In addition, incubators are agile, and maintain an open-door policy, welcoming participants interested in enterprise education and business creation. Moreover, they foster combined creativity is witnessed as incubators encourage the development of new ideas and the application of courses and programs to real-world settings and industry expectations [13].

Important advantage of academic innovation incubators is to bring the academia and industry closer to each other. They create a symbiotic relationship in which the industry experts will be included to the process of learning and upon whom academia will draw to produce new ideas and research results for the industry.

Another critical factor in the success of incubators is support network, which gives the students a community of peers, mentors, and advisors who can help them with advices, feedback, and encouragement, which might have important role in process of overcoming challenges and uncertainties involved in that entrepreneurial activity. Image and reputation are reflected in academic incubators providing more visibility and credibility to student projects, students entrepreneurs and students startups.

Some studies show that most recognized enabling factors of business incubators are [14]:

- access to industry networks - participants highlights the significance of relationships between business incubators and industry partners, which provide market insights, potential customers, and industry-specific expertise;
- entrepreneurship education - the presence of entrepreneurship education and training programs within incubators was identified as crucial for developing entrepreneurial skills and knowledge among startups;
- flexibility and adaptability - the ability of business incubators to adapt to the changing needs of startups and offer flexible, tailored support was regarded as essential.

In order to overcome the challenges of increasing the entrepreneurial education in Serbia, part of The Education Development Strategy of the Republic of Serbia until 2030 is dedicated to developing and increasing student's entrepreneurial education through the activities and role of innovation incubators. Higher education institutions plan to establish organizational units focused on innovation and technology transfer. These centers will conduct training programs for developing creative thinking and entrepreneurial skills, promote entrepreneurial programs, organize open innovation campaigns with companies, and host bootcamps and competitions for the best student ideas. It will support students in idea development and validation, assist students with using equipment and software in prototype workshops, team mentoring, and facilitate the creation of startups and spinoff companies for commercialization. Additional plan is to increase the participation of content related to entrepreneurship in study programs at faculties [15].

To advance the necessary reforms in entrepreneurship education in Serbia, particularly at faculties that are lacking comprehensive entrepreneurship education programs, fourteen innovation incubators were established at faculties and institutes across Serbia at the end of 2023. This initiative, supported by the Ministry of Science, Technological Development, and Innovation of the Republic of Serbia aims to [16]:

- foster and support the development of entrepreneurial competencies,
- increase the number of startup teams with business ideas,
- boost the number of startups in the earliest stages of development,
- emphasize the provision of training, mentorship, and counseling,
- facilitate their growth and enable smooth entry and success in the market,
- support multidisciplinary and collaboration of scientific research organizations with one or more related scientific research organizations and/or Science and Technology Parks.

Special goals are focused on the development of the entrepreneurial competence, an increase number of startup teams in earlier phases of business idea development, with emphasis on the providing training courses, mentoring and counseling. Establishing innovation incubators is intended to ignite entrepreneurial spirit among youth and enhance the success rate in the early stage of business development. In the first quarter of the current year, 117 activities were held, including training sessions, workshops, and seminars, with the participation of over 900 students, researchers, and professors.

4. INNOVATIVE INCUBATOR OF FACULTY OF TECHNICAL SCIENCES IN ČAČAK

One of the academic incubators established by the end of the 2023 is the Innovative incubator of the Faculty of Technical Sciences in Čačak. As one of the three incubators that were founded at the University of Kragujevac, incubator strives to become driving force for the development of new ideas, to create innovation community and promote entrepreneurship. This incubator, aims to serve as a catalyst for the development of new business ideas, foster an innovation community, and promote entrepreneurship.

The Innovation incubator of the Faculty of Technical Sciences in Čačak helps tech-students to transform their ideas into viable businesses through guidance, resources, and networking opportunities. By fostering a supportive environment, innovation incubators could play a crucial role empowering student entrepreneurship.

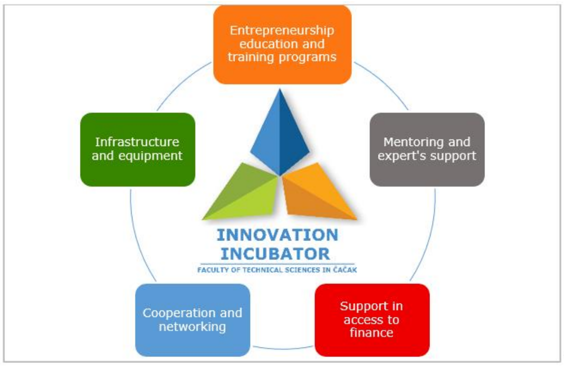

Figure 1. *Main services of Innovative incubator of Faculty of Technical Sciences in Čačak to support entrepreneurship venture development*

The basic elements and activities of the Innovation Incubator, presented at Figure 1, are:

- Innovation infrastructure and equipment – with focus on encouraging development of business ideas, connecting subjects of innovative activities from the academic community and the business sector, providing a knowledge infrastructure and equipped laboratories and facilities;
- Entrepreneurship education and training programs - providing entrepreneurship trainings as well as organizing workshops, bootcamps, courses and seminars aimed to improve entrepreneurial skills of students and faculty staff;
- Mentoring and expert's support – main focus is connecting experienced individuals and experts with startup teams with goal of exchanging knowledge and experience, as well as providing advices in areas such as business idea development, business model development, presentation skills development, market research, marketing, sales and finance, etc.;

- Access to finances - providing information on available sources of funding innovative ideas and organizing events where ideas can be pitched to potential investors, and supporting teams to apply to available calls for idea funding;
- Networking and cooperation with scientific research organizations, companies and innovation centers with goal of knowledge and technology transfers.

The primary role of incubator in entrepreneurship education is expressed through direct entrepreneurship education and training programs, which are among main services provided by the Innovative incubator of Faculty of Technical Sciences in Čačak. During the first half of year 2024 more than 180 tech-students were participants of several activities organized by incubator where they had opportunity to learn more about innovative entrepreneurship and trends in startup world, how to generate startup ideas through problem-solution fit and how to improve their presentation skills.

One of the most prominent events in entrepreneurial education was two-day bootcamp Startup Weekend, held at the end of April 2024. The event was organized by the Innovative Incubator of Faculty of Technical Sciences with support of Digital Serbia Initiative, ICT Hub, PwC, 30Hills, Venture Idea program, USAID Serbia and Science and Technology Park Čačak.

This event brought together 30 students who, over the course of two days, learned about startups and innovative entrepreneurship, teamwork, market research, business model development, digital product development, idea presentation, all through working with experienced mentors from the industry and startup founders. For most of them, this was an opportunity to learn about business development for the first time, and to acquire new skills and abilities that will enable them to turn their ideas into businesses.

It is important to point out that students gained entrepreneurial knowledge and improved their knowledge of entrepreneurship and innovation through intensive teamwork and cooperation with experts, professors and mentors. During mentoring sessions, there is a significant transfer of knowledge and experience, which is crucial in entrepreneurship education for enhancing entrepreneurial knowledge and essential skills.

Through student visits to important institutions such as the Science and Technology Park or fairs such as The International Fair of Techniques and Technical Achievements, students had the opportunity to learn about innovation and entrepreneurship from experienced founders and to increase their motivation to be startup founder or business owner.

5. CONCLUSION

By fostering innovation and entrepreneurial spirit, the role of academic innovation incubators in empowering tech-student entrepreneurship education is crucial for the development of future entrepreneurs. These incubators provide a unique environment where students can learn about entrepreneurship, improve their skills and form their innovative mindset. Through diverse programs, such as bootcamps and mentorship sessions, students gain essential skills in business development, teamwork, and market research.

Academic innovation incubators also play a pivotal role in bridging the gap between academia and industry, promoting interdisciplinary collaboration, and enhancing the commercialization of student's ideas. By providing access to infrastructure, mentorship, and industry networks, incubators help students turn their innovative ideas into viable venture. The collaboration between academic institutions and industry experts within these incubators facilitates a significant transfer of knowledge and experience. This approach not only enhances students' entrepreneurial competencies but also increases their motivation to pursue entrepreneurial careers.

The establishment of innovation incubators at faculties and institutes throughout Serbia, supported by the Ministry of Science, Technological Development and Innovation, underscores the national commitment to entrepreneurship promotion and education. These incubators aim to foster entrepreneurial competencies, increase the number of startup teams, and support the growth of startups in their early stages. The success of these initiatives is evident in the significant participation and engagement of students, researchers, and professors in various training sessions, workshops, and seminars. The Innovation Incubator of the Faculty of Technical Sciences in Čačak showed significant results during the first half of the year, with over 180 students participating in incubator activities to enhance their entrepreneurial knowledge and skills.

Research shows that academic innovation incubators are essential for cultivating an entrepreneurial mindset among students and equipping them with the necessary skills to succeed in the rapidly evolving technological landscape. They are important platforms for experiential learning, fostering innovation, and driving economic development through the creation of new businesses and startups. Therefore, continued support and development of these incubators are crucial for the advancement of entrepreneurship education and the empowerment of the next generation of entrepreneurs.

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Paradigms of Digital Competencies of Students in Higher Education in the Age of COVID-19

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Abstract: *This qualitative study aims to investigate the degree of digital competences of students at the university level and their readiness for the modern digital surrounding context. In this sense, the challenges in higher education that are a consequence of the pandemic, COVID 19 will be presented, focusing mainly on the increased use of ICT in the learning process among students. By reviewing the representative literature in the field of digital competences, the existing models and programs for the development of digital competences, i.e. the factors that influence their development, will be evolved. The aforementioned activities will be undertaken with the aim of proposing recommendations for the improvement of educational, i.e. curricula, as well as strategies for the development of digital competences in educational institutions, to investigate students' perceptions of their digital abilities and needs, as well as to propose recommendations for promotion. For the purposes of the work, research will be conducted through semi-structured interviews, where through cooperation with students and professors We will try to answer the research questions. The results of existing research confirm the hypotheses of this work that based on predictions, there may be significant differences in the level of digital competences among students of different study programs, as well as depending on the availability and use of technology in the educational process. In this direction, it is expected that this research will provide a deep insight into the level of digital competences of students, which will enable a better understanding of their needs and challenges in the modern educational context. We hope that the results of this work will serve as a basis for the development of effective strategies and programs for the improvement of students' digital competencies. The results of the analysis will also show to what extent the daily use of ICT has burdened students and teachers or made their work easier.*

Keywords: *Educational software; Digital literacy; Electronic education, Digital competences, COVID 19 .*

1. INTRODUCTION

In the 21st century, in the time we call the information age, technological innovations, entrepreneurial development, expansion of business, globalization, internationalization of higher education, privatization and commercialization of public sectors, higher education institutions must significantly improve teaching activities and follow modern trends in order to remain competitive. Based on the review of relevant literature and experiences in practice, it is evident that the application of ICT improves teaching and learning and is gaining more and more importance for both students and teachers in their daily teaching activities. Some authors in this sense emphasize that ICT gives educational institutions an advantage by providing improved services to students and staff, ensuring more visible efficiency and improving teaching sessions [1]. This is followed by opinions that ICT helps teachers to present their teaching in the most interesting way and to be able to teach students at any level of educational programs [2].

One of the key factors in the effective application of ICT in the teaching process is digital competences. Based on their importance, many authors emphasize that educational institutions must have strategies for the development of digital competences among students through the integration of ICT in teaching, providing access to modern technologies and tools, as well as through training and support for students in developing their digital skills. [3].

2. PANDEMIC COVID 19 AND IMPLICATIONS ON EDUCATION

The results of the research show that the pandemic caused by the virus COVID 19 had a significant impact on the undertaking of tectonic changes in many areas of life and work, especially in the education system, the realization of which in a short period of time was adapted to the newly created circumstances - the application of new models of online teaching, i.e. distance learning and more purposeful the use of sophisticated technologies in the teaching process.[4] The above-mentioned views are confirmed by relevant researches that indicate that, without a doubt, the education sector was one of the most affected by the pandemic, because it affects the growth and development opportunities for more than 1.5 billion students, which represents 91% of the world's school population on at all levels of education [5]. This is followed by opinions that educational institutions around the world have quickly moved to digital transformation in education and have begun to actively encourage the use of online learning, teaching and assessment methods much more than ever before the pandemic [6]. In this regard, some authors more closely define the term distance learning as a comprehensive term for the provision of education where there is a geographical and cognitive separation between students and teachers. [7].

The almost total suspension of all activities and the sudden forced termination of the traditional form of teaching in such a specific environment was a special challenge for educators at all levels of education. Research results indicate that COVID-19 has strongly affected not only university education, but also the operational functioning of universities, as well as workforce management [8].

In the relevant literature, it can be found that in the past, teaching through distance learning was organized through correspondence courses or courses through television and telephone [9]. However, over time, it was the rapid development of ICT that transformed the education sector by encouraging the development of different approaches. In electronic learning, appropriate e-learning systems are applied that integrate various tools such as writing technologies, communication technologies, visualization and storage[10]. The latest research in practice shows that advanced mobile devices will initiate and condition the application of new methods, forms and techniques of learning, training and education that will be available to everyone. In this direction, it is emphasized that in this way of learning, the so-called Combined or hybrid learning is increasingly changing, where the student is not completely guided, but has the freedom to explore and find content that he will use during his studies [11]. Various acts and strategies for the development of the IT sector in the environment by the relevant bodies prescribe appropriate plans and programs for the professional development of educators, however, only with the establishment of an emergency situation did such actions get their full justification and their full meaning of application. Namely, with the introduction of the state of emergency in the newly created circumstances, everyone, without exception, was forced to immediately switch from the traditional way of teaching to online, i.e. electronic, teaching. [12]. Therefore, Karakose (2021) suggests that conducting scientific research on the impact of the COVID-19 pandemic on educational environments and communicating the results of such research to political decision-makers and higher education experts would significantly contribute to the urgent implementation of measures needed to reduce the effects of the pandemic. Higher education institutions and policy makers around the world could then use the strategic insights of such scientific research to discover appropriate solutions to the educational problems they face during the pandemic, thus helping to better prepare all stakeholders for similar crises that may arise in the future.[5].

In particular, the use of online teaching in higher education at universities was specific. It is known that in Europe, the understanding of the emergence of the term university is firmly connected with the Middle Ages, because universities first appeared between the 12th and 13th centuries. In the history of the University of Bologna, it is stated that it was founded in 1088, which, according to the opinion of many experts, makes it the oldest university in the West, and one of the oldest in the world in general [13].

In the first decades of the 21st century, education, especially higher education, experienced the emergence of the so-called digital disruption. In this direction, some authors explain that this is not only about new technologies, but about how technology can enable the improvement and modernization of higher education, as well as other spheres, using artificial intelligence, mixed and hybrid courses, and open educational software, i.e. resources [14]. The latest estimates indicate that in the next year 2025, there will be more than 262 million students in higher education institutions around the world, in this sense the authors Krulj and Arsić believe that a university professor must be ready for pedagogical work, development and improvement [15]. There are also realistic expectations and predictions that innovative approaches in teaching and learning will expand and be used more effectively thanks to the application of educational technologies and digital literacy. In addition to the above, it is only thanks to striving for higher quality pedagogical and didactic-methodical competences that expertise, i.e. competitiveness and successful teaching can be ensured [16]. Building on this, well-known authors Kolo and others believe that universities will change in the future [17]. In this sense, some experts emphasize that global higher education is still evolving, and world leaders should recognize the key role of global higher education in the creation, exchange and implementation of knowledge in the global market [18]. This is followed by Ehlers, who estimates that as a result of changes in the structure of work, new requirements will be needed for higher education systems [19]. Similar views are held by other authors who point out that it is obvious that regardless of geographical distance and political agendas, countries around the world face similar challenges in relation to the quality, financing, management and internationalization of higher education [20]. In this direction, some authors emphasize that numerous technologies that have not been applied until now will probably further transform and cause changes in the current higher education environment, which will most likely cause the need for a new approach and reexamination of the very role of educators, i.e. pedagogues, and effective education at ways that were not so relevant ten years ago [21].

3. DIGITAL COMPETENCES OF STUDENTS

Developing digital competencies among students is an important process that requires adequate education, training and practical experience. The research results indicate that in practice there are several different types of online lectures. According to data from well-known authors, the most common form of online teaching during the pandemic was a video conference in real time (59.4%), while the following forms are asynchronous: sending presentations to students (15.2%), videos (11.6%) and written communication through forums and chats (9.1%). The least frequent form was audio recording (4.7%), which is not surprising given the wide spread of educational platforms and video conferencing systems (e.g. Moodle, Zoom, MS Teams, BigBlueButton), which have been widely available for some time[22].

Below are some of the methods and strategies that educational institutions and teachers can use to develop digital competencies in students: [23]

1. Integration of ICT in teaching:
2. Training and support:
3. Projects and practical exercises:
4. E-learning and online resources:
5. Stimulating independent learning.

Experiences in practice indicate that institutional support plays an important role in the development of digital competences of students and professors, which means the provision of modern teaching aids (computers, projectors, printers, cameras, etc.), modern software and the provision of continuous professional development programs [12].

In this context, according to the opinion of some authors, students who are able to organize themselves independently, without constant reminders, will surely learn successfully at a distance [24]. Accordingly, it can be argued that universities represent the best places for developing digital competences [25]. In the literature, one can find numerous advantages of applying online teaching, as well as opinions that when considering the advantages, the financial aspect should be taken into account; Tuition at online universities can cost as much or more than college tuition, but if you consider the total costs, including the cost of accommodation in a student dormitory or apartment, transportation and food costs, you can see that at universities where Teaching online to a college can save a significant amount of money [24]. This is followed by authors who emphasize that even in higher education institutions that teach in a traditional way, hybrid or mixed forms can help improve the quality of teaching by moving content to the Internet [26].

The results of the research indicate that the development of digital competences can be closely related to the enthusiasm of the teachers themselves through the existence of the desire to use modern teaching tools. In this regard, Sabaliauskas and colleagues write about the existence of basic digital competences, the existence of ethical competences in the use of ICT, the integration of ICT in the teaching process and methods of their application [27]. The well-known author Krumsvik points out that the "path" to digital competences implies their application in practice, on the one hand, and self-reflection, on the other hand, through four simple stages: adoption, adaptation, appropriation and innovation [28].

Examples from practice indicate that teachers are currently faced with an abundance of digital (educational) resources that they can use in teaching. One of the key competences of every educator is to accept this diversity, to effectively choose the resources that best suit the educational goals, the group of students and the teaching method, organize all the collected materials, establish connections, and to change, supplement and independently develop the digital resources that support his learning [29]. Certain authors emphasize that today teachers are increasingly expected to use big data; in order to analyze patterns and trends in student behavior and their academic progress, assess their academic readiness and potential success, identify opportunities for intervention where necessary, regularly develop effective educational techniques and approaches, analyze the effectiveness of different assessment methods [30].

Based on the above, the conclusion is that the digital competencies of students and teachers play a key role in modern education and society as a whole. In this sense, some authors point out that in an age where technology is constantly developing and changes are taking place at a fast pace, it is important that students possess appropriate digital skills that will enable them to function successfully in their academic, professional and personal lives [31]. Modern tools for e-learning (ICT) are necessary for the realization of the aforementioned activities. Through education, they provide the possibility of obtaining higher education for many students of different educational levels and cultural backgrounds. However, research results in practice indicate that if by any chance the possibilities of e-education are underestimated, they may not be successful in higher education. This is followed by opinions that say that some people simply do not sufficiently understand the limitations and weaknesses of e-learning, while others may have too high expectations [32].

In the literature, it can be found that digital competencies include a variety of different skills and knowledge, including a basic understanding of information technology, the ability to use computers and the Internet, critical thinking in relation to information on the Internet, the ability to communicate effectively in a digital environment, creativity in the use of various digital tools and platforms, as well as many others [33].

Students and teachers who have well-developed digital skills have an evident advantage in accessing and absorbing knowledge and information [34]. Digital competencies are known to enable students to learn and explore independently. Some authors in this regard point out that the Internet offers a huge source of information and resources that students and teachers can use to expand their knowledge and understand complex concepts [35]. In addition, digital competences enable students and teachers to connect with people around the world. This is followed by opinions that through social media, online forums and other digital platforms, students can exchange ideas, collaborate on projects and learn from other colleagues and experts from different parts of the world [36].

In the literature, it is pointed out that in addition to the basic ones, there are also advanced competencies, which on the other hand, refer to advanced skills and specialties that are needed for certain fields or professions, such as web application development, artificial intelligence, etc. [37]. Also analyzing the current literature that deals with the question of what skills and abilities will be important for a future professional career, the increasing role of information and communication technology (ICT) progress and its increasing global application should be highlighted.

In this sense, students' digital competences include various characteristics that help them function successfully in a digital environment. Here are some key features: [35]

1. Technical basis;
2. Communication and collaboration;
3. Informational understanding;
4. Problem solving;
5. Creativity and innovation;
6. Security and privacy;
7. Adaptability and learning;

Based on all of the above, the conclusion is that students should have the opportunity to apply their digital skills in real situations through various projects, internships, specializations, practical works, etc. The stated opinion is confirmed by the authors who emphasize that students could develop their creativity and skills for solving problem situations, as well as learn how to deal effectively with the challenges arising from the use of digital technologies [38].

4. THE RESULTS OF THE CONCUCTED RESEARCH ON THE APPLICATION OF EDUCATIONAL TECHNOLOGIES IN TEACHING

This research included a sample of 519 students from thirteen higher education institutions that carry out their teaching activities in the AP of Kosovo and Metohija. It is known that modern higher education is defined as an organized tertiary activity of learning and training, as well as institutions that adhere to established general norms and rules; for example, universities - which include faculties of arts, humanities and natural sciences, as well as specialized institutions for engineering, science and technology [39]. The following table 1 provides an overview of higher education institutions of the University of Prishtina with temporary headquarters in Kosovska Mitrovica according to scientific fields.

Table 1. *Overview of higher education institutions per scientific field*

Nr.	Scientific field	Higher education institution
1.	Social-humanistic	1) Faculty of Economics in Kosovska Mitrovica, 2) Faculty of Law in Kosovska Mitrovica, 3) Faculty of Philosophy in Kosovska Mitrovica, 4) Teacher Education Faculty in Leposavić, 5) Faculty of Sports and Physical Education in Leposavić, 6) Kosovo and Matohija academy of Applied Studies Leposavić
2.	Natural sciences-mathematics	Faculty of Natural Sciences and Mathematics in Kosovska Mitrovica
3.	Technical-technological	1)Faculty of Technical Sciences in Kosovska Mitrovica, 2) Faculty of Agriculture in Lešak, 3) Kosovo and Matohija academy of Applied Studies Leposavić
4.	Medical sciences	Faculty of Medicine in Kosovska Mitrovica
5.	Arts	Faculty of Arts in Kosovska Mitrovica

Below are the forms of teaching that are conducted at the researched higher education institutions. Based on the survey results, which are shown in Table 2, it can be seen that the structure of the surveyed students by gender consists of 305 male students (58.1%) and 214 female students (41.9%).

Table 2. *Teaching forms at faculties/schools of applied studies in the function of the students' scientific filed*

Teaching forms at faculties/schools of applied studies	Students' scientific field					Total
	Social-humanistic	Natural sciences-mathematics	Technical-technological	Medical sciences	Arts	
Conventional	27	7	12	17	0	63
With the assistance of IT	23	25	67	14	3	132
Both forms	125	64	89	31	15	324
Total	*175*	*96*	*168*	*62*	*18*	*519*

Out of a total of 519 respondents, 62.20% (324 students, of which 160 are male and 164 female) declared that the combined or hybrid form of teaching prevails at their faculty/university. 23.03% (132 students, of which 81 are male and 51 female) declared that teaching is conducted with the help of ICT, and 14.77% (63 respondents, of which 40 are male and 23 female) declared that classes are conducted in a conventional way.

Table 3. *Application of e-learning using Moodle at faculties/high schools as a function of gender of students*

E-learning through Moodle at faculties/schools of applied studies	Students' scientific field					Total
	Social-humanistic	Natural sciences-mathematics	Technical-technological	Medical sciences	Arts	
Yes	0	0	95	59	0	154
No	173	92	71	1	17	354
Total	*173*	*92*	*166*	*60*	*17*	*508*

The results of the survey, shown in Table 3, show that 354 surveyed students (69.68%) answered negatively, and 154 students (30.32%) answered positively to the question about the application of electronic learning with the help of Moodle at their faculties/universities . When it comes to the gender of the respondents, it can be noted that 188 male respondents (63.73%) gave a positive and 107 respondents (36.27%) a negative answer to this question. On the other hand, 166 female respondents (77.93%) have a negative and 47 respondents (22.07%) a positive answer about the application of Moodle at their higher education institutions.

5. DISCUSSION OF RESULTS

Regarding the survey question about the factors that have an influence on the level of ICT application at colleges/universities, depending on the gender of the students, it can be noted that out of 295 male respondents, 50.85% (150 respondents) put the equipment of their of ICT higher education institutions. In second place, 36.61% (108 respondents) declared for the activity and expertise of teaching staff, and in third place, 12.54% (37 respondents) for the activity of deans/directors and school administrations, i.e. the Ministry of Education, of the Republic of Serbia. For female respondents, the sequence is identical. Namely, out of 213 female students, 58.69% (125 respondents) declared in favor of equipping faculties/high schools with modern ICT, 29.58% (63 respondents) for the activity and expertise of the teaching staff, and 11.74% (25 respondents) for the activity of deans/directors and school administrations, that is, the Ministry of Education, of the Republic of Serbia. The research results show that the COVID 19 pandemic has led to a shift to combined or hybrid teaching that combines elements of online learning with less frequent lectures in physical space. In this sense, Farnell et al. expressed concern about inequality in access and participation in higher education[40]. The perspective of combined or hybrid learning is supported by El-Azarova and Nelson (2020), who believe that higher education in the future will be based on combined-hybrid learning [41]. In this direction, the authors emphasized that the existing pedagogical practice must be reexamined, that we should work on the development of methodological approaches that support learning without attending classical lectures, then that it is necessary to deepen professional practice and change and modernize the way of training and professional development of educators. Experiences in practice also indicate that it was the time of the pandemic that initiated the opportunity to research alternative solutions in the implementation of teaching. Experiences in practice show that in the future, traditional teaching and online teaching will not separately have primacy or priority, but more and more so-called combined approaches will be used in the implementation of teaching. In addition to all the implications of the pandemic on all spheres of life and work, it enabled software companies that offered higher education and educational software or tools via the Internet, creating new billionaires and corporations worth billions of dollars, including the companies Zoom and Turnitin.

6. CONCLUSION

The conducted research found that teachers consider professional obligations related to continuous professional development with an emphasis on the development of digital knowledge and skills as very challenging. Digital competences represent a key aspect of education in the 21st century and are extremely important for students in modern society. As technology becomes an inevitable part of our daily lives, it is important that students develop the skills that will enable them to function successfully in a digital environment. Research results indicate that through the development of digital competencies, students acquire abilities that help them adapt to rapid technological changes and innovation, to think critically and analyze information, to communicate and collaborate with others in new ways, and to be ready for the challenges that they face. they expect Encouraged by the development of digital competences, students become more capable in performing their academic tasks, but also in applying the acquired knowledge in real life. Also, these competencies enable them to be more creative, innovative and to take the initiative during schooling in their learning and development. Based on the research, the conclusion is that educational institutions, state bodies and ministries should provide adequate resources and educational programs that will help them acquire these competencies and be ready for the challenges that await them in the future. Only in this way can we ensure that the graduates are successful and competitive in the increasingly open world labor market. In this sense, students' digital competences represent a set of skills (including basic IT skills such as working with a computer, using operating systems, processing text and tabular data, browsing the Internet and using electronic mail, knowledge and abilities) that enable them to use ICT effectively in his academic, personal and professional activities. In addition, digital competences include advanced skills such as programming, web design, data processing and analysis, media literacy, digital ethics and internet safety. However, despite the increasing application of digitization and automation, the human factor still has a key importance in quality teaching, which is why the process of education and developing skills is essential. In this sense, since the future cannot be predicted, perhaps the best advice is to develop different kinds of skills, in different areas, in different ways.

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Session 6:

Outlines of the Digital in ESP: Language and Technology

Notes:

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Students' Evaluation of ESP Textbook in the IT Field – A Pilot Study[1]

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Abstract: *The research presents an evaluation of a textbook used in ESP classes, based on students' perceptions, aiming to identify strengths and areas for improvement. Data were collected from 60 respondents who rated various aspects of the textbook on a 7-point Likert scale. Students evaluated categories based on pre-determined criteria. The results indicate that students highly appreciate the textbook's clarity in grammar and its contemporary and relevant topics. On the other hand, lower scores were noted for the balance of textual and visual elements and the language level of tasks, suggesting a need for better integration of visuals and more advanced tasks to cater to higher proficiency levels. Additionally, including different varieties of English could enhance the textbook's appeal. Overall, while the textbook is well-received, addressing these specific areas could further improve student satisfaction and learning outcomes. This study emphasizes the importance of continuous feedback in the language learning and teaching process, which would further contribute to improvements in educational resources, primarily textbooks, to better meet learners' needs.*

Keywords: *ESP; IT; technology; textbooks; textbook evaluation*

1. INTRODUCTION: ENGLISH FOR SPECIFIC PURPOSES AND ESP IN IT

Ever since the emergence of English for specific purposes (hereinafter: ESP) in the late 1960s, it has become one of the most important parts of English language teaching (and learning). ESP is, unlike ELT, a learner-oriented approach and tailored to the specific context in which the language is to be used, ensuring that learners acquire the language skills most relevant to their specific professional or academic requirements [1]. One of the definitions of ESP was given by Hutchinson and Waters, who are among the most influential authors in the field. They defined it as an approach to course design which starts with the question "Why do these learners need to learn English?" [1].

Needs analysis, hence, takes a central place in ESP, since we need to know why our learners need English and what type of English they need. In the field of IT, ESP is of great importance, since many future jobs, particularly in the IT sector, require good knowledge of English and future IT experts need to have rich vocabulary, specific to their professional needs. That is one of the reasons why ESP in the field of IT is crucial for equipping IT professionals with the specific language skills necessary for their work. IT English is, like ESP in many other fields, genre-specific and linguistic characteristics are somewhat unique to it.

Thus, the books and additional materials used for ESP classes for IT professionals should reflect those characteristics.

Teaching English for specific purposes in the field of Information technology involves some specifics which differentiate it not only from general English language teaching but also from ESP teaching in other professional fields as well. Other than the aforementioned needs analysis, ESP in IT is characterized by content specificity, i.e. by technical jargon and specialized vocabulary that would most probably focus on software, data management, cyber security, coding and programing languages etc. Another characteristic of ESP in IT which is shared with other fields is learning in context, since teaching materials need to reflect real-life scenarios and situations typical for the IT field. That is also the reason why another ESP feature should be applied: use of authentic materials. It is of crucial importance that the materials used in IT be as authentic as possible,

[1] The research was done within the pre-research process for the PhD paper "Evaluation of university ESP textbooks by immediate users in the education process "

since using real-world materials helps learners become familiar with the types of documents and communication they will encounter in their jobs [2]. Task based learning is another feature necessary for ESP in IT, where learners engage in tasks that replicate real IT work activities (such as coding meetings, bug fixes and other problem-solving activities typical for the IT field). Task-based learning is a method which emphasizes practical application and problem-solving skills, both of which are essential for a future IT professional.

Finally, one of the most common problems for ESP instructors in the IT field is that they might not have sufficient knowledge related to this scientific area, so collaboration with IT professionals is necessary. ESP instructors often collaborate with IT professionals to ensure the relevance and accuracy of the course content, but also to get clarification when necessary and check the adequacy of the teaching input. All of the abovementioned needs to align in order to get a quality curriculum and teaching materials for this specific field.

2. ESP TEXTBOOKS EVALUATION: THEORETICAL BACKGROUND AND PREVIOUS RESEARCH

The textbook is considered a universal element of the language learning and teaching process and hardly any language course takes place without a textbook as a starting point [3]. Most of the authors in the field of ESP justify the use of textbooks during the course (the most prominent ones among them are Allwright, Lee and Skierso) and see it as a valuable tool which helps the language learning process, by motivating and stimulating students [4]. One of the biggest proponents of textbooks in ELT and ESP classroom is O'Neil who believes that the role of textbooks in the classroom is justified by the fact that the material in the textbooks is presented in a systematic way, so students have the opportunity to see what they did and what they will do in class and to revise previously studied material [5]. Textbooks can be chosen to be in accordance with the needs of students, and they also provide the possibility of adaptation and improvisation for teachers [5]. These and many other reasons account for using textbooks in an ESP classroom and the most important thing is to choose an adequate one.

One of the ways to ensure that is to perform an evaluation of textbooks, in order to choose the book which complies with student’s specific needs.

Theoretical framework related to ESP and ELT evaluation of textbooks often stems from applied linguistics and second language acquisition theories, emphasizing the alignment of instructional materials with learners' needs, professional contexts, and real-world applications. This is especially important, since ESP students learn English for the purpose of their current or future jobs, hence the themes and vocabulary need to be relevant and as authentic as possible. Moreover, learners’ needs in ESP field are diverse, so it is necessary to employ a textbook which suits their needs best.

Some of the most prominent authors in the field of ESP are Hutchinson and Waters (1987) whose work provides valuable insights into evaluating English for Specific Purposes books, emphasizing a learning-centered approach, crucial for ESP [1]. We can summarize their recommendations and conclusions in the following way:

1. Relevance to learners' needs: ESP books should be evaluated based on how suitable they are for the specific language needs of the learners. This includes the content, tasks and topics, as well as language system (vocabulary and grammar) and skills.
2. Authenticity of materials: Authentic texts and tasks help learners develop the language skills necessary for real-life communication in their specialized fields and future jobs.
3. Task-based learning: ESP books that incorporate task-based learning approaches are often more effective. Tasks should be designed to simulate real-world communication situations, allowing learners to practice language skills in context, which is of vital importance for ESP.
4. Feedback and assessment: An ESP book should provide opportunities for feedback and self-assessment, which would allow students to monitor their progress.
5. Flexibility and adaptability: ESP books should be flexible and adaptable to accommodate the diverse needs of learners. Teachers should be able to customize materials according to the specific requirements of their learners and contexts in which the language is used or will be used. This is very often the case in our education system, since ESP teachers often emphasize the need to incorporate additional materials, as it was noted in many informal conversations with them.
6. Integration of skills: ESP books, like any other ELT book, should integrate the four language skills: reading, writing, listening, and speaking — in a balanced manner. Learners should have opportunities to develop each skill within the context of their specialized field [1].

Research in textbook evaluation focuses on a multidimensional approach, considering both content and pedagogical effectiveness. Key findings include the importance of relevance and authenticity, balanced skills development, alignment with modern teaching methodologies, and the provision of supplementary materials and teacher support. Evaluators are encouraged to use comprehensive frameworks that incorporate feedback from teachers and learners to ensure textbooks meet diverse educational needs and contexts.

Textbook evaluation is important and vital for many reasons, but one of the main ones is that textbooks are here to stay and that there are not many teachers and learners who would choose an ESP course without a textbook [4]. There are many different schemes of textbook evaluation and Sheldon (1988) suggests that no general list of criteria can ever really be applied to all teaching and learning contexts without some type of modification [6]. Notable authors in the field of ELT textbook design and analysis such as Williams (1983), Sheldon (1988), Brown (1995), Cunningsworth (1995) and Harmer (1996) all agree, for instance, that evaluation checklists should have some criteria pertaining to the physical characteristics of textbooks such as layout, organizational, and logistical characteristics [4], which is the reason why that was our first category to be evaluated in the evaluation scale.

Previous research in the field of textbook evaluation was mainly focused on using existent checklists and scales and implementing them (Atigh & Khabbazi, 2021, Harbi, 2017, Koltai, 2018, Litz, 2005, Sari, 2019) [4, 7, 8, 10]. The results show that there are elements that students consider useless, such as listening exercises, even if they are generally satisfied with the textbook [7]. Research also shows that the students of ESP value authentic materials, modern and contemporary topics [8], aligned with the duration of the course and students' future profession [9], hence we incorporated those elements in our evaluation scale. There are also studies whose subject of research was evaluation of textbooks by both students and teachers, as a result of the poorer achievement of students in the ESP subject, and as the main drawback in this case, they pointed out poor organization of the book and inadequate level of it [10], so we wanted to obtain our students' perception regarding these aspects as well.

Our evaluation is based on a scale developed for the purpose of the research, which is a part of a larger sample. We developed a scale based on a pre-determined criteria, which is explained in detail in the Methodology chapter.

The statements in the scale and categories within which they are grouped are based on recommendations from notable authors, such as Hutchinson and Waters (1987) whose main recommendations are given above, as well as on the previous scales mentioned in the chapter.

3. METHODOLOGY

The subject of the research is the evaluation of ESP textbooks on the tertiary level of education in the field of IT. The research took place in May 2023, at The Faculty of Technical Sciences, University of Kragujevac. The corpus for the research was the textbook used in ESP classes for technical sciences, "Professional English in use - ICT", by authors Santiago Remacha Esteras and Elena Marco Fabre, published by Cambridge University Press), 2007 edition. The textbook is organized into 40 modules, on 117 pages.

The sample consisted of 60 students from the field of information technology, aged from 19 to 32 years (M=19.74, StD=1.496), unequally distributed according to gender criteria (m=30, f=25). Reasons for this type of sample are multiple: it was necessary to have students who study IT, who have ESP classes and who use an ESP book whose author is not the teacher on the subject. In this way, we wanted to ensure the objectivity of the research. The instrument that was used was an evaluation list with a 7-point Likert scale, ranging from 1-absolutely not true/present to 7-absolutely true/present. The evaluation scale was based on pre-determined criteria, which consisted of the following: physical appearance of the book, subject and topics, language skills (further divided into sub-criteria: reading, listening, speaking and writing), language system (grammar and vocabulary), activities and tasks and motivational aspect. The evaluation scale had 78 statements in total, divided into the aforementioned categories.

Finally, the reliability of the scale was checked, and it showed good value (α=0.957).

The data was collected by distributing the questionnaire to the students, after their ESP class. The data was analyzed by using statistical program SPSS 21 (Statistical Package for the Social Sciences). The following analysis includes descriptive statistics (means, standard deviation, frequences), independent samples t-test for sex differences, Shapiro Wilk test for normal distribution and Cronbach alpha (scale reliability test).

The research was anonymous and voluntary, and the respondents agreed to have their answers used for the purpose of the study.

3.1. Evaluation criteria

The evaluation scale consisted of a list of criteria divided into different statements. The process of forming the scale implied synthesis of previous research and previous ready-made scales, with special focus on the principles of contemporary teaching and contemporary education in the field of ELT. The most frequent criteria were used, and we followed the guidelines of the most prominent authors in the field. To be precise, most authors agree that the criteria should include physical characteristics, subjects and topics, language system and skills, activities and exercises, and general impression (Byrd, 2001; Daoud & Celce Murcia, 1979; Litz, 2005; Sheldon, 1988; Skierso,

1991) [4, 6]. We added the dimension of motivation, since motivation is an important factor in the language learning process, as many authors stated in the past. For instance, Gardner and Lambert explored the role of various factors in language learning, including motivation, and concluded that motivation was a critical element for successful language acquisition [11]. That is the reason why motivation was part of our evaluation scale, although previous scales did not have that aspect. To elaborate further, the criterion physical appearance of the book was important since a clear organization of textbooks affects better involvement of students and generally has a positive effect on the teaching process [12]. Topics or themes are of crucial importance for an ESP textbook, since they shape the course and determine the vocabulary and conversation activities. Within this category, we wanted to investigate students' perception regarding the diversity of topics, how interesting they were, their usefulness and adequacy, their compliance with the personal needs of the participants, professional topics, as well as elements of stereotypes and discrimination. When it comes to categories of language skills and language system, most of the statements dealt with presence, authenticity, alignment with students' level of English, usefulness, clarity of instructions and how interesting the tasks were, along with the content. The criteria activities and tasks focused on all the tasks in the book in general, and the focus here, among other things, was the interactive nature of the tasks and authentic language. The interactive nature of the activities and tasks in the textbook is an important factor, since it is one of the elements of the principles of contemporary teaching [13], so it was important to investigate whether the tasks in the book had that feature.

Finally, motivation was the criterion which focused on students' motivation to use the language and their readiness for further language learning, as well as the usefulness of the entire textbook for their future profession. In this part, the primary goal was to examine whether the textbook was designed to enable students to use the knowledge and skills acquired through the use of the textbook in a real-life scenario, in a business or real-life environment [14, 15].

4. RESULTS

The reliability of the scale was tested, and it showed good internal consistency α=.957, hence the scale was reliable. The Shapiro-Wilk test showed that the distribution of responses on the entire scale was normal (test scores were normally distributed) (W (58) =.970, p=.161). However, we have excluded listening and writing since those skills were not present in the analysis, which also applies for the scale reliability test.

Table 1. *Tests of normality*

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
Scale overall	Statistic	df	Sig.	Statistic	df	Sig.
	.087	58	.200	.970	58	.161

As it can be observed, table 1 represents the results of the tests of normality along with Lilliefors Significance Correction. According to the Shapiro-Wilk test, a p-value greater than 0.05 ($p > 0.05$) represents the assumption that the data have been approximately normally distributed.

We have also conducted independent samples t-test, to compare the mean values of two groups, namely male (N=30) and female respondents (N=25). Five of our respondents did not want to choose sex on the demographic questionnaire part of our scale. By the sex criterion, independent samples t-test showed (M_1=5.2, SD=.672; M_2=5.43, SD= .815), t (53=-1.124, t=.266).

The results of students' evaluation are given in table 2, distributed among different categories that were tested. The initial scale had categories of listening as writing as well, but since it was confirmed that the book itself did not have listening or writing activities, those categories were eliminated from the evaluation and are not given in the table.

Table 2. *Results of students' evaluation of their textbook by categories*

Scientific field	**Technical sciences**				
Category:	***N***	***M***	***SD***	***SE***	***Min/ Max***
Physical appearance	60	5.18	.901	.116	3/7
Topics	60	5.52	.907	.117	2/7
Reading skill	59	5.31	.693	.090	4/7
Speaking skill	59	5.33	.916	.119	3/7
Language system: vocabulary	59	5.24	.943	.123	3/7
Language system: grammar	58	5.33	.817	.107	4/7
Activities and tasks	59	5.31	1.046	.136	3/7
Motivation	59	5.33	1.015	.132	3/7

The means for the different categories range from 5.18 to 5.52, which suggests generally positive evaluations across all categories, as the means are above the midpoint of the typical 1-7 scale. Students, in general, evaluated positively their textbook and all the categories are either present or very present in their textbook.

The category Topics has the highest mean score of 5.52, indicating that students evaluated this aspect of the textbook the highest. The book is focused on the topics that are completely in accordance with students' study field, all of them are from IT and it is not surprising that the students value that the most. Topics in the book are related to computers, programming and hardware and software. Positive feedback on the diversity and relevance of topics indicates that the textbook covers a wide range of interesting and pertinent topics that align well with students' future professions and current field of study.

Speaking skill and Motivation share the same mean score of 5.33, suggesting that students found the textbook to be equally effective in enhancing speaking skills and motivating them and the same can be said for the category of grammar. These three categories were all positively evaluated, indicating that the students found the criteria stated within them present in their textbook.

Reading skill and Activities and tasks have mean scores of 5.31, indicating a generally positive evaluation, slightly lower than previous categories. This might be due to the fact that texts within the textbook are not modern enough for the students and they might not be up-to-date, especially when taking into account their age. Activities and tasks are also somewhat traditional, which students may not find challenging enough.

Surprisingly, the category of vocabulary received a low score, compared to other categories, which indicated that the vocabulary within the textbook was not completely suitable for the students in our sample. This was unexpected, since the vocabulary is from the field of IT and all the activities related to it are IT oriented.

The category of Physical appearance was the worst evaluated category, it had the lowest mean score of 5.18, which showed that it was the least positively rated aspect, although still positively evaluated. Clearly, organization of the textbook and lack of illustrations are nor suitable for the students.

Overall, the textbook appears to be well-received by students, as all categories have mean scores above 5. This indicates that students generally find the textbook effective and satisfactory.

Since the textbook is focused on IT, i.e. students' field of study and topics are the highest rated category, this suggests that students find the topics covered by the textbook relevant and engaging.

The relatively lower score for Physical appearance suggests room for improvement in the design and layout of the textbook, which could enhance the overall user experience.

5. DISCUSSION

To elaborate more on the results of students' evaluation, we shall focus on the statements which received highest and lowest scores on the scale.

Four of the statements which were best evaluated by our respondents were from the category of Topic *("Topics are modern" and "Topics and texts following them do not contain any elements of discrimination (gender, racial, ethnic) or any stereotypes"*) and from the category of Grammar (*"Grammar tasks have clear instructions" and "Grammar is presented with clear examples").* As regards the topics, it was expected that there were no elements of discrimination or any stereotypes, since the style of the book is neutral and academic. Since the topics were from the IT field, it was also expected that the vocabulary itself would be useful for future IT professionals, so that explains why these two statements (and these two categories as well) received the highest scores.

As for the lowest scores, three of the categories had statements with scores significantly lower than others: Grammar (with the statement *"Grammar tasks are interesting*"), Activities and tasks *("Tasks are too easy for my level of English"* as well as the statement *"The textbook contains different varieties of English, such as British English or American English"*) and Physical appearance *("The textbook has balance of textual and visual elements (images follow the text and explain it"*).

The category of physical appearance had the lowest score overall, probably due to the fact that the textbook does not have sufficient number of images, graphs or diagrams which would be interesting to students. Also, there are no different varieties of English in the textbook and grammar tasks are fairly traditional, so that explains why these statements received the lowest score on the scale.

Since there are no writing or listening activities in the book, the ratio of the skills to the language system elements is not even, which is also showed by the students' responses. The respondents indicated that interactive activities and exercises were somewhat lacking, which is another aspect of the textbook that received lower score. High scores for statements related to independent learning and overall impression of the textbook suggest that the textbook effectively supports independent learning, which is crucial for students who need to study outside the classroom (even more important for ESP students). Also, the statements that focus on overall impression of the textbook show us that the students would recommend it to their colleagues and that the textbook, observed as a whole, was positively evaluated.

The study, however, had certain limitations. Firstly, there is an uneven distribution according to the sex criterion, sample size and nature. Most of our respondents were male and our sample was not large enough, since we had only 60 participants. Another limitation is caused by the fact that there was no listening activity in the book, as well as writing. This does not offer us comprehensive insight into skills within the textbook. That is one of the areas for improvement of the textbook and of the scale as well. The research itself emphasizes the importance of continuous improvement in educational materials and of the ways their effectiveness and suitability for learners' needs is measured.

Clarity in grammar instructions and the relevance and inclusivity of themes are strong points of the textbook. These aspects should be maintained and highlighted as key strengths, however there is a need to challenge higher proficiency students more, and to incorporate better balance of textual and visual elements. Additionally, reflecting more varieties of English could improve the textbook's effectiveness.

The students' evaluation reflects a generally positive reception of the textbook, with specific strengths in clarity and relevance, which is of special importance for an ESP textbook. However, addressing the areas where scores were lower could further enhance the textbook's effectiveness and student satisfaction in general.

6. CONCLUSION

The respondents' evaluation provides valuable insights into both their perspectives and the strengths and weaknesses of the textbook.

Some implications that might be drawn refer to the content of the textbook, language variety and incorporation of all four language skills, along with adding elements of contemporary teaching and learning.

Since it was clear that the textbook does not have all four language skills and all elements of language system, a more balanced approach to grammar/vocabulary and skills practice can cater to a broader range of learning objectives and proficiency levels.

Moreover, contemporary teaching and learning implies interactive activities within the textbook, which was not evident in our research, so adding interactive activities could make learning more engaging and effective and contribute to its relevance and modern approaches to language learning.

The textbook was mainly focused on British English, with no examples of other dialects and varieties, which students would encounter in their future professional work. Incorporating more dialects and accents could prepare students for real-world English usage, particularly in professional settings. This could be solved by adding some additional materials and activities (listening activities, role-plays) to the textbook.

Furthermore, ESP students are often older than other students and might need English for their job or they study English in their workplace, as part of their professional training, so it is important for their textbook to offer them a possibility of studying by themselves at a certain point. Also, educational needs of ESP students are diverse, since they often come from different backgrounds with different levels of English and maybe even different needs and expectations. Some respondents might be focused on improving specific language skills, such as grammar, vocabulary, or conversational skills, indicating the necessity for a comprehensive approach in the textbook.

Overall, the results suggest that while the textbook has many strengths, there are specific areas where enhancements can be made to better meet the diverse needs of its users. Regular feedback and updates are important so that the textbook remains a valuable resource for both learners and teachers.

These insights can guide future revisions and improvements to ensure the textbook fulfils students' needs. By actively seeking feedback from students and incorporating their suggestions, the textbook can evolve over time to better serve its audience and remain relevant in an ESP educational setting.

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Information and Communication Technology as a Valuable Tool for Enhancing Students' Performance in ESP

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Abstract: *The paper explores the attitudes of university students attending ESP classes towards the use of Information and Communication Technologies (ICT), both generally and specifically for learning English. Additionally, it measures the impact of various ICT tools and applications on the development of different aspects of English language competence. The research adopts explorative design. The results show that listening and speaking are the most positively affected skills by ICT use. The inferences also indicate that integrating various ICT tools and platforms can promote the development of all the aspects of ESP competence. Additionally, the results show that male students utilize ICT for learning English more frequently than female students. This research could serve as a guideline for teachers and instructors in deciding which tools and applications to use to enhance their students' foreign language proficiency. The study acknowledges the limitation of a small sample size, suggesting that the validity of the results could be enhanced by conducting the research with a larger number of participants.*

Keywords: *ICT, ESP competence, multinomial regression analysis*

1. INTRODUCTION AND RELATED RESEARCH

1.1. Electronic Learning and Distance Learning

Electronic learning or e-learning is commonly known as educational process which includes information and communication technologies (ICT).

There are several definitions of e-learning, often depending on the aspect considered, whether technological or pedagogical. The technological aspect emphasizes technology and defines it as follows: "E-learning is any form of learning, teaching, or education that is supported by computer technologies, particularly computer networks based on internet technology" [1]. However, the pedagogical aspect focuses on teaching and learning, defining e-learning as: "E-learning is an interactive or reciprocal process between the teacher and the student using electronic media, with an emphasis on the learning process, while the media serve as auxiliary tools to complement that process" [1].

Depending on the manner and extent of ICT application, e-learning can be categorized as [3]:

- traditional teaching,
- teaching with the use of ICT,
- blended learning, and
- online learning.

Traditional teaching or face-to-face teaching occurs in classrooms, utilizing tools such as Microsoft Word for lesson preparation. ICT-supported teaching involves technologies used as aids for traditional teaching, including presentations, websites, web-based testing programs, and email forums. Blended learning combines classroom teaching with ICT-supported teaching, utilizing Learning Management Systems (LMS) for learning management and video conferencing. Online learning is entirely technology-dependent, where students learn independently using internet-based learning methods. When teaching is conducted without any direct contact between the teacher and the student, it is referred to as distance learning.

In e-learning educational approaches, the student is in focus of the teaching process, while the teacher is a mentor who not only imparts knowledge but also supports, motivates, guides, and evaluates tasks and projects [2]. ICT has become a basic necessity and a vital component of contemporary education, while digital literacy, as a form of ICT, is one of the essential competencies that teachers must possess [4].

1.2. ICT and English language learning

With the emergence of ICT, the traditional classroom as a common learning context has been significantly affected.

Communication between language learners, as well as between teachers and students, has gained new forms of technology-mediated interaction [5]. Furthermore, foreign language (FL) students now have the opportunity to instantly access a variety of authentic language inputs. These changes have impacted overall learning and teaching methods, leading to the creation of new personalized learning models for FL learners. Additionally, the integration of ICT in English language learning can improve students' language skills, as well as inspire and motivate them to continue further studying [6]. Accordingly, this paper investigates students' viewpoints regarding how ICT influences the development of various aspects of ESP competence.

2. METHODOLOGY

2.1. Research design

This explorative research was conducted to determine whether the students of study programs (Production Management, Printing Technology, Mechanical Engineering and Informatics, and Electrical Engineering, i.e. other than Information Technology) use ICT to help them improve their ESP competence. For that purpose, we composed the following research questions:

- To what extent do students use ICT to improve different aspects of their ESP competence?
- Which ICT tools most effectively promote different aspects of ESP competence?

2.2. Research instrument and sample

To address the research questions, we designed an online Google Forms questionnaire consisting of six questions (two multiple-choice questions and four 5-point Likert-scale questions). It is based on the questionnaire referring to contemporary trends in teaching and learning English for Specific Purposes (ESP) in the field of Information Technology [7]. The survey was conducted during summer semester in 2024.

The participants were students of the Faculty of Technical Sciences Čačak at the University of Kragujevac enrolled in ESP classes within their respective study programs: Production Management, Printing Technology, Mechanical Engineering and Informatics, and Electrical Engineering. The total number of participants was 41 students.

3. RESULTS AND DISCUSSION

We used basic statistical analysis and multinomial regression analysis to analyse the answers to the survey questions.

The first question was demographical to establish the gender status of the participants.

Table 1. *Participants' gender*

Gender	Percentage
Male	51.3
Female	48.7

The analysis of the first-question results showed that the sample was homogenous, i.e. there was approximately equal number of male and female students participating in the survey (51.3 % of male students and 48.1% of female students) (see Table 1). This leads us to examine the distributions of ICT use, both in general and for learning the English language, in our case ESP, within the general population and by gender. We present these findings later in the paper.

The second and third questions provided answers to the survey questions regarding the frequency of using ICT in general and specifically for learning English (Figure 1).

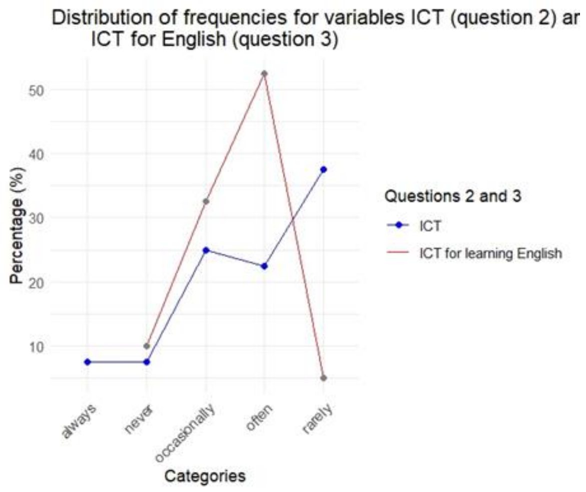

Figure 1. *General use of ICT and ICT use for learning English*

According to the results presented in Figure 1, approximately 35% of students rarely use ICT, while just above 5% always use ICT. This percentage is similar to those who never use ICT (5%). About 25% of students occasionally use ICT, and a roughly equal number, 23%, often use ICT. However, when comparing these results with the responses of students who use ICT to improve their English language knowledge, over 50% of those who generally use ICT also use it to learn English. Additionally, a little over 30% of students who generally use ICT admitted to using it only to improve their English. As expected, no students always used ICT solely for English language purposes. The inferences show that the largest percentage of students often use ICT for English language improvement.

These findings suggest that while general ICT usage among students is varied, a significant portion of those who do use ICT are leveraging it for educational purposes, particularly in learning English. However, the results presented reflect the distributions for these two observed variables individually. This raises the question of how dependent these variables are on each other and what the distribution of the combined variable looks like. The new variable is represented by ordered pairs, where the first coordinate represents the response to survey question 2, the frequency of ICT usage, and the second coordinate represents the response to survey question 3, the frequency of ICT usage for learning English. The distribution of frequencies for the new variable is shown in Figure 2.

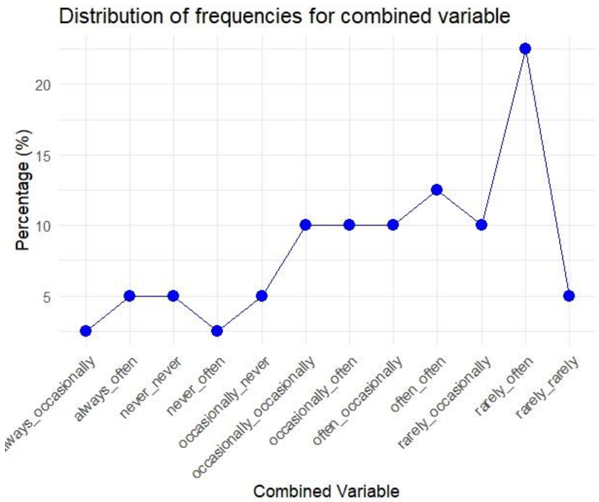

Figure 2. *Ordered pairs of ICT use and ICT use for learning English*

Figure 2 illustrates the distribution of frequencies for a combined variable representing ICT usage patterns, encompassing both general ICT usage and ICT usage specifically for learning English. The x-axis categorizes the combined variable, while the y-axis depicts the percentage of respondents falling into each category.

The results show a surprising peak for those who generally rarely use ICT, with the category (rarely, often) emerging with the highest percentage, slightly exceeding 20%. This category includes participants who admitted to rarely using ICT but often use it to learn English exclusively. Additionally, 12.5% of students fall into the category (often, often), indicating they frequently use ICT in both contexts. Conversely, the categories (never, often) and (always, sometimes) exhibit the lowest frequencies (less than 5%), indicating these combinations are less common among respondents.

In summary, the graph underscores diverse patterns of ICT usage among students. It should be noted that some categories are missing.

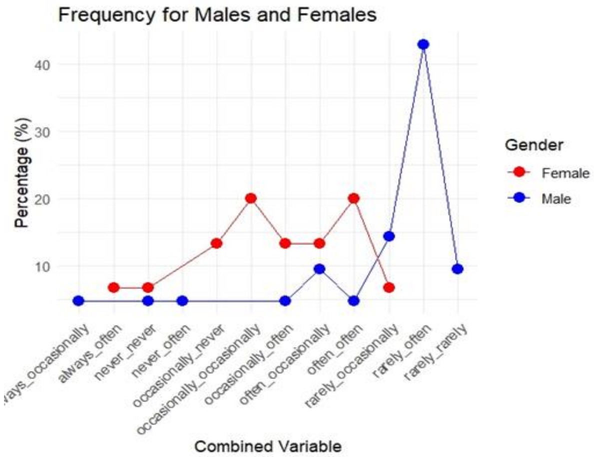

Figure 3. *General ICT use and ICT use for learning English distributed among males and females*

Figure 3 presents the use of ICT generally and ICT used especially for English language learning, distributed among the male and female participants. As for female students, it is noticeable that nearly the same number use ICT frequently and occasionally for both general purposes and for learning English. These groups are the largest, each making up about 20%. For male students, it is significant that they rarely use ICT for general purposes but often use it for learning English, with this group constituting around 40% of the total male student population. This suggests that male students use ICT more for learning English compared to female students. The most similar percentages for both genders are in the category where neither male nor female students ever use ICT, whether in general or for English language learning.

Table 2 presents the answers to the fourth survey question. The fourth survey question was composed to check to what extent students agree/disagree with the statements that ICT help them complete pre-examination tasks more efficiently, or that they find information necessary for learning English quickly and easily. We also wanted to check whether the possibility of not attending classes in person due to ICT usage represents a favorable condition and whether the students are motivated to study in more interesting manners when they use ICT.

Table 2. *ICT use for particular EFL activities*

Statement	I completely disagree (%)	I disagree (%)	I am neutral (%)	I agree (%)	I completely agree (%)
They help me complete pre-examination tasks more efficiently.	/	2.40	41.50	29.30	26.80
I quickly and easily find the information I need for studying.	/	4.88	34.15	29.27	31.70
I don't have to attend classes regularly at the faculty.	41.46	/	19.51	14.63	24.40
They motivate me to study in a more interesting way.	/	4.88	9.76	58.54	26.82

The survey of the Table 2 results shows that almost half of the total number of students completely agree or agree that they do their pre-examination tasks more efficiently with the help of ICT (56.1%), while the others are either neutral, 41.5% or they disagree (2.40%) about using ICT for fulfilling pre-examination tasks. As many as 60.97 % of students agree or completely agree that they find the information necessary for studying quickly and easily, while 34.15% are neutral, and 4.88% disagree. What is interesting, the majority of students, 41.46%, completely disagree that not attending classes at the faculty due to the existence of ICT is an advantage, whereas 39.03% agree or strongly agree that ICT facilitates not attending classes represents a favorable condition. As many as 19.51% are neutral. The majority of students completely agree or agree that ICT technology motivates them to study in more interesting ways (85.36%), whereas 9.76 % of students are neutral, and only 4.88% disagree with the statement.

Table 3 shows which tools and applications students use most frequently for English language learning.

Table 3. *Frequency of using applications and tools for English language learning*

Applications and tools	**always (%)**	**often (%)**	**sometimes (%)**	**rarely (%)**	**never (%)**
ChatGPT	19.52	9.76	36.58	17.07	17.07
Google Translate	29.27	53.66	9.76	7.31	/
Video- conference	7.31	7.31	39.02	26.83	19.53
Facebook	9.76	/	12.19	17.07	60.98
X (Twitter)	7.31	9.76	12.19	24.39	46.36
Instagram	19.51	19.51	17.07	9.76	34.15
TikTok	12.19	12.19	17.07	9.76	48.79
Films and music	34.15	21.94	34.15	4.88	4.88
Websites	21.95	37.71	17.07	2.44	20.83
Online English language teaching courses	4.88	7.32	12.19	26.83	48.78

The results presented in Table 3 show that Google translate and Films and Music are the most frequently used applications, while Facebook and Online English language teaching courses are never used for English language learning by the majority of students.

Finally, Table 4 shows what skills and competences students perceive as the most improved by ICT application.

Table 4. *Skills and competences improved by ICT use*

reading	4.8%
writing	12.2%
listening	31.7%
speaking	24.4%
vocabulary	17.1%
grammar	9.8%

Regarding the results presented in Table 4, we can see that 31.7% of students regard listening skill as the most improved one, closely followed by speaking skill, 24.4%. As many as 17.1% of students consider that ICT use has improved their vocabulary. Writing has been improved by ICT use, according to 12.2% of students, followed by grammar at 9.8%, while the least promoted skill is reading, with only 4.8% of respondents

These answers were subsequently analysed by multinomial regression analysis. The obtained results indicate the specific impacts of various activities on the development of language skills for the students who declared that they used ICT for the English language learning.

All the coefficients that will be mentioned are statistically significant ($p < 0.05$), indicating their impact on the development of respective language skills. The interpretation of the results shows that different activities can have varying effects on different aspects of language development, emphasizing the need for specific approaches in educational strategies that integrate modern technology.

As far as speaking is concerned, Facebook shows the greatest positive influence (coefficient = 40.24), while Instagram has a notably negative impact on speaking (coefficient = -33.27). Google Translate also contributes positively (coefficient = 23.84). Additionally, Google Translate has significant impact on the development of grammar knowledge (coefficient 13.63, $p < 0.05$), while other activities, e.g. those that are supported by Video-conferences have negative influence on the development of grammar knowledge, while Facebook has a minor positive influence. When we consider writing, the influence of Facebook on writing skill is -39.92, while the impact of Video-conferences is 13.47, which shows quite opposite values, with Video-conferences affecting substantially the development of the writing skill. When listening skill is regarded, the results show that Instagram (coefficient 41.15) and Video-conferences (coefficient 19.47) have positive impact on their development. What is interesting, the vocabulary is improved by using Video-conferences (coefficient 34.07) and negatively affected by visiting websites (coeffiecient-19.58).

4. CONCLUSION

This research was conducted provide the answers to the research questions concerned about the extent to which students use ICT to improve different aspects of their ESP competence and which ICT tools most effectively promote different aspects of ESP competence. As far as the first research question in regarded**,** the analysis show that students rarely use ICT for general purposes. However, if they use ICT, they predominantly use them to learn English. It is interesting that male students use ICT for learning English more often than female students. The answers to the second research question provide some interesting implications. The respondents of the research find ICT useful for improvement of different aspects of EFL competence. They regard listening and speaking as the most positively affected skills by the impact of ICT. On top of this, the results suggest that while social media platforms like Facebook and Instagram can significantly affect language proficiency, the type of activity and technological tool used also play crucial roles. While Facebook positively enhances speaking skills and Instagram shows a notable negative impact, Google Translate contributes positively to both speaking and grammar skills. The mixed effects of video-conferences indicate their potential for improving grammar and listening skills but special attention should be paid when their exclusive use for vocabulary development compared to web-based activities is concerned.

The research results implicate that integrating various ICT tools and platforms can promote the development of all the aspects of ESP competence. Future studies could be based on investigating a larger sample of students in order to enable more reliable inferences. Also, the attitudes of students on different levels of education could be investigated to compare with the results obtained in this study.

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APPEDIX

The role of ICT in learning English for specific purposes

1. Specify your gender:
   ☐ male
   ☐ female
2. How often do you use ICT generally?
   ☐ Always
   ☐ Often
   ☐ Sometimes
   ☐ Rarely
   ☐ Never
3. How often do you use ICT for learning English?
   ☐ Always
   ☐ Often
   ☐ Sometimes
   ☐ Rarely
   ☐ Never
4. In your opinion, how much do ICT help you in studying English for curricular activities? (Choose the appropriate number: 1 - strongly disagree, 2 - disagree, 3 - unsure, 4 - agree, and 5 - strongly agree)
   Choose an item. ICT help me to better fulfil pre-exam obligations.
   Choose an item. I easily and quickly find necessary information for learning.
   Choose an item. I don't have to attend classes regularly at university.
   Choose an item. They motivate me to learn in a more interesting way.
5. Which of the mentioned ICT tools do you use for learning English language and how frequently? (Insert the appropriate number by each tool: 1- never, 2-rarely, 3-sometimes 4- often, and 5- always)
   Choose an item. Chat GPT
   Choose an item. Google Translate
   Choose an item. Video conference
   Choose an item. Facebook
   Choose an item. X (Twitter)
   Choose an item. Instagram
   Choose an item. Tik Tok
   Choose an item. Films and music
   Choose an item. Websites
   Choose an item. Online English language courses
6. Which skills and competencies do you believe you have most improved through the use of ICT? (Multiple answers are possible).
   ☐ Reading
   ☐ Writing
   ☐ Listening
   ☐ Speaking
   ☐ Vocabulary
   ☐ Grammar

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Digital Games as Informal Medium in English Language Learning

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Abstract: *The results of many recent surveys in the Western Balkan region indicate an increase in the number of lower grade elementary school students with significant amount of EFL knowledge or successful proficiency in English as a foreign language. One of the reasons may lie in the large number of language lessons that students attend weekly in formal education, but the reason may also lie in the informal educational impact of the digital media that the children are surrounded by, especially digital games. This paper reviews the results of various research carried out with the aim of identifying adequate and current digital games for learning the basics of English, especially in the process of mastering new words and pronunciation.*

Keywords: English language*; digital games; informal education*

1. INTRODUCTION AND RELATED RESEARCH

Digital games are complex software products with a number of subsystems which affect the gameplay, a large number of stories to follow or secrets to discover, all with the aim of providing entertainment for the players. The influence of digital games on the interaction of early adolescents and their motivation for communicating in a foreign language has been the topic of many studies conducted over the last two decades [1]. It has been found that the students who actively play digital games, including those who passively watch someone else play, significantly expanded their English vocabulary [2, 3]. In addition, the results show that the students who observed someone else play had better performance on vocabulary tests compared to those who actively played the digital game. This can imply that interactivity is not a necessary element for expanding the vocabulary. However, there are some shortcomings that need to be addressed. Namely, the aim of the games that were played was not to learn languages, they were intended for entertainment, and therefore understanding and possibly expanding vocabulary was not really necessary [4]. Another problem is that the digital game genre is closely related to narrative, which can be problematic in arcade games, which do not require players to understand the plot and context in order to adequately respond to the challenges of the game. Researchers often use Role-Playing Games as a genre that is particularly suitable for language learning through the use of students' positive motivation to practice linguistic skills on their own [5, 6]. A positive correlation was found between students' experience in playing Role-Playing Games with the level of language skills they present. The reason for this connection may lie in the fact that for the successful acquisition of a language, especially a non-native one, the student must be able to create "comprehensible sentences" in the language he is practicing [7]. Since most Role-Playing Games use communication abundantly in the English language and provide an opportunity for players to use it in mutual synchro communication, they present a very desirable medium in informal learning.

The desire for communication is crucial in learning a new language and is the best way to increase performance, not only for academic purposes but also in everyday life. The genre of digital games that stands out in this aspect is Massively Multiplayer Online Role-Playing Games (e.g., MMORPG). In this genre, the multiplayer component stands out, providing an easy and natural way to produce the language through direct interaction with other players online [8, 9]. There are two distinctive types of skills that MMORPGs develop in players: understanding and expression. The way the digital games cultivate the art of understanding is by offering the player an expanded set of vocabulary used in an appropriate context. This is done spontaneously in combination with other sensory stimuli by the player perceiving the corresponding images/video or by expecting the player to perform a certain action. Interacting with non-player characters (e.g., NPCs) as intelligent agents controlled by some of the AI algorithms in modern games is also very useful. Digital games represent a great way to learn a variety of accents. Understanding what NPC is saying is a very important part of completing the goals in the games. Expression skills are spontaneously cultivated during playing in two ways- by using “transmediality” and “culture of participating”. The requirements of contemporary digital games are very complex, so it is often necessary to use the experiences of other players and communicate with them to successfully pass them. Transmediality is reflected in discussions in other forms of media (forums, chats, social networks, etc.). As already stated, MMORPG players in the international community communicate in English, which is most often not their native language. This creates a direct correlation for its improvement [10].

Players usually pay more attention to keywords which convey meaning. Task-Based Language Learning is a method of creating tasks which is successfully applied in the research of the use of digital games as a medium in informal learning [11]. The idea is to set a “task” as a focus of planning and studying. Although the definitions of the tasks vary among different research, there is an agreement that a task represents an activity or a goal which is being done, namely fulfilled by using the language, e.g., problem solving, puzzles, map reading, giving instructions, phone calls, writing letters, reading tutorials etc. This method helps to better understand the way the digital games can afford the potential as a language learning tool, given that the player is active within a virtual world that provides them with often unlimited opportunities for linguistic input combined with visual and audio feedback and context. Several elements of digital game design are particularly useful for language learning and can be found in almost every contemporary game. The most important principle is the instant availability of information, that is instant feedback, which is the key to progress in most digital games. The same applies to the language used in a game. The linguistic message is always presented in context, but it is crucial for it to be a direct result of the player's actions, which makes him emotionally "attached" to the game narrative and to better acquire the language. Digital games connect language with visual elements as well as sound signals [12]. Such a hypermedia environment enables the player to create associative linguistic phenomena using multiple senses, which improves the retention of what has been learned. The ability to replay the dialogue from the game allows the players to incorporate spoken words into their vocabulary and later use them in real life.

Playing digital games in a social environment is not a mandatory condition for acquiring and developing language skills [13]. Digital games provide a set of stimuli that help the player to adapt to the "language" of the game through virtual gameplay. Visual indicators, voice acting, narrative, virtual environment and context are combined with linguistic resources to enhance the language learning process. Digital games enable informal learning through a pre-established contest that places the player with the role to guess the meaning of unknown words. Students use dictionaries very rarely nowadays, not even in digital forms. Digital games are mainly for entertainment. Although the researchers have been trying for years to design high quality Serious Games (e.g., SG) with the purpose of learning the English language, the results of numerous findings show that Commercial Off-the-Shelf Games (e.g., COTS) have a significant potential for this application and represent a valuable tool for informal learning [14]. Gaming communities provide additional motivation to use the language, thereby indirectly increasing the quality of pronunciation of the language being used. A potential problem lies in the fact that playing digital games can cause cognitive overload, during which the brain will not have enough capacity for active language learning when playing certain complex digital games [15].

2. DESIGN OF DIGITAL GAMES FOR LEARNING LANGUAGES

Well-designed digital games for the development of reading and writing in English should consider several key principles in order to be effective and motivating for students [16]. Here is a list of features that need to be fulfilled in order to meet the quality criteria:

- Simplicity and clarity – digital games should be easy to understand and guide the users clearly throughout the learning process. Precise steps and instructions are important in order to avoid confusion, especially with younger students;
- Interactivity – interactive elements in the game, such as selecting, dragging or entering text/characters, enable students to actively participate in the activities. This makes them engaged and makes it easier for them to understand the material;
- Motivation and rewards - using a reward system, such as points, stars or unlocking new levels, motivates students to continue playing the game and achieve better results;
- Adapting the difficulty level – games should be designed to meet the individual needs and abilities of students. At the beginning of the game, easier tasks may be offered that gradually become more complex as you progress;
- Variety of content – various tasks and activities within digital games enable the development of different reading and writing skills. This can include word games, puzzles, reading stories or even creative writing;

- Appropriate visual design – the visual elements of the game should be attractive and pleasant for students. Clear pictures, colorful characters and animations can motivate them to engage in the game;
- Customizing feedback – the feedback allows the students to see their progress and understand possible mistakes. This helps them understand the material better and motivates them to continue learning.

In our opinion, in order for the game to be adapted to the different development levels and abilities of the students, it is crucial to provide options for adjusting the level of difficulty or adapting the tasks based on individual needs. For example, it may be possible to choose among multiple difficulty levels or to adjust the speed and complexity of the tasks based on the player's performance during the game. It is also important to have personalization options that allow parents or teachers to adjust the game according to the specific needs and goals of the students. This may include choosing a topic, exercises or assignments that match student individual's interests and preferences.

2.1. Implementation

Implementation in the educational process involves the application of various methods, tools and resources in order to achieve the ultimate goal - learning. For example, the use of mobile games in informal education can be extremely useful [17]. Digital games can be designed to stimulate children to develop critical thinking and problem-solving skills. This can be achieved through games that require problem solving or strategic thinking. Teaching staff should receive a training on how to successfully integrate digital games into their educational practice. All actors in the educational process should communicate with parents about the importance of using digital games in an informal educational context [18]. An explanation of how games support children's development and how parents can incorporate games into everyday activities can alleviate acceptance and cooperation. Cooperation may be sharing resources and tips about the games with parents, helping to create game supports, recommendations for games that support learning and development, and ways to integrate games into daily schedule. It is useful to discuss on how the games affect students' development. This type of communication can help identify best practices and adjust digital games to students' needs. The inclusion of mobile games in working with students requires planning, training and cooperation with all participants in the educational process, but when successfully implemented and integrated, they can be a powerful tool to support children's development, especially in preschool institutions and lower grades of elementary school.

2.2. Monitoring and evaluation

Monitoring and evaluation of the progress in the development of language skills by using digital games can be challenging, however there are different methods and techniques that can be applied. Digital games may include built-in mechanisms to track player progress [19]. For example, a game can track the number of tasks a student successfully completes or the speed and accuracy of their answers. Such data can be used to monitor the development of writing and reading skills or other aspects of language literacy. In addition to the built-in mechanisms in games, specialized tests and assessments can be applied to monitor the progress. These segments can be composed by an educational professional based on specific learning objectives.

The use of digital games in children's development can have significant ethical aspects, both positive and negative. It is important to be aware of the risks and apply only good practices in the use of digital games in an educational environment. For example, too much time spent in playing games can have negative consequences on students' health and development, including cognitive, affective and psychomotor problems [20]. Certain digital games may contain inappropriate or aggressive content that is not suitable for an educational context, while excessive addiction on digital games may lead to a loss of interest in other forms of learning.

Parents and teachers can use surveys and questionnaires to learn about children's opinion about the games and notice changes in their abilities and interests related to the development of the English language literacy [21]. Teachers can actively observe children playing digital games and document their progress and reactions.

This may include notes on how children interact with the game and how they apply skills in the context of the game. Progress data can be used to adjust learning for each child individually. For example, students who show faster progress can be exposed to new challenges, whereas children who struggle can be given extra help and support.

Games should be fun and interesting in order for children to be motivated to participate in the work. Interaction with the child through a game can further stimulate interest in reading and writing. Using funny sounds can help children recognize letters and words. Attractive visual effects can further enrich the gaming experience. The games should include various exercises that encourage reading and writing in English, such as recognizing letters, sentences, putting words together, etc. It is possible to integrate interactive exercises that help children recognize sounds.

2.3. Examples of digital games for learning the basics of English

Endless Alphabet is an interactive educational game designed for young players to learn the English alphabet and pronounce letter sounds. Interactive and funny animations are used to introduce different words. Each word is illustrated with animated characters and situations which enable the students to understand their meaning in an interactive way. The player can choose each letter of the alphabet and follow its pronunciation.

In addition to learning letters, the game also offers various activities that encourage the development of skills such as the ability to differentiate letters, understand the word meaning and improve vocabulary. Endless Alphabet game is free and designed without ads.

Figure 1. *The layout of Endless Alphabet Game*

Writing Wizard is a digital game designed to help learn and practice writing letters, numbers and words. The game allows a user to gradually progress through various exercises in writing letters and numbers on the screen of your phone or tablet using your fingers or a digital pen. The game supports a variety of writing styles, including freehand, print, and cursive. With this, students practice different writing styles and skills.

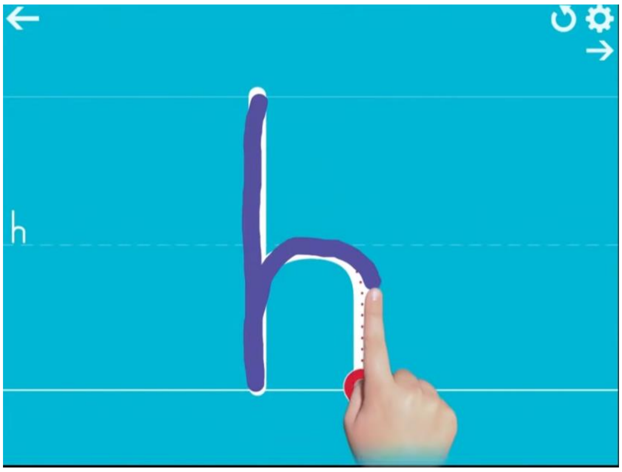

Figure 2. *The layout of Writing Wizard game*

Reading Eggs is a game designed to help students learn to read and develop language skills in English. The game offers a wide range of interactive lessons and activities which encourage the development of phonetic awareness, text comprehension, word recognition and other skills. The game has a progressive level system that allows different challenges and activities according to the student's abilities. The game contains different type of content, including e-books, interactive displays, songs, audio and video materials, which allow children to learn in different ways and in different contexts. Reading Eggs is designed as a safe environment for students with privacy protections and controls that allow parents to monitor their children's activities in the app.

Starfall is an educational game designed to help young students learn reading, writing and other basic English language reading and writing skills. The Starfall ABCs modules are designed to help teach the alphabet and basic literacy skills. It offers a variety of interactive activities that help learn the alphabet, pronounce letter sounds and develop basic language skills. Activities include games, songs, interesting stories and other interactive exercises. The game is designed as a progressive level system that allows progress through various challenges and activities. This helps the student to gradually learn and develop language skills according to their ability. *Starfall* ABCs game is available on various platforms including PC, Android and iOS devices.

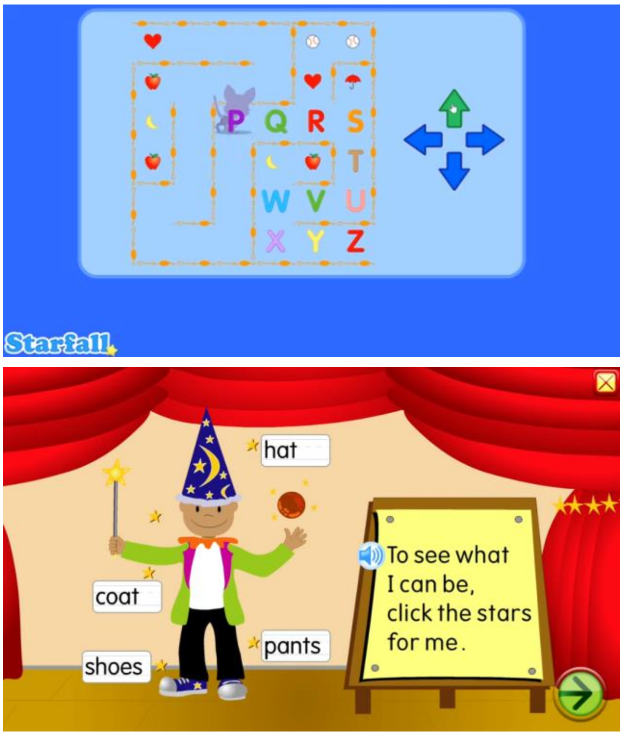

Figure 3. *The layout of Starfall game*

Starfall Learn to Read is a module designed to help children in the reading process. It promotes a phonetic language learning methodology to encourage students to know letter sounds and combine them to form and read words. The game offers different activities that help understanding the connections between letters and sounds. The game uses a progressive level system that allows gradual progress through the different stages of learning to read, from learning the basics to reading more complex words and sentences. The Starfall It's Funny to Read module is a part of the game designed to help you learn to read. This module focuses on various aspects of learning to read through fun and interactive activities including phonetic reading, word recognition, text comprehension, etc.

3. CONCLUSION

Digital games have many advantages in learning English. The most obvious one lies in the use of visual indicators to show the player the names of game objects, which is not possible with other non-interactive media such as films or books. Interactivity is a major advantage, because an accurate understanding of the task and the environment is necessary to achieve the goals of any digital game. This environment encourages players to explore and find out what the game is about, resulting in active learning of unfamiliar words and phrases. The connection between digital games and other digital media is obvious. Researchers suggest many ways in which digital games can be used for language acquisition, so they can be seen as a valid tool and a medium in informal education.

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The Role of Study Field and Gender in University Students' Attitudes towards Computer-Assisted Language Learning

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Abstract: *Just as it has permeated all other aspects of modern life, technology has inevitably transformed the way English is taught and learned, making Computer-assisted Language Learning (CALL) an indispensable component of contemporary language education. This study explores Serbian university students' attitudes toward CALL and examines whether these attitudes vary by field of study and gender, through an exploratory, mixed-method design, using a sample of 183 students from diverse academic disciplines. The findings reveal that university students generally hold positive attitudes towards CALL, with moderate to high mean scores for both internal and external factors related to ICT integration. This suggests a perceived benefit of ICT, particularly in enhancing classroom atmosphere and instructional practices. Contrary to expectations, no significant differences were found in attitudes towards CALL based on the field of study. Both technological/engineering and social sciences/humanities students displayed similar acceptance levels of ICT in English learning, indicating a uniform appreciation of ICT's role across disciplines. Similarly, no significant differences were found in attitudes toward CALL based on gender, with the only notable difference being that female students showed a slightly higher appreciation for the external motivating role of ICT.*

Keywords: *CALL; ELT; study field; gender; ICT tools.*

1. INTRODUCTION

Recent decades have witnessed a remarkable transformation in language education, largely driven by the integration of technology. From traditional face-to-face methods to incorporating various tools, and most recently, the integration of AI, language teaching has continually adapted to new technological advancements to enhance the learning experience. This constant evolution mirrors broader societal trends where technology permeates every aspect of life, making it inconceivable to discuss English Language Teaching (ELT) without addressing Computer-assisted Language Learning (CALL).

Today's students, often referred to as 'digital natives' [1], have grown up with technology at their fingertips. This familiarity with digital tools has naturally extended into their learning environments. When it comes to language learning, CALL leverages this affinity, offering dynamic and interactive methods for language acquisition. Unlike conventional methods, CALL provides learners with the flexibility to engage with educational materials at any time and place [2]. Through the internet, students can collaborate, communicate, and access resources globally, thus removing the constraints of time and space that once defined traditional ELT education.

Moreover, CALL empowers learners to take charge of their own education. They can tailor their learning experiences to suit their individual needs, gaps, and preferences, leading to a more personalized and effective learning journey. This autonomy not only fosters greater engagement but also encourages self-directed learning, which is crucial in developing proficiency and confidence in a new language [3, 4].

However, despite the apparent advantages of CALL, student attitudes towards this mode of learning can vary widely. While some students embrace the autonomy and flexibility that CALL offers, others may prefer the structure and personal interaction of traditional face-to-face methods. This study aims to explore these varied attitudes among university students and determine how different factors might shape their perceptions of CALL.

2. THEORETICAL FRAMEWORK

Computer-assisted Language Learning (CALL), a subfield of Second Language Learning (SLL), has been constantly evolving for over half a century, as a response to the demands of language teachers and students in a world increasingly immersed in technology [5]. Over the years, various terms have been proposed to describe this subfield, such as Technology-Enhanced Language Learning (TELL) and Computer-Aided Language Instruction (CALI). However, CALL has become the most widely accepted term [5], with numerous scholars offering different definitions.

Levy [6] describes CALL as "the search for and study of applications of the computer in language teaching and learning" [6]. A broader definition offered by Beatty [7] accommodates the evolving nature of CALL and its practical outcomes: "any process in which a learner uses a computer and, as a result, improves his or her language." The acronym itself, widely adopted from the early 1980s, poses a challenge due to its constraint of incorporating the term 'computer' in an era dominated by smartphones, tablets, the internet, and artificial intelligence (AI) [8]. Hubbard [9] acknowledges this by suggesting that the term 'computer' in CALL extends beyond traditional desktop and laptop devices to include networks, peripheral devices, and various technological innovations such as PDAs, mp3 players, mobile phones, electronic whiteboards, and DVD players [9].

Taking into consideration all of these definitions Singh [10] concludes that "CALL is a multidisciplinary field; it is complex, dynamic, and quickly changing; it involves various contexts and methods; and it encompasses various activities associated with learning a language using computers" [10].

2.1. Previous research

As Singh points out in [10] CALL, constantly developing since the 1960s, has historically been predominantly practice-oriented and it continues to be. The practice serves as the driving force behind research in CALL, which has seen substantial growth and diversification over the past few decades. Scholars have extensively explored the role of CALL in enhancing and influencing all aspects of language acquisition, including reading comprehension and vocabulary knowledge [11], [12], writing [13], oral skills [14], etc.

Furthermore, the COVID-19 pandemic acted as a significant catalyst for the expansion of CALL research, highlighting the necessity and benefits of remote and technology-enhanced learning environments [15]. Concurrently, the advent of artificial intelligence (AI) in education has opened new avenues for research [16]. Faster than scholars and practitioners could decide whether AI was a "friend or a foe'', it has further advanced CALL, offering personalized and efficient learning experiences for language learners [17]. This development has marked the onset of a new, revolutionary phase in CALL history, known as Intelligent CALL (ICALL) [18], suggesting that the evolution of CALL is far from reaching its zenith and will continue to expand as technology progresses.

A recent focus within CALL research has also been on underrepresented and underdeveloped contexts. Works such as the "Handbook of CALL Teacher Education and Professional Development: Voices from Under-Represented Contexts," edited by Dara Tafazoli and Michelle Picard [19], emphasize the importance of inclusivity and the diverse needs of learners from various backgrounds. This shift highlights a growing recognition of the global nature of language learning and the need to address the unique challenges faced by learners and educators in less developed regions.

Serbia, as part of this global landscape, finds itself in a transitional phase regarding the integration of CALL in its educational systems. While there have been efforts to incorporate technology in language teaching, comprehensive studies specifically focusing on Serbia are still relatively few (see, for example: [20, 21, 22]). This presents an opportunity for further research to explore how CALL can be optimized for Serbian students, taking into account their unique cultural and educational context.

When it comes to students' attitudes to CALL, it refers to their emotions connected to the use of technology in language learning. In general, attitudes can be defined as evaluative orientations or predispositions towards objects, individuals, or concepts that influence behavior, decision-making, and responses to stimuli [23]. In educational settings, attitudes play a significant role in shaping students' engagement, motivation, and learning outcomes, as they can impact learning experiences and academic performance. Consequently, measuring computer attitudes can be seen as an evaluation whereby individuals respond favorably or unfavorably to computer use in the context of teaching and learning language. Existing research on CALL attitudes has extensively covered aspects such as individual differences (ID), motivation, age, and gender [24, 25, 26].

Although computers are used by both genders, it is stereotypically still perceived that computers belong to the traditionally male domain of mathematics, science, electronics, and machinery. Studies have consistently shown that boys tend to hold more positive attitudes towards computers compared to girls [27] and that girls were less likely to use computers and exhibited lower confidence in utilizing information and communications technology (ICT) than boys [28].

The disparity in gender attitudes towards computers can be observed in the choice of academic discipline as well. For example, research conducted in [29] revealed that girls exhibited decreased interest in computer science in terms of self-efficacy and overall identification with the discipline. While some studies suggest the gender gap has lessened over time, others indicate persistent differences, with boys viewing computer knowledge as more valuable for future employment [30].

Academic discipline can also be seen as a factor influencing CALL, given the possible varying degrees of familiarity and comfort with technology that students in different fields of study possess. Engineering and Technology students are generally more exposed to and required to use advanced technological tools and applications, which likely fosters a more favorable attitude towards CALL. In contrast, students from Humanities and Social Sciences may not interact with technology as intensively, potentially leading to less enthusiasm and confidence in using computers for language learning. However, there is a noticeable gap when it comes to examining differences in attitudes towards CALL based on academic disciplines or majors. One of the few studies addressing this issue, among other factors, was conducted by Al-Emran et al. [31], who found no significant differences in attitudes towards CALL across various majors.

3. METHODOLOGY

3.1. Research aims

This study aims to fill the aforementioned gap by exploring the attitudes of university students in Serbia towards CALL, with a specific focus on differences across scientific fields and gender. By doing so, it seeks to contribute to a more nuanced understanding of how various factors shape students' perceptions and acceptance of CALL, thereby informing more effective, inclusive, and tailored language teaching practices.

To achieve this, the following research questions were formulated: (1) What are Serbian university students' attitudes towards CALL? (2) Are there differences in attitudes based on the field of study? (3) Are there differences in attitudes based on gender?

3.2. Sample

The sample consisted of 183 university students from Serbia: 92 females (50.3%), 87 males (47.5%), and 4 individuals (2.2%) who chose not to reveal their gender. Regarding their field of study, 59% were from technological/engineering fields (including engineering, computer science, and other related disciplines), and 41% were from humanities and social sciences (such as law, economics, philology, psychology, etc.) (Fig. 1).

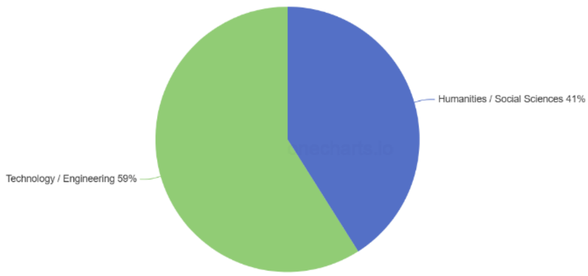

Figure 1. *Distribution of students' based on field of study*

3.3. Variables

In this study, the independent variables are the field of study and gender, while the dependent variable is the attitudes towards Computer-assisted Language Learning (CALL). Attitudes towards CALL in university settings are influenced by various factors, which can be divided into internal and external. Internal factors refer to individual beliefs, emotions, and perceptions that influence one's stance towards utilizing technology in language learning. These internal factors may include personal experiences with technology, perceived effectiveness of CALL compared to traditional methods, individual preferences, and comfort levels with digital tools. External factors, on the other hand, encompass environmental or contextual elements that impact attitudes towards CALL. These factors involve institutional support for technology integration, availability of resources, curriculum requirements, and societal norms regarding technology use in education. Additionally, teacher-related factors such as pedagogical approaches, affective attitudes, and beliefs can also influence students' perceptions of CALL.

3.4. Instrument and procedure

This study employed an exploratory, mixed-methods design, combining both qualitative and quantitative research techniques to comprehensively explore university students' attitudes towards CALL. The data collection was conducted through an online questionnaire administered via Google Forms.

The questionnaire consisted of three parts: 1) Demographic Information: The first section gathered basic demographic information, including age, gender, field of study, and competence in computers; 2) CALL Attitudes: The second part included 28 questions specifically designed to assess students' attitudes towards CALL. These questions were based on an instrument developed in [32], which has been further adapted and validated in [33], to ensure reliability and accuracy. This instrument is an eight-factor questionnaire which consists of both internal and external components. The internal factors included Internal Affective ICT Strategies (8 questions), Internal

Metacognitive Strategies (5 questions), Internal Personal Significance of ICT (3 questions), and Internal Importance of Mobile Tools (2 questions). The external factors comprised External Curriculum-based Limitations (2 questions), External Task-Centered Strategies (3 questions), External Use of ICT Tools in Learning (3 questions), and External Motivating Role of ICT (2 questions). A four-point Likert scale (1=strongly disagree, 4=strongly agree) provided the scoring framework, with means categorized as follows: 1-1.59 (very low), 1.6-2.16 (low), 2.2-2.79 (moderate), 2.8-3.39 (high), 3.4-4 (very high). To accommodate the participants, the questions were translated into Serbian using a blind back-translation method to maintain the integrity and accuracy of the content; 3) Open-Ended Questions: The third section comprised open-ended questions created by the authors to gain deeper insights and support the statistical analysis. These questions aimed to capture the views and personal experiences of the students regarding CALL.

For the quantitative analysis, the Statistical Package for the Social Sciences (SPSS 2020) was used. The data were analyzed using descriptive statistics and t-tests to identify any significant differences in attitudes based on gender and field of study. Thematic analysis was employed to analyze the qualitative data from the open-ended questions, allowing for the identification of common themes and patterns in the students' responses.

4. RESULTS AND DISCUSSION

Apart from general demographic questions, the first part of the questionnaire also included a self-assessment scale regarding competence in computer knowledge, as mentioned in 3.2 section. The majority of students (60.7%) rated their proficiency in computers as intermediate, whereas 30.1% perceived their level of knowledge as advanced, and 9.2% as beginners. Overall, 90.8% of respondents feel confident in their computer skills. These findings appear significant as they confirm that students' attitudes towards CALL are not influenced by the level of ICT competence.

4.1. Attitudes towards CALL

The results of both internal and external factors, which altogether constitute the CALL attitude scale through eight constructs, are given in Table 1.

Internal Factors Total: The overall mean of 2.80 (SD=0.608) for internal factors indicates a moderate to high attitude towards the internal use of ICT strategies in English language learning. The lower standard deviation suggests that these attitudes are relatively consistent across the student population. Internal factors encompass the personal significance of using ICT and mobile tools (smartphones and tablets), and affective and metacognitive strategies. Affective strategies refer to emotions and enjoyment derived from ICT use, such as feeling happy or finding it personally important. Metacognitive strategies involve cognitive processes like remembering and understanding facilitated by ICT. The means for all these factors indicate a moderate to high level of acceptance, as shown in Table 1.

External Factors Total: The overall mean of 2.77 (SD=0.589) for external factors reflects a similar moderate attitude towards external uses of ICT. External factors encompass several key areas: constraints on using ICT for both classroom activities and self-study, the integration of ICT content into the curriculum (External Task-Centered Strategies), the utilization of ICT tools in learning by teachers and their support (External Use of ICT Tools in Learning), and the motivational role of ICT in classroom management. Again, the means for the external factors indicate a moderate to high level of acceptance (Table 1).

Table 1. *Overall students' attitudes towards CALL regarding different factors*

Factors	Min	Max	Mean	St. dev
Internal Affective ICT Strategies	1	4	2.91	.706
Internal Metacognitive Strategies	1	4	2.89	.795
Internal Personal Significance of ICT	1	4	2.64	.738
Internal Importance of Mobile Tools	1	4	2.75	.697
Internal factors total	1	4	2.80	.608
External Curriculum-based Limitations	1	4	2.68	.812
External Task-Centered Strategies	1	4	2.66	.876
External Use of ICT Tools in Learning	1	4	2.73	.836
External Motivating Role of ICT	1	4	3.03	.805
External factors total	1	4	2.77	.589

Overall, the lowest score is given to the factor of the internal personal significance of ICT, which included statements such as 'I cannot learn without ICT' or 'ICT plays a very important role in my learning process.' This suggests that students do not perceive ICT as indispensable or deeply integrated into their learning strategies. The relatively low mean score of M=2.64 for this factor highlights a gap in the perceived intrinsic value of ICT in individual learning experiences. This could imply that while students recognize the utility of ICT, they may not yet see it as crucial to their academic success or as a central component of their learning identity (Table 1).

On the other hand, the highest mean score (M=3.03) was observed for the factor "External Motivating Role of ICT," which included statements such as 'ICT tools create a better atmosphere in the classroom' and 'Teachers should incorporate the use of ICT tools into their teaching.' This indicates a strong acknowledgement among students of the positive impact ICT have on classroom dynamics, including increased engagement and a more stimulating learning atmosphere.

Although the overall results show that internal factors are rated high (M=2.80) and external factors are rated moderate (M=2.77), these values are on the borderline, and the difference between them is negligible, suggesting that students are almost equally receptive to both dimensions of ICT integration in English language learning.

Thematic analysis of open-ended questions provides further support for the statistical findings. Students were asked to share their positive and negative experiences with CALL. The responses were overwhelmingly positive. Many students cited specific applications and tools that enhanced their learning experience. Popular mentions included Duolingo for its engaging exercises, Google Translate for quick translations, various online grammar exercises for practice, and Grammarly and ChatGPT for real-time writing feedback. These tools were praised for their accessibility, user-friendly interfaces, and tangible improvements to language skills. The students also emphasized the importance of support from teachers and parental encouragement in facilitating a positive atmosphere and effective use of such tools.

This positive feedback aligns with the high mean score for the "External Motivating Role of ICT" factor, highlighting the effectiveness and motivational impact of these ICT tools in language learning. Conversely, the lower scores in areas such as "Internal Personal Significance of ICT" suggest that while students benefit from these tools, they do not yet view them as indispensable to their learning process.

4.2. Influence of study field on attitudes towards CALL

When examining differences between study fields, distinct educational approaches are evident. As mentioned above, the Technological/Engineering field emphasizes practical, technology-driven education, while the Social Sciences and Humanities field prioritizes theoretical, analytical studies related to human behavior and culture. However, the SPSS analysis showed that there were no significant differences between the fields, as the mean scores for both fields were similar regarding both internal and external factors. For internal factors, the Technological field obtained a mean score of M=2.84, while students in the Social Sciences and Humanities field had a mean score of M=2.73. For external CALL factors, the Technological field had a mean score of M=2.81, compared to M=2.72 for the Social Sciences and Humanities field (Table 2).

Table 2. *Influence of study field on the attitudes towards CALL*

Factors	Study field	No.	Mean	St. dev
Internal factors	Technological / Engineering	108	2.84	.636
	Social Sciences & Humanities	75	2.73	.562
External factors	Technological / Engineering	108	2.81	.620
	Social Sciences & Humanities	75	2.72	.540

Although the results for the Social Sciences and Humanities fields were slightly lower, a T-test indicated no significant differences between the fields (Table 3). This suggests that despite the different educational emphases, students from both fields have comparable attitudes towards the use of CALL, whether considering internal motivations and strategies or external influences and support.

Table 3. *T-test study field means differences on attitudes towards CALL*

Study field	t	df	Sig.
Internal factors CALL total	1.210	181	.228
External factors CALL total	1.119	181	.265
Internal Metacognitive Strategies	1.185	181	.238
Internal Significance of Mobile Tools	.947	181	.345
Internal Personal Significance of ICT	-.066	181	.948
External Curriculum-based Limitations	-.365	181	.716
External Task-Centered Strategies	2.348	181	.020*
External Use of ICT Tools in Learning	.919	181	.360
External Motivational Role of ICT	.162	181	.872

* level of significance $p<0.05$

These findings are in line with the findings of Al-Emran et al. [31] who also found no significant differences among the students' attitudes towards the use of M-learning with regard to their major (IT, English, Business Management, and Project Management were the study fields included in this study).

When considering individual factors, the only significant difference was observed in the factor related to External Task-Oriented Strategies (Table 3). For this factor, the mean for the Technological field was M=2.79, while for the Humanities and Social Sciences field, it was M=2.47. The T-test results confirmed a significant difference at level of significance $p<0.05$.

This difference could be attributed to the nature of the fields themselves. In the

Technological/Engineering field, there may be a greater emphasis on practical, hands-on learning, which necessitates more direct guidance and support from teachers on using ICT tools for specific tasks. In contrast, the field encompassing Humanities and Social Sciences may focus more on independent, theoretical work, where students might not require as much direct instruction on using ICT tools for specific learning tasks. This could explain why students in the first field report higher levels of teacher guidance and support for using ICT tools at home and in the classroom compared to their peers in the other field.

4.3. Influence of gender on attitudes towards CALL

When examining gender differences, the sample comprised 92 female students and 87 male students. Overall, the results indicate generally positive attitudes towards CALL among both genders, with mean scores ranging from M=2.83 for females to M=2.79 for males regarding internal factors, and M=2.86 for females and M=2.70 for males for external factors (see Table 4).

Table 4. *Influence of gender on attitudes towards CALL*

Factors	Gender	No.	Mean	St. dev
Internal factors	Female	92	2.83	.577
	Male	87	2.79	.622
External factors	Female	92	2.86	.574
	Male	87	2.70	.576

Similar to the findings obtained for study fields, although minor differences suggest a slightly more positive inclination towards CALL among female students, statistical analysis using a T-test revealed no significant differences between genders (Table 5).

Table 5. *T-test gender means differences on attitudes towards CALL*

Study field	t	df	Sig.
Internal factors CALL total	.389	177	.698
External factors CALL total	1.874	177	.063
Internal Affective Strategies	-.862	177	.390
Internal Metacognitive Strategies	.039	177	.969
Internal Significance of Mobile Tools	.428	177	.669
Internal Personal Significance of ICT	1.742	177	.083
External Curriculum-based Limitations	.788	177	.432
External Task-Centered Strategies	1.220	177	.224
External Use of ICT Tools in Learning	2.045	177	.042*
External Motivational Role of ICT	1.151	177	.251

* level of significance $p<0.05$

However, when examining specific variables within these factors, a significant difference emerged regarding the external use of ICT tools in learning, where female students exhibited a higher mean score compared to male students. The T-test for Equality of Means revealed a statistically significant result, at the level of significance $p<0.05$, indicating that this difference is unlikely to have occurred by chance. This finding, while significant, does not necessarily reflect the overall moderate to high positive attitudes towards CALL observed across both genders in the study.

These findings align with the results obtained by Tafazoli et al. [26] and Al-Emran et al. [31], who also found no significant differences between male and female students. However, more recent research by Batool et al. [24] indicated that there are differences in attitudes and familiarity with CALL between genders, with female students showing a greater propensity to use technology in ELT classes than their male counterparts. It is important to note that this study only included students from the humanities, which might limit the generalizability of the findings. Similarly, the researchers in [25] found that female students were more positively oriented towards using ICT tools in learning English as a foreign language (EFL). These mixed results suggest that more research is needed to better understand the gender differences in attitudes towards CALL across different disciplines and contexts.

4.4. Pedagogical implications

The generally positive attitudes of students towards CALL, regardless of their field of study or gender, suggest that educators and curriculum designers should continue promoting the integration of ICT in English language teaching, emphasizing its external motivating role and the benefits it brings to classroom engagement. Professional development programs should focus on enhancing teachers' ICT skills and strategies to effectively support student learning across diverse disciplinary backgrounds and gender perspectives. Moreover, efforts to further investigate and address gender-specific attitudes towards ICT can ensure equitable access and utilization of technology in educational settings.

5. CONCLUSION

By examining the attitudes of students from diverse study fields and considering the impact of gender, this research seeks to provide a comprehensive understanding of the factors influencing students' acceptance of CALL. Based on the research questions regarding Serbian university students' attitudes towards CALL, several key findings and implications have emerged.

Firstly, the findings indicate that Serbian university students generally hold positive attitudes towards

CALL, as reflected in moderate to high mean scores for both internal and external factors related to ICT integration in English language learning. These scores suggest that students perceive ICT as beneficial, particularly in terms of its external motivating role in enhancing classroom atmosphere and instructional practices.

However, the study found no significant differences in attitudes towards CALL based on the field of study. Despite distinct educational emphases between the Technological/Engineering field, which prioritizes practical and technology-driven education, and the Social Sciences and Humanities field, which focuses on theoretical and qualitative studies, both groups of students displayed similar attitudes towards ICT use in learning English, with minor variations observed only in specific aspects such as external task-oriented strategies.

Similarly, when examining the differences in attitudes towards CALL based on gender, it was found that overall attitudes were generally positive among both male and female students. However, significant differences emerged in the external use of ICT tools for learning. Female students exhibited a slightly higher mean score, indicating a greater appreciation for the external motivating role of ICT in classroom dynamics. This finding underscores the importance of considering gender-specific preferences and needs when integrating ICT into educational practices.

Future research should expand to include other fields of study, such as medicine and arts, to gain a more comprehensive understanding of students' attitudes towards CALL across different disciplines. Additionally, further studies should delve deeper into the specific ICT tools students prefer and the aspects of English language learning most positively impacted by these tools, and any differences in students' perceptions based on demographic factors. Longitudinal studies examining the long-term effects of ICT integration in language learning can also provide valuable insights into its sustained benefits and potential areas for improvement. By addressing these areas, future research can contribute to a more nuanced understanding of the role of ICT in language learning and help educators optimize their teaching strategies.

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Public Speaking Anxiety: Can It Be Reduced in an Online Environment?

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Abstract: *This study aims to determine whether public speaking anxiety can be reduced when the oral presentation is performed in an online environment. For the purpose of the research, two groups of approximately equal numbers of university students delivered oral presentations: the control group in the classroom and the experimental group online using the MS Teams platform. Their levels of self-perceived communication anxiety and fear of negative evaluation were subsequently assessed using the Oral Presentation Anxiety Scale, which was designed specifically for this study. The results show that the online group was more relaxed when delivering oral presentations. However, other parameters did not show any significant differences in anxiety levels. The limitations of the study include a small sample size, suggesting that further research with larger samples is necessary to reach more reliable inferences.*

Keywords: *oral presentation, FL, public speaking anxiety*

1. INTRODUCTION

Incorporating activities and tasks that promote students' speaking competence in foreign language education is highly recommended, particularly in tertiary-level study programs. Modern education aims to prepare students for future professional environments where they will need to deliver presentations and engage in various speaking activities. As a result, the oral presentation is a common component of English for specific purposes curricula. Students learn to perform in front of an audience, fluently and enthusiastically without hesitations. However, since oral presentations are complex tasks performed publicly, they can induce a certain level of anxiety. In the following sections, we will explore foreign language anxiety, with a specific focus on public speaking anxiety, to provide a clearer understanding.

2. LITERATURE REVIEW

2.1. Anxiety of public speaking

One of the most important foreign language teachers' tasks is to instruct students on how to overcome public speaking anxiety which represents an affective component that can have a significant impact on the overall students' performance [1].

Public speaking is an oral production performance that implies speaking in front of an audience [2]. It includes a range of activities such as giving instructions, holding lectures, delivering presentations, reading aloud from notes, etc. Public performance often causes distress for speakers since most people feel uncomfortable when they need to address a group of listeners [3]. Being connected with fear and anxiety, emotional reactions to public speaking can also be physical, causing speakers to sweat, feel dizzy, and the similar. Therefore, public speaking anxiety (hereinafter: PSA) usually makes speakers feel restless, distressed, uncertain and afraid of the forthcoming situation [4, 3].

Since the 1970s, with the emergence of learner-centred teaching approaches, substantial research has been conducted on PSA as it has been considered a powerful factor that can impede successful FL language learning and proficiency [5]. Generally, psychology identifies three different types of anxiety: 1) trait anxiety, 2) state anxiety and 3) situation-specific anxiety. Trait anxiety is a personal feature typical for certain people [6]. State anxiety, on the other hand, appears as a reaction on certain occasions when an individual recognises a stressful situation [5]. Finally, situation-specific anxiety is connected with a specific context in which an activity takes place. Thus, public performances, including public speaking, reciting or taking exams are frequent situations in which learners feel anxious.

In accordance with the previous discussion, Horwitz et al. mention foreign language anxiety as a set of beliefs, feelings and behaviours related to the classroom context, encompassing communication apprehension, test anxiety and fear of negative evaluation [7]. Communication anxiety arises from a learner's apprehensions that they will not be able to participate in a communicative situation to their satisfactions [5]. Test anxiety is the fear of not performing well in an examination. Fear of negative evaluation provokes learners' anxiety since they are afraid of other peoples' judgements. Raja [3] explains that being a focus of somebody else's attention is a primary fear that can cause failure. As consequences, students can avoid live communication with their peers and teachers, and assessment tasks [5].

The previous arguments witness that foreign language anxiety (hereinafter FLA), and particularly public speaking anxiety as one of its forms, can represent a considerable obstacle in successful foreign language use. Apprehension, fear, uneasiness and restlessness are frequent negative emotions arising in foreign language classroom due to speakers' insecurity into their ability to communicate or perform well at the tests. This is the reason why FLA and PSA still appear as fruitful research field, even in technologically advanced environment.

In their study, Campbell & Larson compared the results of measuring PSA levels with students who performed face-to-face presentations and those who presented their topics to virtual audience using web-conferencing [8]. Surprisingly, they came to conclusion that there were no significant differences in the amount of anxiety expressed between these two groups of students. Almost a decade later, El Shazly [9] wanted to check the impact of AI tools on PSA level by exposing undergraduate students to implementing chatbots to practise FL communication for several weeks. In line with the previous research, El Shazly's study showed that the speaking interaction with chatbots did not lead to FLA release. On the contrary, the anxiety was slightly increased [9]. These examples imply that PSA and FLA remain the fields that require further investigation to help reduce apprehension and anxiety during live communication.

Regarding the previous inferences, this study was designed to check the effects of using e-learning platform MS Teams on regulating PSA with ESP students at academic level. The primary objective of the paper was to investigate whether there were any significant differences in students' perspectives on PSA based on their experience with traditional presentations in front of a live audience versus online presentations with a virtual audience.

3. METHODOLOGY

In line with the literature review, we designed experimental research with the aim to answer the following research questions:

- To what extent do students perceive to feel anxiety when delivering oral presentations in ESP?
- Are there differences in the estimation of anxiety levels between the group that delivered oral presentations in person and the group that presented online?

3.1. Research Design

The respondents of the research represent two groups of students who attended Business English lectures at the Faculty of Technical Sciences Čačak, the University of Kragujevac. The control group consisted of 35 students who delivered their presentations in the classroom, and the experimental one consisting of almost equal number of 32 students. Both groups were exposed to the same scenario during the instructional phase in their lectures. They prepared the same task, oral presentations, following the TBL teaching approach (pre-task, task cycle, focus on form) (see [10]). The task preparation lasted for three weeks. The students had the opportunity to choose appropriate topic which they prepared for the final speech delivery. However, for the sake of the research, the oral presentation phase was different. Namely, the control group presented their topics in the classroom with live audience, while the experimental group delivered their presentations using MS Teams platform having virtual audience.

Both groups were later asked to complete the survey consisting of Oral Presentation Anxiety Scale adapted specially for the purpose of this research. The answers were collected from the beginning of April to the end of May in 2023 via online Google Forms Questionnaire.

3.2. Research Instrument

For designing the PSA scale for our research, we relied on Foreign Language Classroom Anxiety Scale [7] and Public Speaking Class Anxiety Scale (PSCAS) [11]. Hence, these two scales are further elaborated in the following passages.

Horwitz, Horwitz & Cope [7] created the Foreign Language Classroom Anxiety Scale (FLCAS) encompassing 33 items rated on a five-point Likert scale ranging from "Strongly Agree" to "Strongly Disagree". It estimates students' self-reported anxiety levels by summing up their ratings across these items. As mentioned earlier, the FLCAS is structured on three basic features: (1) fear of negative evaluation, (2) communication apprehension, and (3) test anxiety [6].

Public Speaking Class Anxiety Scale predominantly relies on Foreign Language Classroom Anxiety Scale and encompassing research [11]. It adopts similar framework consisting of 17 items on a five-point Likert scale ranging from "Strongly Agree" to "Strongly Disagree".

The scale used in this research was adopted and modified based on previously mentioned scales, with specific adjustments to focus on presentations as a form of public speaking activity. Also, the questions adapted for our research refer to classroom apprehension and fear of negative evaluation. It consists of 13 items. Five-point Likert scale ranging from "Strongly Agree" to "Strongly Disagree" and was also used to check the students' self-perceived level of anxiety.

4. RESULTS AND DISCUSSION

To gain the main objective of this research, descriptive statistics and t-tests were performed. Table 1 presents the means and standard deviation for 13 items for both groups (students who had oral presentation in face-to-face class and a group of students who used video-conferencing platform MS-Teams).

Table 1. *Average levels of speaking anxiety for control group and experimental group*

Items	Face-to-face/online	N	Mean	Std. Deviation
I didn't feel quite sure of myself while I was giving the presentation in English.	Face-to-face	35	2.49	0.981
	online	32	2.44	1.162
I got nervous and confused when I was giving the presentation in English.	Face-to-face	35	2.74	1.268
	online	32	2.50	1.016
I was afraid that my presentation wouldn't be enthusiastic and persuasive enough.	Face-to-face	35	2.51	0.981
	online	32	2.94	1.075
I was afraid that I would not speak fluently.	Face-to-face	35	3.06	1.235
	online	32	2.72	1.325
I was afraid that I would make errors while speaking.	Face-to-face	35	3.06	1.235
	online	32	3.20	1.080
I was afraid that other students would laugh at me while I was speaking.	Face-to-face	35	2.34	1.235
	online	32	2.53	1.217
I had no fear of presenting my topic.	Face-to-face	35	2.83	1.504
	online	32	3.37	1.070
I could feel my heart pounding when I was going to deliver my speech.	Face-to-face	35	2.80	1.346
	online	32	2.69	1.2291
I felt relaxed while I was speaking.	Face-to-face	35	2.49	0.98
	online	32	3.03	1.031
Certain parts of my body felt very tense and rigid while I was speaking English.	Face-to-face	35	2.11	1.131
	online	32	2.44	1.014
I disliked using my voice and body expressively while I was delivering my speech.	Face-to-face	35	2.40	1.116
	online	32	2.56	1.045
Even though I was well prepared, I felt anxious about giving presentation.	Face-to-face	35	2.86	1.216
	online	32	3.16	1.110
I was afraid that I wouldn't be able to adjust the pace of my presentation with the pace of presenting the video material (slides, images, animations etc.)	Face-to-face	35	2.31	1.078
	online	32	2.69	1.119

The average levels of speaking anxiety during presentations, both face-to-face and online, show that students in both groups did not experience high levels of anxiety. Only one item, which estimated the fear of making mistakes during presentations, had means above 3 for both groups (M=3.06 for face-to-face and M=3.16 for online). Students who gave face-to-face presentations reported a similar level of fear regarding their fluency (M=3.06). Also, students who presented online also reported similar anxiety levels despite feeling well-prepared (M=3.16).

However, the item that received the highest evaluation from students in the online mode referred to their lack of fear during presentations (M=3.38), while the fear of not being fluent enough and the fear of making errors in front of the audience were the greatest sources of anxiety for the control group (M=3.06).

The items rated with the lowest scores were body tension for the group who had face-to-face presentations (M=2.11), and the possibility of other students laughing at presenters for the experimental group (M=2.53).

In order to evaluate potential differences in measured speaking anxiety between those two groups of students, t-test was conducted.

The overview of the results presented in Table 2 show that the only statistically significant difference in anxiety scores between the two groups of students is related to how relaxed they felt during face-to-face or online presentations. The group who presented in person reported feeling less relaxed (M=2.49) compared to the group who presented online (M=3.03), t (65) =-2.22, p=0.03. Therefore, the findings reveal a difference in how relaxed students felt during their presentations, depending on the mode of delivery. Namely, students who presented face-to-face reported feeling significantly less relaxed compared to those who presented online. This suggests that the traditional classroom setting may contribute to higher anxiety levels, possibly due to the immediate presence and scrutiny of peers and instructors. On the other hand, several factors could explain why students felt more relaxed presenting online. The online environment might provide a sense of physical separation and anonymity, reducing the perceived pressure of public speaking. Apart from this conclusion, we can notice that the overall results of this survey are in line with the findings of the study presented by Campbell & Larson [8], who also showed that there were no significant differences in the self-perceived levels of anxiety between in-person presenters and online presenters. Thus, we reach the conclusion that the instructors should persist in searching for more suitable methods to reduce public speaking anxiety of their students.

Table 2. *T-tests for evaluating differences in speaking anxiety*

Independent Samples Test					
Levene's Test for Equality of Variances			t-test for Equality of Means		
Items	F	Sig.	t	df	Sig. (2-tailed)
I didn't feel quite sure of myself while I was giving the presentation in English.	0.607	0.44	0.12	65	0.85
I got nervous and confused when I was giving the presentation in English.	4.971	0.03	0.86	65	0.34
I was afraid that my presentation wouldn't be enthusiastic and persuasive enough.	0.005	0.94	-1.68	65	0.10
I was afraid that I would not speak fluently.	0.271	0.60	1.08	65	0.28
I was afraid that I would make errors while speaking.	0.148	0.70	-0.35	65	0.73
I was afraid that other students would laugh at me while I was speaking.	0.003	0.95	-0.63	65	0.53
I had no fear of presenting my topic.	6.890	0.01	-1.72	61	0.09
I could feel my heart pounding when I was going to deliver my speech.	1.205	0.28	0.36	65	0.72
I felt relaxed while I was speaking.	0.004	0.95	-2.22	65	0.03
Certain parts of my body felt very tense and rigid while I was speaking English.	0.379	0.54	-1.23	65	0.22
I disliked using my voice and body expressively while I was delivering my speech.	0.156	0.70	-0.61	65	0.54
Even though I was well prepared, I felt anxious about giving presentation.	1.103	0.30	-1.05	65	0.30
I was afraid that I wouldn't be able to adjust the pace of my presentation with the pace of presenting the video material (slides, images, animations etc.)	0.103	0.75	-1.39	65	0.17

5. CONCLUSION

This survey aimed to determine how students of Business English felt while delivering oral presentations and which parts of the presentation made them feel nervous. We were eager to find out whether presenting in an online environment could reduce the anxiety and tension associated with public speaking.

The results revealed that both in-person and online groups showed moderate degree of anxiety concerning the levels of their self-confidence, nervousness and confusion during their performance. They were also equally worried about whether the presentation would be enthusiastic and persuasive or whether they would make speech errors. Also, the students of both groups were equally anxious about whether their peers would laugh at them while they were presenting. Both groups could feel physical signs of anxiety in almost the same measure regarding heart beat rate, tension of certain parts of the body or quality of voice. Finally, both groups were moderately apprehensive about whether they would be able to adjust the pace of speech delivery with the presentation of video material on the slides. However, the online group was significantly more relaxed and less anxious when giving presentation when compared to the students who performed in the classroom. This implies that the online oral presentations could serve as a good preparatory task for public speaking tasks.

To obtain more reliable results, the study should have encompassed a larger sample of participants. Additionally, the control and experimental groups did not contain an equal number of participants, which represents a shortcoming of the research. Possible implications could direct future research toward finding more suitable methods for relieving public speaking anxiety that occurs when students deliver their speeches, regardless of the presentation context

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Session 7:

Resilience and Support in the Digital Environment

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Empowering Psychological Resilience: Evaluation of Training

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Abstract: *Psychological resilience is a positive psychological adaptation in times of challenges and crises. Many training programmes focus on psychological resilience. The training programme "Manual: Step by step from trainees to trainers and supporters in student peer support network" is developed within the project "Enhancing digital and psychological resilience through peer networking in the online environment in times of crisis". The sub-programme A focused on psychological resilience, well-being, stress, and social support. The paper presents this sub-programme and discusses the programme structure. The sub-programme A was realized as hybrid and on-site and in four languages (English, Italian, Polish, and Serbian). The main goal is to evaluate the A sub-programme realization. The programme evaluative questionnaire was developed. The comparison of the sub-programme realization in English as a medium of instruction (80 trainees in the international pilot training realized at three universities, the sub-programme evaluated by 32 trainees) and Serbian as a medium of instruction (37 trainees in the national training realized in two groups, the sub-programme evaluated by 31 trainees) is presented. Trainees from both groups evaluated the A sub-programme with high grades; however, trainees trained in Serbian evaluated the A sub-programme higher (trainees in English: M=4.40; trainees in Serbian: M=4.82). Trainees rated the A sub-programme's particular aspects as highly useful to develop skills for peer support and recommended it to other students/ participants.*

Keywords: *psychological resilience; enhancing resilience training; English as a medium of instruction; programme evaluation; DigiPsyRes.*

1. INTRODUCTION

Psychological resilience is a positive psychological adaptation in times of challenges and crises. According to the APA Dictionary, "resilience is the process and outcome of successfully adapting to difficult or challenging life experiences, especially through mental, emotional, and behavioral flexibility and adjustment to external and internal demands" [1]. It is the focus of many educational skills training programmes and is considered in the context of psychosocial support. In the paper, the evaluation of the programme of empowering resilience in the context of peer support is considered.

The training programme "Step by step from trainees to trainers and supporters in the student peer-support network" is developed within the project "Enhancing digital and psychological resilience through peer networking in the online environment in times of crisis – DigiPsyRes" [2]. One of the parts of this programme is sub-programme A "Psychological resilience, wellbeing, and support" [3].

1.1. Psychological Resilience and Well-being

The review of definitions reveals that the concept of resilience transcends the boundaries of academic disciplines and represents an area for interdisciplinary inquiry [4].

Garmezy, as one of the founders of research on resilience, defined resilience in the following way: "resilience is designed to reflect the capacity for recovery and maintained adaptive behavior that may follow initial retreat or incapacity upon initiating a stressful event" [5].

According to Ungar [4] "Resilience is the capacity of individuals to navigate their way to resources that sustain well-being, the capacity of individuals' physical and social ecologies to provide these resources and the capacity of individuals, and their families and communities to negotiate culturally meaningful ways for resources to be shared".

The construct of resilience is "dynamic, complex in nature, and conceptualized as multidimensional" [6]. As part of the DigiPsyRes project [7] several review papers on the definitions of resilience have been considered [8, 9, 10]. A common understanding of resilience stands out as the capacity of an individual (personal strength) that is activated in stressful situations and allows for overcoming stress and reestablishing well-being and balance.

Resilience is both a capacity and an active process encompassing a person's flexibility in response to changing situational demands, and the ability to bounce back from negative emotional experiences. It involves behaviors, thoughts, and actions that anyone can learn and develop.

Resilience is a "construct connoting the maintenance of positive adaptation by individuals despite experiences of significant adversity" [12].

For people without professional groups, the concept of well-being means "the values of mental health, feeling valued, work-life balance, and the notion of inner harmony" [13]

According to the APA Dictionary well-being is "a state of happiness and contentment, with low levels of distress, overall good physical and mental health and outlook, or good quality of life" [1]. Two conceptions of well-being are considered. Based on the hedonic approach, a person has high subjective well-being if dominantly experiences positive moods and emotions, and less often unpleasant emotions, and vice versa; the person has low subjective well-being if rarely feels happiness, but often experiences negative emotions. The eudemonistic conception of psychological well-being emphasizes the need for people to live in accordance with their true nature, to grow, develop, and realize their potential [3].

1.2. Empowering Resilience and Well-being

Psychological research demonstrates that the resources and skills associated with more positive adaptation (i.e., greater resilience) can be cultivated and practiced [1].

Resilience research shows how individuals develop successfully despite the risk of mental illness and adverse living conditions.

Individual well-being is based on the five pillars (according to the Seligman's PERMA model [3, 14, 15, 16]:

- **P**ositive emotions (the ability to remain optimistic about one's past, present, and future).
- **E**ngagement (in activities that keep our mind on the present and, ideally, in a state of "flow").
- **R**elationships (strong and loving social connections with others).
- **M**eaning (a sense of greater purpose, spirituality, or religion).
- **A**ccomplishment (having goals and ambitions).

Therefore, relationships as important tools for resilience support! And "developing resilience is a personal journey" [1].

1.3. Educational Interventions on Psychological Resilience and Well-being

Educational interventions to enhance resilience and well-being have gained increasing attention in recent years, during and after COVID/19 pandemic, recognizing the critical role of mental health in academic and personal success. There is growing evidence in favor of resilience and subjective well-being as decisive psychological variables in the prediction of school engagement and perceived performance [17]. These interventions are designed to equip students with the skills and tools needed to cope with stress, adversity, and challenges, thereby fostering a more positive and productive learning environment.

There are many programs aimed at enhancing resilience in pre-university education (for example, The Resilience Project [18], Resilience and Well-Being training for teachers [19], RISE – Resilience in Schools and Educators [20]). Programs can be divided into several categories, depending on the main approach: mindfulness and meditation programs; programs based on SEL (Social and Emotional Learning; Primary SEAL -Social and Emotional Aspects of Learning); programmes based on Cognitive-Behavioral interventions; and programmes based on Positive education [21, 22]. Some programmes were designed for the higher education students and staff. For example, Mexico's Universidad Tecmilenio has aimed to enhance the well-being of its students and staff and it was based on the Positive education approach. Inspired by the PERMA model, which posits that well-being and happiness can be learned and measured, they added two elements: physical well-being and mindfulness, as well as character strengths, creating their "well-being ecosystem." This model was integrated into the university's entire organizational ethos and culture. As a result, students showed significant improvements in PERMA measures, mindfulness, and gratitude after a positive psychology course compared to their pre-test scores. Students with full exposure to the well-being ecosystem outperformed those with partial or no exposure in average grades, positive emotions, engagement, relationships, and achievements [23].

1.4. Enabling people to support resilience development

The training programme: "Step by Step from trainees to trainers and supporters in student peer support network" is developed as a part of the development of the student peer supportive network in the project DigiPsyRes.

The main goals of this programme [3]:

- The introduction of a peer support network and the training of teams for support (students and staff).
- Extended support to students to develop and implement the students' peer support network in resilience development.

Table 1. *Structure of the programme "Step by step from trainees to the trainers and supporters" [3]*

Programme Step by Step	E-courses	Duration of e-course	Training workshop (insite) / duration
Pre-training activities: 3 h	e-course Pre-training day	3 hours	no
A programme: 9 h	**e-course A**	**3 hours**	**6 hours**
B programme: 10 h	e-course B	4 hours	6 hours
C programme: 14 j	e-course C	8 hours	6 hours
Post-training activities: 4	e-course Post training	4 hours	no
40 hours		22 hours	18 hours

The sub-programme A focused on highlighting psychological resilience and social support.

Aims of the sub-programme A: to introduce students to key features of psychological resilience, wellbeing, and support focused on peer networks.

Objectives of the sub-programme A:

- To introduce the constructs of psychological resilience, wellbeing, and support, their place in general psychological and social functioning, and the ways to enhance them;
- To develop self-awareness in terms of self-resilience, stress and coping, as well as seeking social support [3] (DigiPsyRes, 2024, p. 25).

The sub-programme A comprises four thematic parts:

- Psychological resilience, wellbeing, and mental toughness,
- Stress;
- Wheel of life;
- Social support.

The sub-programme A consists of e-course and on-site training workshops. Both components of the programme were developed in four languages: in English as a medium of instruction for trainees from three countries, and in Italian, Polish, and Serbian for the partners and participants from three universities: University of Kragujevac in Serbia, University of Kazimierz Wielki in Bydgoszcz in Poland, and University of Foggia in Italy.

1.5. English as a medium of instruction

English as a medium of instruction (EMI) is the term that describes any form of formal education in which teaching is carried out in English. EMI refers to "the use of the English language to teach academic subjects, other than English itself" [24], usually without an explicit focus on language learning or specific language aims [25].

Four core criteria, usefully extracted from the literature, which are used to describe what is considered prototypical EMI settings include the following [26]:

- English is the language used for instructional purposes;
- English is not itself the subject being taught;
- Language development is not a primary intended outcome;
- For most participants in the setting, English is a second language (L2).

Many non-prototypical EMI practices, which are excluded from core criteria, should be addressed [24]. Firstly, the term 'instructional' may be seen as downplaying the interactive nature of knowledge creation between teacher/trainers and learners/trainees, co-construction of knowledge, teacher/trainer and peer support, and interactional student-centered approach. Furthermore, the perspective that English is not the object of study in EMI artificially separates thinking from language and ignores the role of language as a meaning-making tool. Language is not just a means for individuals to formulate ideas and communicate them but is also a means for people to think and learn together [27]. Additionally, in theory, EMI does not aim to enhance English language skills. However, in practice, English proficiency is a key reason why many participants enroll in this kind of programme. Lastly, although English is a second language for EMI participants, we should bear in mind that these learners/trainees create new intercultural spaces where their native language, multilingual skills and trans-lingual practices may be employed to navigate complex conceptual knowledge and, simultaneously, help them to bond emotionally and interpersonally with their peers.

2. RESEARCH METHODOLOGY

A very important element of the development and implementation of different training and courses, and for the DigiPsyRes project as well, is the evaluation of the effectiveness of implemented programmes.

The main goals of this paper are:

- to present an evaluation of the A sub-programme realization;
- to compare the sub-programme realization in English as a medium of instruction and in Serbian as a medium of instruction.

2.1. Variables

Evaluation of the subprogramme A (e-course and training).

Type of training:

- international training – English as a medium of instruction and online communication between groups;
- national training – Serbian as a medium of instruction, separate activities of the groups.

2.2. Method and techniques

An investigation of how participants evaluate the programme (e-courses and trainings) was realized by the Evaluation Questionnaire. The questionnaire was developed as a part of the project activities and consists of 55 items (questions). A part of the questionnaire was used for the evaluation of A sub-programme (see 12 items for evaluation of A sub-programme in Table 2). The evaluation included evaluation of teaching materials, applied e-tools, complexity of tasks and activities, way of implementing training, development of e-course, and teaching communication.

2.3. Sample and procedures

In the international sub-programme A, realized at three universities in three states (University of Foggia, Italy; University of Kragujevac, Serbia, and University of Kazimierz Wielki, Bydgoszcz, Poland – partners in DigiPsyRes project) in three countries, 80 trainees were enrolled, and 35 of them evaluated this sub-programme. In the national sub-programme A, at the University of Kragujevac, 37 trainees were enrolled, and 31 of them evaluated this sub-programme.

The comparison of the sub-programme realization in English as a medium of instruction (80 trainees in the international pilot training realized at three universities, the sub-programme evaluated by 35 trainees) and Serbian as a medium of instruction (37 trainees in the national training realized in two groups, the sub-programme evaluated by 31 trainees) is presented.

Sub-programme A for international groups was realized synchronously, at the same time, in a hybrid format (on-site and online between five groups in three universities) on December 18, 2023, at: the University of Kragujevac in Serbia, University of Kazimierz Wielki in Bydgoszcz in Poland, and University of Foggia in Italy. We should bear in mind that English was the second language for all participants who were exposed to the training in EMI.

Sub-programme A for national groups was realized in two terms: March 21, 2024. for trainees at the Faculty of Technical Sciences in Čačak, and March 25, 2024, for the trainees at the Rectorate of the University of Kragujevac – Faculty of Arts and Philology.

The sub-programme A was realized as hybrid and on-site and in four languages (English, Italian, Polish, and Serbian). This paper focused on the sub-programme A realization in two languages: English as a medium of instruction in the international training groups, and Serbian as a medium of instruction in the national graining groups.

Evaluation of the whole programme (three sub-programmes consisting of training and e-courses) at the end of all activities (after training and after completing activities in e-courses) is realized by the questionnaire in the Post-training e-course in Moodle LMS.

3. RESULTS AND DISCUSSION

The comparison of the sub-programme realization in English as a medium of instruction in the international pilot training groups, evaluated by 32 trainees, and the sub-programme realization in Serbian as a medium of instruction in the national training groups, evaluated by 31 trainees, is presented.

The evaluation of sub-programme A (e-course and training) was realized by the questionnaire used for the final evaluation of the programme Step by step. It included an evaluation of the different aspects of sub-programme A, taking into account the participants' perception of the delivery of the training and e-courses, and their assessment of the knowledge and skills they may have acquired following the training and realization tasks in e-course A (Table 2). The lowest grade of sub-programme A (common sample consisting of participants of international training in English as a medium of instruction and participants of national training in Serbian as a medium of instruction) is 2.17 (on a scale of 1-5), and the highest is 5. An average score of 4.60 was obtained.

Table 2. *Evaluation of A sub-programme (e-course plus training) by the international training groups and Serbian training groups*

	Items	Min	Max	Mean	St. dev.
A01	The content and activities of the A e-course and A training are connected and harmonized	2	5	4.58	.78
A02	Lessons in the A e-course are useful for the A programme outcomes.	2	5	4.66	.69
A03	The tasks in e-course A were well designed and realistic.	2	5	4.58	.72
A04	The workshops in the A training were dynamic and well-designed.	2	5	4.61	.74
A05	The leading trainer from A training and facilitator/trainer in my group coordinated activities and encouraged the work of the group.	3	5	4.75	.59
A06	I am satisfied with the exchange of ideas in remote online mode in A training between groups.	1	5	4.51	.84
A07	Evaluate the quality of the lessons in e-course A with a grade (from 1 – very poor to 5 - excellent).	2	5	4.48	.80
A08	The A programme contributed to my better understanding of psychological resilience,	3	5	4.64	.62
A09	The A programme contributed to my better understanding of the most frequent stress	2	5	4.63	.67
A10	The A programme contributed to recognizing reactions to stress (physiological, emotional, cognitive, behavioral).	2	5	4.58	.72
A11	The A programme contributed to developing my self-awareness in terms of my own resilience, stress and coping, and well-being.	2	5	4.61	.76
A12	The A programme contributed to developing my self-awareness in terms of seeking social support.	2	5	4.60	.74
	Evaluation of the sub-programme A	2.17	5.00	4.60	.63

Min – the smallest average value ((Participant score / N of items). Max – the highest average value (Participant score / N of items). Mean – average value (Sum of participants scores / N of items / N of participants).

Trainees from both groups – international trainees' group and trainees at the University of Kragujevac – evaluated the A sub-programme with high grades (M=4.60). Trainees perceived A sub-programme simillarly generally uniformly, with relatively small deviations: the standard deviation of the evaluation of programme A as a whole is 0.63.

However, trainees trained in the groups in the national language (Serbian) evaluated the sub-programme A higher (M=4.83) than the trainees from the international pilot training groups (M=4.40) (Table 3, next page). The results of the comparison obtained by ANOVA are supported by the comparison tested using the t-test.

The trainees rated the A sub-programme's to engage in a fruitful discussion about particular aspects as highly useful to develop skills for peer support and recommended it to other students/ participants. The training in the national (Serbian) language was rated with better grades than in English, which is expected.

The most obvious differences were in the quality of group exchange, harmonization of activities between e-course and in-person training, and in contribution of the training to personal development (self-awareness, stress, resilience and coping, and well-being).

Also, the contribution of sub-programme A to skills of seeking social support was marked as very high in the national training. The difference in the perceived quality of the exchange of ideas between the groups at three universities and three countries, which was significantly lower within the group exposed to EMI, may be ascribed to the different levels of English language proficiency among the participants and groups at three universities (English was the second language to all trainees). The different levels of proficiency potentially hindered the interaction between the Italian, Serbian, and Polish groups. The differences in the perceived contribution of the training to personal development and to skills of seeking social support, which were significantly lower within the group exposed to EMI, can be attributed to the fact that personal development topics and seeking social support skills are easier to process and acquire in one's native language.

Table 3. *Comparison evaluation of A sub-programme (e-course plus training) between I - international training groups and national training groups*

	Items	Inter-national groups	National Serbian groups	F	sig.
A01	The content and activities of the A e-course and A training are connected and harmonized	4.34	4.84	7.55	.008**
A02	Lessons in the A e-course are useful for the A programme outcomes.	4.46	4.87	6.73	.012*
A03	The tasks in e-course A were well designed and realistic.	4.43	4.75	3.45	.068
A04	The workshops in the A training were dynamic and well-designed.	4.40	4.84	6.56	.013*
A05	The leading trainer from A training and facilitator/trainer in my group coordinated activities and encouraged the work of the group.	4.63	4.87	3.05	.086
A06	I am satisfied with the exchange of ideas between groups.	4.17	4.87	13.98	.000**
A07	Evaluate the quality of the lessons in e-course A with a grade (from 1 – very poor to 5 - excellent).	4.29	4.69	4.38	.040*
A08	The A programme contributed to my better understanding of psychological resilience,	4.51	4.78	3.20	.078
A09	The A programme contributed to my better understanding of the most frequent stress	4.46	4.81	4.98	.029*
A10	The A programme contributed to recognizing reactions to stress (physiological, emotional, cognitive, behavioral).	4.37	4.81	6.81	.011*
A11	The A programme contributed to developing my self-awareness in terms of my own resilience, stress and coping, and well-being.	4.37	4.88	8.18	.006**
A12	The A programme contributed to developing my self-awareness in terms of seeking social support.	4.37	4.84	7.48	.008**
	Evaluation of the sub-programme A	4.40	4.83	8.44	.005**

Min – the smallest average value ((Participant score / N of items). Max – the highest average value (Participantscore / N of items). Mean – average value (Sum of participants scores / N of items / N of participants).
F – Fisher coefficient. **p<0.01; *p<0.05

The study found no statistically significant differences in how trainees perceived the task design and its realistic features between those trained in EMI and those trained in Serbian as a medium of instruction. A similar result was recorded for the trainees' perception of trainers/facilitators' ability to coordinate activities successfully and encourage the work of the group. Also, there were no significant differences in how the two groups perceived the A-programme's contribution to understanding psychological resilience.

We will now give a few qualitative observations from both international and national trainings. Activities that were best received by the participants were breathing exercises, after being a bit skeptical at the very beginning. Muscle and mind relaxation as well as heightened awareness were reported after this exercise. “The Weight of Fears” activity was one of the most interesting and valuable, helping participants the power of cognition in coping - how changing perspective on stress could help alleviate it. The Wheel of Life was done online by the participants, during pre-training. This activity unveiled their level of satisfaction with various aspects of their lives. Discussion followed about their insights on how to make balance and improve satisfaction in those areas that were not highly marked. They highlighted the issues of social exactions regarding personal goals and various aspects of life – the pressure they feel from society to devote time to certain aspects of life that they do not “feel” as truly important.

4. CONCLUSION

Psychological resilience is a crucial aspect of mental health. Strengthening the psychological resilience of university students is a key objective of the university's support initiatives. The A training sub-program "Psychological Resilience, Well-being, Stress, and Social Support" is designed as part of the broader "Step by Step from Trainees to Trainers and Supporters in Student Peer Support Network" programme, aimed at developing an international peer support network among university students.The trainees on the sub-programme A, who were trained in groups in the English language (in which students and university staff from three universities in three countries participated) and in the Serbian language (organized for students and university staff as well), evaluated the programme. Their programmme perception and evaluation confirmed its usefulness for understanding and strengthening psychological resilience.

There is a paucity of research that considers the comparison between students/trainees' perception of EMI and non-EMI programmes (the programmes that are realized in native languages), though some recent research [28] focuses on the differences between these two types of programmes in terms of students' motivation and engagement in learning English in the fields of international business, computing, journalism and mass communication, and tourism. The strength of the present study is that it compares the students' perception of training in EMI and non-EMI (Serbian as the native language) settings. The fact that this is done in the highly specific training programme of psychological resilience makes the research even more unique, particularly in the Serbian HEI context.

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Implementation and Evaluation of a Digital Resilience Program

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Abstract: *Digital resilience refers to the adaptive capacity for overcoming the challenges of the digital landscape. It encompasses the ability to effectively respond to and recover from adverse online experiences, demonstrating mental agility and digital competencies. We developed a program "Digital Resilience and Networking" under the Erasmus+ project "Enhancing digital and psychological resilience through peer networking in the online environment in times of crisis". This paper describes the layout and implementation of the program: the piloting phase (implemented in hybrid mode in the English language at three partner universities from Serbia, Poland, and Italy), the evaluation, and its implementation in Serbian language (national training, held fully online). We prepared a questionnaire to evaluate the effects of the course and cross-analyzed the training session evaluation (international pilot - 35 feedback records, and national training - 32 records). The evaluation showed high ratings for both phases, revealing significant differences between them. Furthermore, a strong correlation was found between participants' satisfaction with the program's implementation and their perceived skill acquisition. These results offer valuable insights into the efficacy of the program in enhancing digital resilience skills and emphasize the significance of well-implemented courses for optimal learning outcomes.*

Keywords: *digital resilience, course development, course evaluation, training effectiveness, skill acquisition*

1. INTRODUCTION

The importance of information technologies (IT) in every aspect of our society is constantly increasing. Therefore, IT issues can severely impact everyday life. Disruption of Internet communication, loss of data, website downtime, and switching to online learning are some of the abrupt challenges that many individuals and companies face. Globalization brought remote crises to everyone's homes. Dealing with such disruptions builds one's capability to cope with challenges, absorb major shocks, adapt, and move to a stable state. Such capability is referred to as digital resilience [1]. Further research enlightened the construct of digital resilience, recognizing the role of peer networking and resilience as a process [2].

Building digital resilience heavily relies on individual experience and is mostly built spontaneously. However, training can be of great importance in supporting the development of one's resilience. An example of such a program is given in [3], where the role of training in recognizing fake news was explored and a positive effect of training on individuals' ability to identify fake news on social media was demonstrated.

Several studies reported the positive effects of digital resilience training in enhancing digital resilience [4, 5, 6, 7]. The study [4] used a qualitative process evaluation approach to examine how students interacted with the asynchronous and synchronous versions of the digital resilience skill enhancement program (RISE). The analysis of themes derived from the participants' comments revealed how the RISE program aided them in their journey towards resilience. Students found the digital resilience program suitable and were able to use their newly acquired skills to boost their resilience and learning [5]. Despite suggesting several improvements to enhance the program's rigor, the study's findings indicate that digital resilience programs are crucial for students' well-being. Another study [6] developed an online ResilienceOnline (ROL) program employed in the context of sales management. Participants found the resilience training highly enjoyable and recognized its potential to enhance their job performance and life skills, which shows the importance of digital resilience skill development in different environments. The primary aim of the study [7] was to evaluate the feasibility of the newly developed RESIST training, a new hybrid web-and app-based digital resilience intervention for employees, in terms of usability, user behavior, user experience, and motivation to use it. Additionally, the study aimed to explore the preliminary effects of the intervention on stress reduction and resilience enhancement through a pilot randomized controlled trial. The results suggest that a resilience intervention can positively impact employees' ability to manage stress and enhance their resilience. The authors of the study [8] investigated the role of digital resilience as a mediator and the role of training protocols as a moderator between the adoption of artificial intelligence and digital innovation links. The results emphasize the importance of digital resilience skills in adopting digital innovation.

This paper presents the implementation of the program 'Digital Resilience and Networking' (also referred as Program B). It is a second part of the 3-program training[1] "Step by step from trainees to trainers and supporters in student peer support network" developed under Erasmus+ project "Enhancing digital and psychological resilience through peer networking in the online environment in times of crises" (DigiPsyRes), coordinated by the University of Kragujevac [9]. The project goal is to develop a peer support network able to assist students in need regarding psychological and digital resilience. In this paper, the implementation of the two phases of the program "Digital Resilience and Networking" is presented - international pilot training in English language and national training in Serbian. Further, the comparison of the evaluation results for the English and Serbian instruction modes is performed.

The main aim of this paper is to determine the differences in the evaluation of the realized pilot e-course of the Program B and national training and to explore the correlation between estimated satisfaction with the realized courses and developed skills. One of the goals is also to determine the relationship between satisfaction with the course implementation and the assessed acquired skills based on the participants' subjective evaluations.

2. THE TRAINING IMPLEMENTATION

There are three objectives students are supposed to achieve with the training "Step by step from trainees to trainers and supporters in student peer support network". First, students should be trained to foster their resilience and to develop skills to cope with different challenges. Second, students are trained to assist other students in need, i.e. to provide peer support. Third, selected students are involved in training activities as trainers. Besides the students, who are the primary training target group, the faculty staff is also involved and trained. The training is set in three iterations: international pilot training in the English language, national training in the Serbian language, and peer-moderated training.

2.1. The objectives of Program B

Objectives of the Program B - "Digital Resilience and Networking" are as follows:

- introducing the concept of digital resilience and its place in the general resilience of a person,
- presenting core features of self-awareness regarding malicious behavior and software misuse,
- introducing the external and internal threats and core defense mechanisms,
- demonstrating privacy control on popular social network platforms,
- discussing various cyberbullying scenarios,
- presenting features of digital resilience in online learning, and
- highlighting the importance of critical thinking regarding social networks and Internet news.

2.2. The implementation of Program B

The program B - "Digital Resilience and Networking" consists of four parts:

- Information security fundamentals;
- Social networks, privacy control and cyberbullying;
- Digital resilience and online learning; and
- Internet sources and critical thinking.

Before the training day, a pre-training activity was set up. Participants were enrolled in the Program B Moodle course and directed to read brief introductory material, before the start of the training. The training was scheduled as a 6-hour session, supplemented with asynchronous activities on the Moodle online learning platform.

The pilot was organized in three partner countries simultaneously: the University of Kragujevac, Serbia, the University of Foggia, Italy, and Kazimierz Wielki University from Bydgoszcz, Poland. Training was setup in hybrid form. Attendants from each partner university were gathered in their local classrooms with facilitators working face-to-face, while interconnected via Zoom. The University of Kragujevac established two groups, one in Kragujevac and one in Čačak. The training was led by teachers from the University of Kragujevac located in Čačak, while Cyberbullying and Fake multimedia were presented by teaching staff in Bydgoszcz.

Briefly, the workflow of the pilot training was set as follows:

[1] Program A is "Psychological resilience, wellbeing and support" and program C is "Horizontal psychological support in the digital network and ethical framework"

- The teacher is giving a lecture. Attendants in the same room are listening face-to-face and following the instructions. Remote attendants are following the instructions via Zoom. The communication was in the English language.
- Participants perform various kinds of activities, engaging in different teaching forms. They post comments and answer questions in Moodle chat and solve quizzes. Participants also work in groups and report summaries, either face-to-face, via Zoom, or in Moodle forums.
- Facilitators are assigned to each group and their role is to foster communication and report for certain group tasks (directly or via Zoom chat).

The national training was slightly modified. The content remained unchanged, while the course delivery was set fully online. Participants, including teachers and facilitators, attended the lecture remotely. Facilitators were supporting group work in breakrooms (separate rooms), formed for certain activities. The pre-training and post-training activities aligned with the activities in the pilot phase. The summarized structure of activities for Program B is presented in Figure 1.

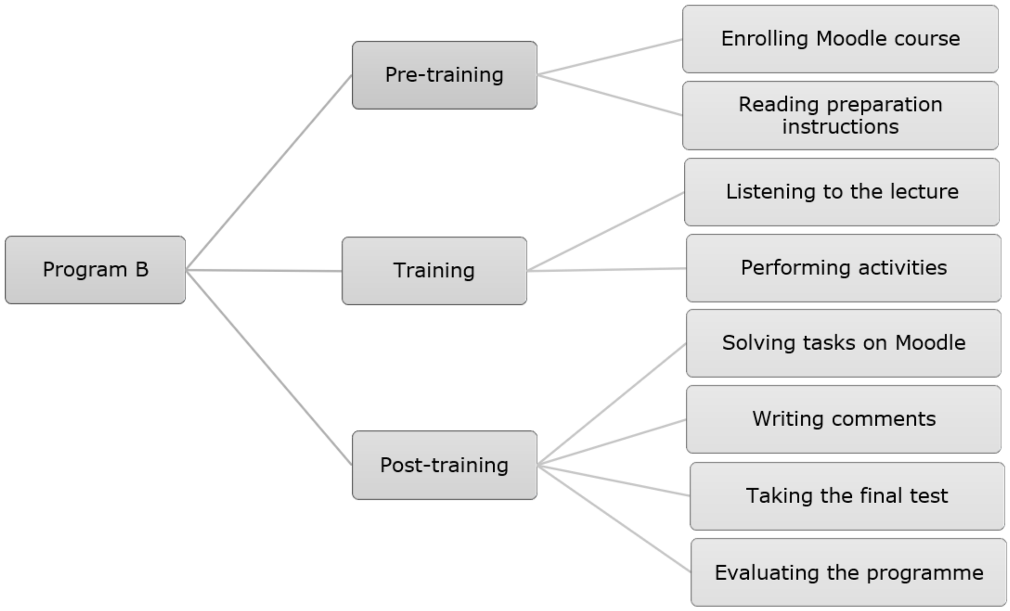

Figure 1. *The structure of activities for Program B*

2.3. Information Technology Support

The program B - "Digital Resilience and Networking" is heavily dependent on technology. In this section, more details on the program implementation, from the technology perspective, are provided.

Zoom was chosen as a video conference solution for the following reasons:

- The premium license with no time restriction was already owned.
- It allows setting up two cameras (one for the presenter and another to record the participants in the classroom).
- All users were already familiar with Zoom.
- Zoom supports breakout rooms, a convenient way to isolate groups of students and enable them to collaborate separately.

In piloting, participants did not run Zoom on their computers - only one computer per room was connected to the Zoom conference, administered by the teacher or facilitator. Since the videoconference is a demanding application, running other resource-consuming applications on the computer used for the Zoom conference was strongly discouraged.

The Moodle platform in use was 3.11.8+ (available at http://eucenje.ftn.kg.ac.rs). All participants, teachers, and facilitators were enrolled to the program course. Standard Moodle modules were used. The WordCloud plug-in was installed to obtain participants' reflections using the word-cloud form. Participants used computers (either their own laptops or classroom computers) to execute tasks in Moodle or to perform certain tasks outside Moodle (e.g. to test their e-mail on haveibeenpwned.com). No special application was required.

2.4. Post-training

The post-training comprises activities to be taken as a follow-up to the main training. Participants contributed to specified tasks on Moodle forums. Also, all participants were enrolled on a distinct Moodle course for student assessment and training evaluation, where evaluation of all programs was conducted and where participants took the final test. The test was configured as a typical Moodle quiz, with 20 closed-ended questions. Additionally, this course provided the training participants the opportunity to contribute with their comments in open form.

3. METHODOLOGY

The main aim of the research is to evaluate differences in efficiency the international (pilot) training and national training. The quantitative method was conducted. The developed questionnaire and research procedure are explained in the following chapters.

3.1. Questionnaire

The implemented courses were evaluated using a questionnaire that the participants filled out after they completed all three programs (A, B, and C) in English (pilot training) and in Serbian (national training) languages (Table 1).

Table 1. *Evaluation questionnaire for Program B*

Evaluate the quality of the lessons in e-course B with the grade (from 1 – strongly disagree to 5 - strongly agree).
1. The content and activities of the B e-course and B training are connected and harmonized.
2. Lessons in the B e-course are useful for the B program outcomes.
3. The tasks in e-course B were well-designed and realistic.
4. The workshops in the B training were dynamic and well-designed.
5. The leading trainer from B training and facilitator/trainer in my group coordinated activities and encouraged the work of the group.
6. I am satisfied with the exchange of ideas in remote online mode in B training between six university groups.
Evaluate the quality of the lessons in e-course B with the grade (from 1 – very poor to 5 - excellent).
1. The B program contributed to my better understanding of the concepts of digital resilience and cyberbullying.
2. The B program contributed to my better recognition of digital disruption events and behaviors and most frequent threats.
3. The B program contributed to improving my skills in applying basic digital protection mechanisms.
4. The B program contributed to improving my skills in how to react to various cyberbullying scenarios.
5. The B program contributed to developing the skills necessary to contribute positively to the network's collaborative and supportive environment.
6. The B program contributed to identifying my need to seek help from others in the context of online teaching and learning.
7. The B program contributed to developing my skills to apply strategies for evaluating information on the network.
8. The B program contributed to recognizing reliable URL addresses and ways of presenting checked information in an online context.
9. The B program contributed to improving my skills to apply rules for sharing information on the network.

The questionnaire was an integral component of the Erasmus+ project "Enhancing digital and psychological resilience through peer networking in the online environment in times of crises". The primary aim of DigiPsyRes was to enhance the capacity, readiness, and procedures necessary to empower students in boosting their digital and psychological resilience.

The questionnaire served to identify and analyze the difficulties students faced during the program, as well as their perceptions of the importance of this program in bolstering psychological and digital resilience. The questionnaire acted as an instrument to encourage critical thinking and receive valuable feedback that can measure the success of the program and give insight into possibilities for improvement.

Participants were informed there were no right or wrong answers. The objective was to reflect on their own experiences and perspectives through the statements provided. Responses played a crucial role in evaluating the project and refining the training program. Their engagement contributed significantly to understanding this critical topic and enhancing the training program for future participants.

The questionnaire was composed by the project team and published using Google Forms. It comprised several sections and typically took about 10 minutes to complete. However, there was no time limit for completion. The evaluation included evaluation of teaching materials, applied e-tools, complexity of tasks and activities, way of implementing training, development of e-course, and teaching communication. The prerequisite for DigiPsyRes training evaluation was completing pre-training activities, e-courses, training, post-training, self-assessment, and assessment activities.

The evaluation consisted of five parts.

- First part - Evaluation of the DigiPsyRes program;
- Second part - Evaluation of the program A;
- Third part - Evaluation of the program B;
- Fourth part - Evaluation of the program C; and
- Fifth part - Evaluation of the participation.

This paper focuses on the evaluation of the program B. The questionnaire aimed to evaluate various aspects of the program B training within the DigiPsyRes project. Participants responded to a series of statements. One of the primary focuses was to determine whether the content and activities of the program B were connected and harmonized. This assessment was crucial to ensure that the program's components were effectively aligned to provide a cohesive learning experience. Another important aspect evaluated was the usefulness of the lessons for achieving the B program outcomes. Participants were asked to rate how well the tasks in the e-course were designed and how realistic they found them to be. Additionally, the dynamism and design of the workshops in the program B training were assessed to understand their impact on the participants' learning experience. The effectiveness of the leading trainer and the facilitator in coordinating activities and encouraging group work was also scrutinized, as their roles were pivotal in fostering a productive and supportive training environment. The questionnaire also delved into the participants' satisfaction with the exchange of ideas in the remote online mode, particularly between the university groups involved in the program B. This aspect was essential to gauge the level of engagement and collaboration facilitated by the program. Participants were further asked to rate the overall quality of the lessons in the program B, providing a comprehensive view of the course's effectiveness. In terms of the program's impact, the questionnaire assessed its contribution to understanding digital resilience and cyberbullying concepts. It evaluated how well the program helped participants recognize digital disruption events, behaviors, and common threats. Moreover, it examined whether the program improved participants' skills in applying basic digital protection mechanisms and reacting to cyberbullying scenarios. The development of skills necessary for contributing positively to a collaborative and supportive network environment was another critical area of evaluation. The questionnaire also identified participants' recognition of the need to seek help in the context of online teaching and learning. It assessed the improvement in skills for evaluating information on the network, recognizing reliable URLs, and presenting verified information. Finally, it evaluated the enhancement of skills related to applying rules for sharing information on the network. This comprehensive evaluation provided valuable insights into the effectiveness of Program B in enhancing digital and psychological resilience among students.

The questions were divided into two groups:

- items regarding the courses and their realization, which contained 6 items, and
- items regarding the estimation of developed skills after courses, which contained 9 items.

For the evaluation of different aspects of Program B, a 5-level Likert scale was used. The five-point scale allowed participants to express to what extent they agree or disagree with a particular statement.

The five degrees mean:

1 – Strongly disagree;
2 – Disagree;
3 – Undecided;
4 – Agree; and
5 – Strongly agree.

In some cases, a five-point scale is used as a grading scale: 1 (very poor), 5 (excellent). Both subscales have high reliability according to Cronbach's alpha coefficient (0.95/0.97).

3.2. Variables

Evaluation of the Program "Digital Resilience and Networking" was divided into two subcategories:

- program implementation, which measures satisfaction with the program and its implementation, and
- developed skills, which measures the estimation of developed skills after training.

For each category, two types of training were evaluated:

- international pilot training, where the English language was used for providing instructions and communication between groups, and
- national training, where the Serbian language was used for providing instructions and in separate group activities.

3.3. Sample and procedures

The international pilot phase of Program B was conducted synchronously on January 10th, 2024, across three universities: the University of Foggia in Italy, the University of Kragujevac in Serbia, and Kazimierz Wielki University in Bydgoszcz, Poland. During this phase, eighty trainees were enrolled, and 35 of them participated in evaluating the program. Subsequently, the national phase of Program B was held on 29.3.2024. at the University of Kragujevac, with 32 trainees enrolled and 32 completing the evaluation. Overall, the total evaluation sample comprised 67 participants.

To compare the effectiveness of the program, a statistical analysis was conducted on the evaluations from both the international phase, and the national phase. This analysis aimed to compare satisfaction with the program's implementation and the estimation of acquired skills after the training.

This paper focuses on the realization of Program B in two distinct phases: the international phase, using English as the medium of instruction, and the national phase, using Serbian. It examines two key categories: participant satisfaction with the program's implementation and the perceived acquisition of skills post-training.

The evaluation of Program B, conducted at the conclusion of all activities including both the training sessions and the completion of e-course activities, was carried out using a questionnaire hosted in the post-training e-course on the Moodle learning management system. This comprehensive evaluation approach ensured that feedback was collected systematically, providing valuable insights into the program's effectiveness across different languages and instructional contexts.

4. RESULTS AND DISCUSSION

The main research aims of this study were to evaluate the effectiveness of Program B through descriptive statistics, t-tests, and correlation analyses. The results, as presented in Table 2, demonstrate the means and standard deviations for two estimated categories of evaluation across two groups: the international pilot and the national training.

Table 2. *Results of Program B evaluation*

Category	Group	N	Means	SD
PI	IP	35	3.99	0.96
	NT	32	4.52	0.59
	Total	67	4.24	0.84
DS	IP	35	4.16	0.97
	NT	32	4.57	0.58
	Total	67	4.35	0.83

** PI - Program implementation, DS - Developed skills, IP – International pilot, NT – National training, SD – Standard deviation*

The findings indicate that both categories of evaluation received high ratings, with means above 4 on a 5-point Likert scale. However, significant differences were observed between the two types of courses (pilot and national training) regarding the evaluation of the courses. The pilot group provided lower ratings for the technical aspects and implementation of the courses compared to the national training group (M=3.99/4.52, $t(65)=-2.77$, $p=0.007$). Similarly, for the evaluation of skill development in terms of digital resilience, the pilot group rated lower than the national training group (M=4.16/4.57, $t(65)=-2.09$, $p=0.042$).

The lower ratings in the pilot group could be attributed to several factors. Firstly, language may have played a significant role. The international pilot phase was conducted in English, which is not the native language of the participants. This could have led to difficulties in understanding the course material and consequently affected their evaluation. Secondly, differences in instructional design and delivery between the international and national phases might have influenced participant perceptions. The national training phase, might have been better tailored to the specific needs and expectations of the participants, resulting in higher ratings.

To gain a deeper understanding of the relationship between course realization and implementation and the evaluation of acquired skills, a correlation analysis was conducted. The analysis revealed a highly significant correlation between these two categories ($r=0.89$, $p=0.000$). This suggests that higher ratings in the technical and implementation aspects of the courses were strongly associated with higher evaluations of skill development.

These findings provide valuable insights into the effectiveness of Program B in enhancing digital resilience skills among participants. While both the international pilot and national training phases were positively received, differences in participant satisfaction and perceived skill acquisition were evident. The results highlight the importance of effective course implementation and instructional design in maximizing participant learning outcomes.

Finally, this comprehensive evaluation underscores the effectiveness of Program B and provides valuable insights for future iterations and improvements.

5. CONCLUSION

Study Overview

This study focused on the implementation and evaluation of Program B, which aimed to enhance digital resilience skills among students. As part of the Erasmus+ project "Enhancing digital and psychological resilience through peer networking in the online environment in times of crisis," Program B was developed and delivered in two phases: an international pilot phase conducted in English and a national training phase conducted in Serbian language. The implementation of the program involved a hybrid model for the pilot phase, with sessions held across three partner universities, and a fully offline format for the national phase. A questionnaire was used to evaluate the effects of the program, and feedback from both phases was analyzed.

Positive Aspects of the Program:

- High Overall Satisfaction: Both phases of the program received high ratings overall, with means above 4 on a 5-point Likert scale, indicating strong participant satisfaction.
- Effective Skill Development: The high ratings for skill development demonstrate that the program was successful in enhancing digital resilience among participants.
- Strong Correlation Between Aspects: The highly significant correlation ($r=0.89$, $p=0.000$) between the technical/implementation aspects and skill development indicates that well-implemented courses effectively enhance skill acquisition.

Limitations:

- Language Differences: The pilot phase being conducted in English might have led to misunderstandings and affected the evaluations due to language barriers.
- The fact that the pilot participants are from three countries (vs. one in national training) may cause bias of the results due to cultural differences.
- Different Instructional Designs: Variations in the instructional design and delivery between

the two phases could have influenced the participants' evaluations differently.

- Sample Size: The relatively small sample size (N=65) might limit the generalizability of the findings to a larger population.

Future Studies:

- Exploring Additional Factors: Future research could explore additional factors influencing participant evaluations, such as cultural differences, individual learning preferences, and prior digital literacy levels.
- Detailed Course Design Analysis: Further studies could delve into specific aspects of course design that contribute to enhanced learning outcomes, identifying best practices for course implementation.
- Longitudinal Studies: Conducting longitudinal studies to assess the long-term impact of Program B on digital resilience skills would provide a deeper understanding of its effectiveness over time.

The overall quality of the training increased, however there are various factors making impact (course delivery mode, language, teaching methods), that cannot be easily distinguished with this sample size. However, this paper set grounds for research of this particular topic and specifically, for evaluation of the remaining triaining step (where students are tutors).

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Horizontal Psychological Support in the Digital Network: *DigiPsyRes* Project Training Evaluation

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Abstract: *Despite extensive research on peer support, there remains a lack of initiatives specifically targeting psychological resilience and digital student networking. Addressing this gap, the training program "Step by Step from Trainees to Trainers and Peer-Supporters in the Student Peer-Support Network" (sub-program C) within the "DigiPsyRes" project aims to equip students to provide peer support. This paper describes the layout and implementation of Program C, which underwent an international pilot phase in January 2024, followed by refinements, and was finally delivered in April 2024 in Serbian in a hybrid format. The aim of the paper is to evaluate Program C and compare the outcomes of its international pilot phase and national training. The evaluation employed a blend of quantitative and qualitative methods, utilizing three distinct types of instruments: knowledge assessment, evaluation questionnaire, and qualitative feedback. The results showed high scores in knowledge assessment and evaluation questionnaires for both phases, with the national training phase receiving higher evaluations than the international pilot. Qualitative analysis confirmed the prevalence of positive feedback and provided insights for future adjustments, leading to improved scores for the national training. These findings underscore the importance of well-structured courses in fostering peer support networks that enhance resilience and highlight their role in achieving optimal learning outcomes.*

Keywords: *Horizontal/peer Support; digital network; psychological resilience; training; program evaluation.*

1. INTRODUCTION

In the contemporary educational landscape, fostering resilience among youth, especially university students, has emerged as a critical objective [1]. Resilience, defined as positive psychological adaptation in the face of change, plays a pivotal role in the well-being and learning outcomes of students, enabling them to navigate and surmount adversity [2, 3]. Moreover, individual resilience is frequently augmented by community support, encompassing interactions with peers, family, teachers, and community leaders [4]. This social aspect of resilience highlights the significance of peer support, a form of social support where individuals with shared experiences offer mutual assistance. Research indicates that resilience helps students navigate difficulties, enhances their satisfaction with university life, and contributes to their academic success [3]. Additionally, high levels of resilience are associated with better psychological well-being, self-esteem, and physical health among university students [5].

Despite extensive research and numerous training programs focusing on peer support, there remains a paucity of initiatives specifically targeting psychological resilience and digital student networking. Addressing this gap, the training program "Step by Step from Trainees to Trainers and Peer-Supporters in the Student Peer-Support Network," developed within the "Enhancing Digital and Psychological Resilience through Peer Networking in the Online Environment in Times of Crisis – DigiPsyRes" project, aims to equip students to provide peer support. This training program seeks to enhance both psychological and digital resilience among peers, fostering a robust peer support network to fortify resilience in educational settings.

This paper describes the layout and implementation of Program C, the third and final part of the training program, with the aim of evaluating it and comparing the outcomes of its international pilot phase with the national training phase that followed after adjustments.

2. PSYCHOLOGICAL RESILIENCE AND PEER SUPPORT

Resilience is related to and overlaps with psychological support. Activities that promote psychological support can contribute to resilience by promoting the core competencies that support well-being and learning outcomes (i.e. skills, behaviours, and relationships), and which in turn allow children and youth and the education systems they are part of to manage and overcome adversity. It is also important to note that individual resilience is often boosted by community support, including interactions with peers, family, teachers, community leaders, and so on [6].

Resilience is defined as positive psychological adaptation in the face of change. It is the focus of many educational skills training programs. It is nurtured, developed, and mobilized in times of stress [7]. Researchers have identified three related uses of the term resilience: recovery, resistance and reconfiguration [8].

Peer Support is a supportive relationship between people who have a lived experience in common in relation to either their own mental health challenge or illness or that of a loved one [9]. Peer support is distinct from other forms of social support in that the source of support is a peer, a person who is similar in fundamental ways to the recipient of the support; their relationship is one of equality. Peer support is used to refer to initiatives where colleagues, members of self-help organizations, and others meet, in person or online, as equals to give each other connection and support on a reciprocal basis. Trained peer support workers such as peer support specialists and peer counsellors receive special training, like clinical staff. The social peer support also offers an online system of distributed expertise, interactivity, social distance and control, which may promote disclosure of personal problems [10].

Peer social support increase the psychological well-being, self-esteem, self-efficacy, self-management of difficulties and social inclusion, engagement and social network, also indirectly influencing academic performance [11]. Peer support is based on the exchange of knowledge, experiences, emotional, social or practical support between persons who are in an equal position, with the aim of mutual assistance. Research on social support has consistently found that knowing about the available support from others is related to adaptive outcomes [12].

While numerous research studies and training programs focus on Horizontal/Peer Support, few delve into the intersection of psychological resilience and digital student networking. The training program "Step by Step: From Trainees to Trainers and Peer Supporters in the Student Peer-Support Network," stands as a pioneering initiative in this field.

This program is meticulously designed to empower students with the skills and knowledge necessary for providing peer support that enhances both psychological and digital resilience. By implementing a structured approach to peer support, the program aims to establish a sustainable network of student supporters capable of aiding their peers in navigating challenges within digital learning environments, especially during crises.

This innovative training model not only addresses immediate student needs but also lays the groundwork for fostering long-term resilience and well-being within educational communities. The program consists of the three sub-programs [13]: A (Psychological resilience, well-being, and support), B (Digital resilience and networking) and C (Horizontal psychological support in the digital network and ethical framework). This paper focuses on Program C, examining its structure and evaluation.

3. HORIZONTAL PSYCHOLOGICAL SUPPORT IN THE DIGITAL NETWORK - TRAINING PROGRAM C

The training program C, titled "Horizontal psychological support in the digital network and ethical framework" was designed with the objective of enhancing communicative skills of students and staff across three partner universities to provide successful support within the DigiPsyRes network. It was developed based on the scientific and educational expertise of university teachers – professionals in the field of communication sciences and psychology of the three partner universities.

The program aims at introducing participants to the key features of peer support, peer networking, and the ethical framework of non-professional psychological peer support, with a focus on the communication skills needed to participate in the peer support network.

Program C consists of five thematic units [13]:

1. Introduction of student support network and network behaviour;
2. Peer communication and supportive communication;
3. Non-professional psycho-social support and non-professional educational support;
4. Ethics and rules of non-professional support;
5. Connections with the portal - DigiPsyRes Network.

In-depth scenarios for each thematic unit are given in detail in the manual titled "Step by Step: From Trainees to Trainers and Supporters in the Network" [14] and they comprise thorough instructions of the program delivery, enriched by various original visuals and numerous interactive activities.

The training model applied in program C delivery is sequential, and consists of phases of experience, reflection, conceptualization and implementation. The delivery format is hybrid, encompassing online-remote and in-person sessions, both synchronous and asynchronous. The course is structured over a total duration of 14 hours, with 6 hours allocated to direct course instruction and 8 hours dedicated to preparatory activities and tasks conducted through the e-course platform. The program underwent an international pilot phase in January 2024, followed by refinements, culminating in its final delivery in national languages in April 2024 in a hybrid format. This international training initiative was concurrently conducted in three partner countries.

3.1. International piloting of the Program C

The international piloting (IP) of the training program C was implemented on January 12th, 2024 in four locations (Kragujevac, Čačak, Bydgoszcz, Foggia) across three countries, reflecting a collaborative effort of a team of DigiPsyRes expert team, with a goal to deliver a comprehensive training that addresses the diverse needs and perspectives of participants. The piloting was conducted in the English language, and all the learning/teaching materials were prepared in English. In the international piloting phase, a total of 81 trainees participated, including students and staff from the three partner universities collaborating within the DigiPsyRes project. Of these, a cohort of 42 participants successfully completed the international pilot program C [15]. The international piloting of all 3 programs, per rule, served as a rigorous control procedure aimed at providing formative assessment and fostering program improvement.

3.2. Implementation of the national program C at the University of Kragujevac

Simultaneously with other partner universities, the national program (NP) C was implemented at the University of Kragujevac in April 2024. The training was implemented in the Serbian language, at two locations: one in Kragujevac for local students and staff, and another in Čačak for participants from that area. The program involved students aiming to become peer supporters alongside their trainers, engaging in an intensive, interactive, cooperative, and collaborative workshop. A total of 37 participants enrolled in the e-courses for program C, with 31 taking part in the training sessions (14 in Čačak, and 17 in Kragujevac).

Phases of the training process included:

- Selection of trainees;
- Enrolment of participants into the Moodle e-learning system;
- Pre-training activities, including lessons, readings, and tasks to be completed within the e-course starting from March 25, 2024;
- Implementation of the training: April 2, 2024, at the Rectorate of the University of Kragujevac and April 4, 2024, at the Faculty of Technical Sciences in Čačak;
- Post-training activities focused on comprehension tasks, testing, and training evaluation, to be finalized by April 17, 2024.

The learning experience during the program C was enriched by pre-recorded lectures and a live presentation of the project portal, supported by appropriate PowerPoint presentations and videos created using the Veedio app. Participants in both IP and NP demonstrated high engagement and interaction, actively participating in discussions, role-playing exercises, and interactive demonstrations.

4. RESEARCH METHODOLOGY

The evaluation and assessment of the Program C training within the framework of the DigiPsyRes project are pivotal to understanding its effectiveness in preparing participants as peer supporters. The evaluation was conducted using a blend of quantitative and qualitative methods. Three distinct types of evaluation instruments were employed during both the piloting phase and the final training phase:

1. Knowledge Assessment in Program C: After completing the initial activities in the e-course and the training implementation, a knowledge assessment was conducted among the trainees. The summative evaluation of participant achievement at the end of the training and e-courses includes three achievement e-tests (knowledge tests), one for each program separately. These tests are part of the post-training e-course at the Moodle Platform. "Test C" comprises 30 closed-answer items. Participants were allowed a maximum of 3 attempts, with a mandatory break period of 12 hours between the attempts (example Fig.1);
2. Evaluation questionnaire: This evaluation instrument for Program C was implemented after the entire Program C had been delivered, following the training and completion of activities in the e-courses. It was conducted through a questionnaire in the Post-training e-course on Moodle LMS (all items presented in Table 2);

Figure 1. *Item from an online knowledge assessment, program C*

3. Qualitative Evaluation: Immediately following the training program C, participants engaged in an online evaluation using Mentimeter, an interactive online app. The trainees were prompted to summarize their impressions of the training in five key words, providing valuable feedback on their overall experience and personal benefits gained from the program (Figure 2).

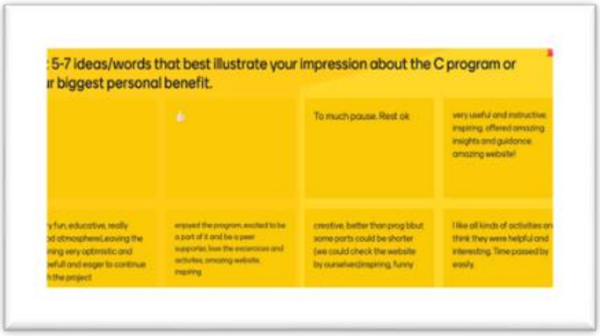

Figure 2. *Mentimeter evaluation example*

5. RESULTS

5.1. Knowledge Assessment in program C

After the international piloting was completed, a total of 42 participants accessed to the knowledge assessment "Test C" and all of them passed the test (Fig. 3). The score 50% and above was considered "pass" (the grade range was 5.00 - 10.00). Overall the participants achieved M=8.65 on the Test C. Based on the participants' achievements on the knowledge tests and high results, it can be concluded that the realized program (e-courses and training programs altogether) enabled learning of the basic and relevant knowledge about the topics of the program C.

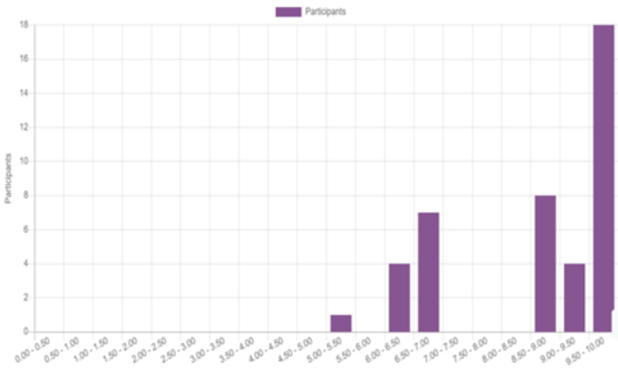

Figure 3. *Test C results at the International pilot*

The national implementation of Program C at the University of Kragujevac saw participation from 31 individuals. Similarly, every participant passed the test, achieving an average grade of M=8.66, with the lowest grade being 6.05 (Fig. 4). These results indicate that the participants' achievements were notably high, demonstrating a strong grasp of the fundamental concepts of Program C.

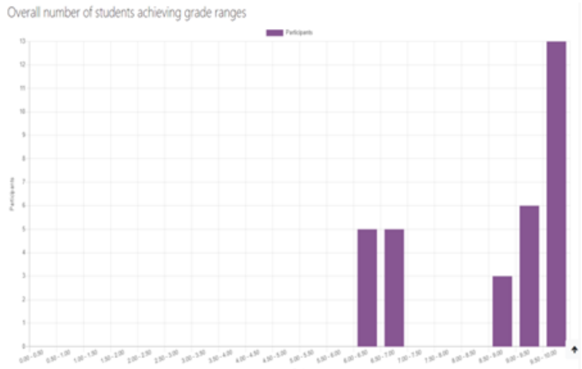

Figure 4. *Test C results at the national program implementation*

5.2. Evaluation questionnaire

Following the international pilot and national implementation, the same evaluation questionnaire was administered to participants to assess the overall success of Program C. The results of the questionnaire are presented in Table 1. When it comes to the international pilot, the findings indicate that it was successful. Participants provided evaluations ranging from 1.23 to 5.00 for the entire program, with an average score of 4.29, indicating a very high level of satisfaction. The standard deviation of 0.95 suggests some variability among participants (some differences in individual assessment), implying a relatively high level of evaluation homogeneity. As for the national implementation of program C, the lowest grade was 3.15, and the mean value 4.75. Comparison of these values confirm that the assessment values were higher in the national implementation, with the standard deviation value significantly lower, which adds to the overall consistency of evaluation.

Table 1. *Participants overall evaluation of program C: international pilot (IP) and national implementation (NP)*

Graphics	Min	Max	Mean	St. Dev.
Evaluation of C program IP	1.23	5.00	4.29	.95
Evaluation of C program NP	3.15	5.00	4.75	.42

Min – the smallest average value (Participant score / N of items

Max – the highest average value (Participant score / N of items

Mean – average value (Sum of participants scores / N of items / N of participants

Table 2 provides a comparative evaluation of IP and NP. The evaluation covers various aspects of the program, highlighting the participants' perceptions and satisfaction levels across different dimensions.

The evaluation was conducted using a set of questions (Q01-Q13) focusing on content integration, usefulness of lessons, design and realism of tasks, dynamic nature of workshops, coordination and encouragement from trainers, satisfaction with idea exchange, quality of lessons, understanding of the support network's significance, familiarization with key roles, improvement in expected behaviour and communication guidelines, skill development, active participation opportunities, and identification of available resources. The overall evaluation shows that the national implementation consistently received higher mean scores compared to the international pilot across all items.

Table 1. *Comparison evaluation of the international pilot program C (IP) and national implementation of C program (NP)*

Items	IP Mean	NP Mean	F	sig.
Q01. The content and activities of the C e-course and C training are seamlessly integrated and harmonized.	4.40	4.84	5.843*	.018
Q02. Lessons in the C e-course are useful for the C program outcomes.	4.29	4.88	10.297**	.002
Q03. The tasks in e-course C were well-designed and realistic.	4.34	4.75	3.925	.052
Q04. The workshops in the C training were dynamic and well-designed.	4.34	4.75	3.761	.057
Q05. The leading trainer from C training and facilitator/trainer in my group coordinated activities and encouraged the work of the group.	4.54	4.78	1.920	.171
Q06. I am satisfied with the exchange of ideas in C training in remote online mode between six university groups.	4.11	4.78	8.786**	.004
Q07. Evaluate the quality of the lessons in e-course C with the grade (from 1 – very poor to 5 – excellent).	4.20	4.77	6.666**	.012
Q08. The C program contributed to my better understanding of the purpose and significance of the student support network within the three higher education institutions.	4.46	4.78	2.842	.097
Q09. The C program contributed to familiarizing myself with the key roles and responsibilities of individuals involved in the network.	4.26	4.75	5.207*	.026
QC10. The C program contributed to improving my insight into the expected behaviour and communication guidelines when interacting within the student network.	4.20	4.66	4.126*	.046
Q11. The C program contributed to developing the skills necessary to contribute positively to the network's collaborative and supportive environment.	4.29	4.66	2.849	.096
Q12. The C program contributed to exploring opportunities for active participation and engagement in the network's activities.	4.17	4.75	6.168*	.016
Q13. The C program contributed to identifying available resources and support systems within the network for addressing student needs and challenges effectively.	4.17	4.59	3.418	.069
Evaluation of program C	4.29	4.75		

Mean – average value (Sum of participants scores / N of items / N of participants)

F – Fisher coefficient. $^{**}p<0.01$; $^{*}p<0.05$

The integration and harmonization of content and activities were rated highly, both with means of 4.40 for IP and 4.84 for NP, showcasing a seamless integration in the national context. The usefulness of lessons for achieving program outcomes also saw significant improvement, with the national implementation scoring 4.88 compared to 4.29 in the international pilot, reflecting better alignment with program goals.

Tasks in NP were perceived as better designed and more realistic. Similarly, workshops were rated as more dynamic and better designed in NP.

Coordination by trainers and facilitators, while only slightly higher in the national program compared to the pilot program, still points to better perceived support and guidance in the national context. Participants in the national program also experienced more effective communication and clearer understanding of their roles and responsibilities within the student support network.

In terms of behavioural and communication guidelines, the NP program provided more comprehensive training, resulting in higher participant ratings. Skill development and engagement opportunities were also more favourably rated, indicating that the national implementation offers better strategies for building necessary skills and encouraging active participation.

Resource identification and overall program evaluation further underscore the advantages of the national program, with participants rating it higher than the piloting program. These findings highlight the importance of contextual and cultural factors in educational program design and implementation. They demonstrate that tailoring training to specific national contexts can significantly enhance the effectiveness of peer support networks, resulting in higher participant satisfaction and better learning outcomes.

5.3. Qualitative Evaluation

More specific evaluation of the pilot program, including participant feedback surveys, was done immediately at the end of training with the aim to provide inputs for improvements of the pilot program and help modify the areas in which weaknesses have been detected.

The evaluation was conducted using the Mentimeter online app. Participants were asked to list 5 to 7 ideas/words that best illustrated their impression about the program or personal benefits they experienced. Responses were collected by a pre-designed QR code generated to be scanned immediately after the training. This qualitative approach aimed to capture immediate feedback to provide insights into the program's strengths, weaknesses, and areas for improvement.

Key Findings of the Mentimeter evaluation yielded valuable insights into participants' perceptions of Training Program C. A total of 44 responses was collected. Two responses were brief, simply indicating "GOOD JOB," while 42 responses provided detailed explanations. Responses were analysed by the method of thematic analysis and then grouped into positive and negative impressions and additional remarks, which were all then further dissected (Table 3).

Table 3. *Thematic analysis results*

Positive impressions		Negative impressions	
No.	*comment*	*No.*	*comment*
14	fun/interesting	2	short breaks
10	learned a lot/ improved skills	1	website presentation unnecessary
7	great/amazing website/portal	1	long pauses
7	useful/instructive	1	too much information
6	inspiring/optimistic		
5	educative/ informative		
5	boundaries/ethics/listening/nonverbal topic		
5	engaging role-plays		
4	Interaction/connection with other groups/collaboration within the group		

The overwhelming majority of positive feedback reflects the effectiveness and success of training program C in meeting its objectives and providing a valuable learning experience for participants. The high number of responses in categories such as "Fun/Interesting," "Learned a Lot/Improved Skills," and "Great/Amazing Website/Portal" suggests that participants found the program engaging, informative, and user-friendly. The emphasis on practical relevance, inspirational content, and opportunities for interaction and collaboration further underscores the program's positive impact on participants' learning and personal development. Overall, these positive comments highlight the strengths of the program in delivering engaging, informative, and impactful training experiences.

While the majority of feedback was positive, a few participants expressed dissatisfaction with the duration or frequency of breaks during the training sessions. Also, one participant noted that the website presentation was unnecessary, suggesting a potential mismatch between their preferred learning format and the program delivery method and another participant expressed feeling overwhelmed by the volume of information presented during the program.

The discussion that followed also provided some recommendations for future program delivery. Participants expressed a desire for more discussion time and suggested the inclusion of additional crisis scenarios beyond COVID-19 to diversify the content and maintain engagement. They also proposed that trainees should explore the portal independently, either in pairs or small groups, fostering a more hands-on and interactive learning experience. Important feedback highlighted the need to adjust break durations and frequency to better accommodate participant comfort and attention span. For the national training that followed, special attention was given to these aspects.

By incorporating participants' suggestions for improvement, the national training of Program C aimed to further enhance participant satisfaction, engagement, and learning outcomes. Following NP, Mentimeter feedback revealed an array of positive sentiments among participants, to mention just a few ("amazing", "stimulating discussions," "enriching learning experiences," "captivating role-plays," "user-friendly interface"). As shown above, improved results in the quantitative analysis highlighted increased participant satisfaction and perceived effectiveness of the program's content and delivery, attesting to the program's adaptability and its alignment with participants' language and cultural contexts.

6. CONCLUSION

The study focused on the implementation and evaluation of Program C, the third and final part of the training program "Step by Step from Trainees to Trainers and Peer-Supporters in the Student Peer-Support Network," developed within "Enhancing Digital and Psychological Resilience through Peer Networking in the Online Environment in Times of Crisis – DigiPsyRes" project. This program was initially conducted as an international pilot and subsequently implemented in national languages at the three partner universities.

Evaluation methods included qualitative feedback and quantitative analysis, both of which yielded very high overall ratings for both the International Pilot and National Program. National implementation of C program demonstrated superior results in participant satisfaction and program effectiveness.

The comparative evaluation reveals that the national context generally enhances program effectiveness and participant satisfaction. The national program consistently outperformed the international pilot program across several key areas, including integration, lesson usefulness, task realism, workshop dynamism, and online collaboration. This trend suggests that localized adaptations of educational programs are more successful in meeting specific needs and preferences of participants.

These findings underscore the critical role of localized adaptations tailored to the cultural and contextual specifics of participants in optimizing educational program outcomes. The success of the national program exemplifies how such adaptations can significantly enhance participant engagement and enrich learning experiences.

It is necessary to emphasize some of the basic limitations of this study that should be eliminated or reduced in some future research. Firstly, the sample size should be larger to allow for generalizations. Additionally, the language of the training is an important variable, as well as differences in cultural context, both of which could influence the implementation of such programs.

Looking forward, future studies could explore the longitudinal impacts of peer networking programs on student resilience and academic performance, offering deeper insights into their lasting effects. Additionally, investigating the scalability of localized educational programs across diverse cultural contexts would be invaluable for developing sustainable and adaptable educational interventions.

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Factorial Structure of Knowledge and Risky Behavior of Information System Users Among Adolescents

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Abstract: *The aim of this research was to examine the latent structure of knowledge and risky behavior of the information system users and self-reports of risky and delinquent behavior. Empirical research was conducted on a pertinent sample of adolescent students ($N = 120$; $M_{age} = 88.34$, $SD = 0.52$). Two measuring instruments were applied: Users' Information Security Awareness Questionnaire and Self-reported delinquency and risky behaviors questionnaire. The calculated alpha coefficients of internal consistency are satisfactory, which indicates satisfactory psychometric characteristics – the validity and reliability of the used measuring instruments and their optimal application to the Serbian adolescent population. Correlation analysis revealed statistically significant low interactions between manifest variables risky and delinquent behavior and risky behavior of computer users ($p \leq 0.01$). Exploratory factor analysis using the method of principal components, oblique rotation according to the Guttman-Kaiser criterion in the UZPK questionnaire, with 65.16% of the variance, identified three factors interpreted as: (1) habitual risky behaviors of computer users, (2) maintaining personal computer systems, and (3) receiving access data. Also, on the SRDP scale, with 62.10% variability, a three-dimensional structure was defined: (1) degree of computer communication security, (2) beliefs about security of computer data and (3) importance of properly storing computer data. The results of the isolated latent dimensions on knowledge and risk exposure of IT system users and knowledge on IT security of adolescents are discussed from a theoretical aspect and implications for research practice.*

Keywords: *high school seniors, factors, information system, information security, communication technology*

1. INTRODUCTION

The Internet, with its public information and communication network and advanced digital technology, represents a relevant resource in all areas of human life, which is why recently there has been a great need to study security and protection mechanisms. The trend of development of today's IT society is characterized by personalization, which enables creators of new applications to provide a more complete service adapted to each individual end user. However, personalization, in addition to better service, requires the user to provide a large amount of personal data, which can lead to violation of privacy. Therefore, it is necessary to protect personal data in order to reduce the risk of misuse of user information. The current ubiquity of the Internet in everyday life has caused the imaginary world to become an objective part of the real world of human life.

The last decade of the 21st century of the modern information society is characterized by an increase in the misuse of the Internet – tricking and persuading users to reveal some of their personal data or do something unwittingly [1]). Hence, social engineering in Internet scams is aimed at the gullible user, who can become tricked. Initial reveal of a minimal segment of personal data or copying of a program into the computer's permanent memory and its implementation, and copying an additional set of commands, e.g. for home cinema, can generate financial loss or loss of privacy. Accepting of new applications, online shopping, digital public administration, electronic health system, and other services have reduced the IT security of users, which will probably never be completely secure [2]. Due to the increase in new services, possible security risks also increase, whereby users of information and communication systems and services are careless and unaware of current dangers [3]. Due to unfortunate circumstances, their ignorance of the digital market does not generate the expected caution, but without realizing the possible risks, they very often accept and start using new services.

In order to ensure information security, the data confidentiality should be protected, which is achieved by applying the prescribed standards of information security – communication channels and data control [4]. Physical and software protection are at a high level today, but the influence of users on security, despite being great, was only recognized in the second decade of the 21st century, and the solutions of control and user education are just at the beginning. The author's research [5] showed that the user has a relevant influence on the security of the IT system, which should be taken into account when developing new security solutions. Current security solutions according to the authors [6] can be classified in several domains: (a) development of the concept of trust on the Internet, (b) creation of analysis models (c) recording (d) prediction of user behavior, (e) user education and (f) raising awareness of privacy issues. The basis of future solutions should be the development of a certain level of mistrust of users of various information systems and the Internet towards the unknown – accepted standards of behavior from the real world, such as locking the house door and mistrusting strangers, which should be applied to the potential digital world. In the study [7], it was emphasized that a person as a user of an information system is its most unstable security component. In addition, it was pointed out that there is no valid method that examines the risk of a person's behavior during the violation of the security of the information system, as well as his knowledge and awareness of possible security difficulties.

Thus, previous empirical studies draw attention to the fact that the structure of knowledge and risky behavior of adolescents when using information systems is a relevant, but insufficiently clarified question of theory and practice, especially in our environment. Therefore, based on the formulated problem, the main aim of this transversal research was twofold: a) to examine on the Serbian adolescent population the structure of the construct of knowledge and risky behavior of adolescents when using the IT system and b) to check the metric characteristics of the applied measuring instruments UZPK and SRDP. In accordance with the theoretical assumptions, the results of previous studies and the aim of the research, two *alternative hypotheses* (H_1) were formulated – It is assumed that the test battery of the used measuring instruments UZPK and SRDP in adolescents will have satisfactory metric characteristics, and (H_2) – It is expected that the method of principal components analysis from the set of manifest variables UZPK and SRDP will identify latent three-factor structures.

2. RESEARCH METHODS

Participants and procedure

This transversal research was conducted on a pertinent sample of high school seniors (N = 180) Economics School (n = 79), Technical School (n = 81) and Agricultural School (n = 80) from the city of Valjevo. The average age of the participants was (M_{years} = 18.36, SD = .51). The existence of multivariate outliers was not registered ($\chi2$ (7) ≥ 19.10, p ≤ .01) [8].

The testing was voluntary and anonymous. The data were collected in groups during classes in schools, while filling out the questionnaire took approximately 30 minutes. Before conducting the research, the opinion of the Scientific Council of the Serbian Academy of Innovation Sciences from Belgrade, based on the Declaration of Helsinki, was obtained. The research was carried out in May 2024.

Users' Information Security Awareness Questionnaire – UZPK [9].

The UZPK includes 37 items, whereby the first 20 statements examine common risky behaviors of users of computer information systems, while the remaining 17 items, which are divided into two subscales, measure knowledge, i.e. awareness of IT security. Participants have the task of selecting the answer on a five-point Likert-type scale. The score for each subscale is based on the arithmetic mean of certain items from 1 (*completely safe behavior of computer users*) to 5 (*high risk behavior when using computers*). A higher score indicates riskier behavior when using computers. The definitive version of the first part of the questionnaire contains 17 statements that are distributed in three subscales: the first (k = 6) examines various risky behaviors, the second subscale (k = 6) measures the maintenance of personal computer systems, while the third subscale (k = 5) examines adaptation access data. The second part of the questionnaire refers to knowledge about information security, and it also includes three subscales: the first examines the assessment of the level of information security of users (k = 5), the second measures the level of users' beliefs about security of computer data (k = 5), and the third subscale assesses the degree of importance proper storage of computer data (k = 6). Internal consistenvcy for the entire UZPK questionnaire in this research was tested using Cronbach's α coefficient. Cronbach's Alpha is satisfactory and is (α = .77).

Self-reported delinquency and risky behaviors questionnaire – SRDP [10].

The SRDP includes 42 items that describe factors on seven subscales: 1) Misdemeanor and minor delinquent behaviors (k=11); 2) Undesirable normative behaviors (k = 7); 3) Risky sexual behaviors (k = 4); 4) Use or abuse of psychoactive substances (k = 6); 5) Violent behavior in close relationships (k = 5); 6) Serious theft, burglary and robbery (k = 6); and 7) Suicidal behaviors and auto-aggression (k=3). The results on individual subscales are defined as the sum of the products of individual behaviors (never, 1 - 2 times, 3 - 5 times and more than 5 times) and the associated weight indices (1 - 9) on all statements within the individual subscale. A higher score suggests more risky and delinquent behavior. In this research, 20 items were selected from the first four subscales that had weaker indices of difficulty, i.e. behaviors that are of a lower level of risk and are more often present in the adolescent population. Based on the results on the selected items, a total score and the arithmetic mean of the selected statements were formed, as a measure of milder forms of risky and delinquent behavior. A higher score emphasizes a higher degree of risky behavior and delinquency. The reliability (Cronbach α) of the SRDP was defined by the method of internal consistency. It is satisfactory because it was (α = 0.75) for the entire questionnaire.

Statistical data processing

Descriptive statistics were used to calculate variable values, distributions to check the normality of variable distributions, Pearson linear correlation coefficient (*r*) to determine the linear connection between variables, while exploratory factor analysis - the method of principal components analysis (PCA), with the Kaiser-Guttman criterion (KK) and the given *Promax* factor rotation was used to check the factor structure of latent dimensions (factors) of measuring instruments. The collected data were processed in the statistical package for social sciences program, SPSS 21 (Statistical Package for the Social Sciences). Complete statistical analysis was performed at the level of significance ($p \leq .01$ or $p \leq .05$).

3. RESULTS

Table 1 shows the basic descriptive statistical data and the variables included in this research.

The results of the skewness and kurtosis coefficients are within the limits of the allowed values, between +/- 1 [11]. This indicates that there are no statistically significant variations of the score distribution from the Gaussian (normal) probability curve, which allows the application of parametric statistics.

Before applying factor analysis, the suitability of the correlation matrix for factorization was tested using the Kaiser–Meyer–Olkin sampling adequacy index (KMO). The calculated KMO exceeded the critical value of .78, which indicates the adequacy of the factor analysis. Also, Bartlett's test ($\chi2$ = 1304, df = 264, $p \leq .01$) was statistically significant, which shows the absence of multicollinearity, confirming that the items are interrelated and that factor analysis is appropriate [12].

Table 1. *Descriptive parameters and measures of skewness and kurtosis*

Subscale	Item	M	SD	Range	Sk	Ku
Sharing access data	PP1	1.82	*.90*	*3-3*	*-.58*	*-.09*
	PP2	1.30	.58	3-3	-.84	.38
	PP3	1.09	.39	2-3	.03	-.59
	PP4	1.20	.50	3-3	-.O5	.94
	PP5	1.05	.38	3-3	-.37	-.43
Maintenance of personal computer systems	OS6	2.01	1.49	3-4	.43	-.19
	OS7	1.73	1.33	3-4	.85	.48
	OS8	1.29	1.22	3-4	-56	.03
	OS15	1.77	1.70	3-4	-.63	.01
	OS17	2.98	1.29	3-4	-57	.15
	OS18	1.27	1.26	3-4	.26	.35
Everyday risky behaviors of computer users	RP9	1.60	.80	3-3	-.58	-.14
	RP11	1.22	.52	3-3	-.80	.37
	RP12	1.13	.28	2-3	.03	.60
	RP13	1.19	.39	3-3	-.08	.95
	RP14	1,54	.66	3-3	-.40	-.20
	RP16	1.99	1.18	3-3	.46	.47
Degree of computer communication security	SS1	2.66	2.99	3-4	.85	.06
	SS2	1.96	.88	3-4	-.57	-.03
	SS3	2.74	1.08	3-4	-.63	-.17
	SS4	2.69	1.22	3-4	-.58	.33
	SS5	2,31	.89	3-4	.16	-.14
Beliefs about security of computer data	US1	1.20	2.99	4-5	-.56	.45
	US2	.88	.88	4-5	-.83	.63
	US3	1.10	.94	4-5	.02	.97
	US4	1.05	1.12	4-5	.04	-.46
	US5	3.32	1.15	4-5	-.37	.23
The importance of properly storing computer data	VP1	2.08	.89	3-4	.41	.48
	VP2	3.03	1.02	3-4	.83	-.05
	VP3	3.19	1.05	3-4	-.57	-.02
	VP4	2.85	.99	3-4	-.64	-.17
	VP5	.97	1.01	3-4	-.58	.35
	VP6	.99	1.04	3-4	.15	-.12

Legend. M = arithmetic mean; SD = standard deviation; Sk = *Skewness*; *Ku = Kurtosis*.

In order to define the validity of the scale of risk behavior of computer users and the Information Security Knowledge Scale, a factor analysis was carried out according to the Kaiser-Guttman criterion –using the method of principal components analysis.

Table 2 shows the characteristic roots/ principal components of the Scale of Risky Behavior of Computer Users.

Table 2. *Characteristic roots of the correlation matrix and the percentage of explained variance of the extracted factors*

Principal components	λ	%V	K%V
1.	2.10	38.03	38.03
2.	1.88	18.71	56.74
3.	1.43	13.33	70.72
			Total: 70.72

Legend. λ = characteristic root or eigenvalue Lambda*;* %V – percentage of the explained variance*;* K%V – cumulative percentage of the explained variance.

The defined three characteristic roots or eigenvalue have significant cross-loadings, where they account for a total of 70.72% of the variance. The partial contribution in the prediction of the total variability in the correlation matrix is: for the first principal component 38.03 %, the second 18.71 % and the third principal component 13.33 % of the total variation. The obtained percentages are not uniform, and the first latent root stands out the most and maximally explains the variability of the analyzed items. In doing so, it is noted that the hierarchical first base eigenvalue Lambda with its five variables contains the maximum total variance, while the second and third main components include a smaller proportion of the residual variability. By inspecting the communality matrix algorithm, it can be seen that the three extracted latent roots are interpretable as they explain enough variation of the manifest variables, which indicates that they are reliable representatives of the object of measurement - latent dimensions of the Scale of Risky Behavior of Computer Users.

In Table 3, the component model of factor analysis with Promax rotation and the criterion of factor loading (λ ≥ .40), shows the communalities and reduced latent dimensions – projections of factor loadings of 17 manifest variables [13].

Table 3. *Communalities and projections of factor cross-standard loadings of manifest variables in the Users' Information Security Awareness Questionnaire*

Subscales			Standardized factor loadings		
	Items	h^2	F_I	F_{II}	F_{III}
Customization of access data	PP_1	.48		.60	
	PP_2	.78		.70	
	PP_3	.76		.78	
	PP_4	.73	.48	.62	
	PP_5	.60		.53	
Maintenance of personal computer systems	OS_6	.57	.70		
	OS_7	.77	.82		
	OS_8	.74	.79		
	$0S_{15}$	.72	.73		
	OS_{17}	.49	.61		
	OS_{18}	.69	.39		
Everyday risky behaviors of computer users	RP_9	.66	.46		.43
	RP_{11}	.47			.58
	RP_{12}	.58			.80
	RP_{13}	.70			.73
	RP_{14}	.46			.49
	RP_{16}	.59	-.42		.47

Annotations. Principal components /factors: F_I, F_{II} i F_{III}; h^2 = Communalities after extraction – the amount of variance of an individual variable explained by an individual factor. Standard loadings lower than .40 are not shown.

In accordance with the obtained communality values – the sum of squared factor loadings or the percentage of variance on the extracted factor, significant correlation coefficients and the criterion of factor standard loadings greater than 0.40 in [14], the analyzed items were transformed into three hierarchical main components – linear combinations of the original variables, which contain significant information. The values of the calculated communalities in the assembly matrix range between .42 – .80, which suggests that it is not necessary to omit any item based on criteria that would imply low communalities. The first main component in the assembly matrix, along with the largest segment of variation of the original variables, is hypothetically interpreted as a higher-order factor F_I – *Expected risky behaviors of computer users*. The second reduced main component, which is isolated based on the maximum projections of six manifest variables, is theoretically defined as F_{II} – *Maintenance of personal computer systems*. In conclusion, the last, third, isolated condensed principal component in the "factor" matrix, with statistically significant "weight" manifest variables projected onto the latent dimension, is identified as F_{III} – *Everyday risky behaviors of computer users*.

In general, the condensed three most relevant main components of the three-dimensional model represent interpretable factors of a higher order, which can contribute to the rational diagnosis of the three-dimensional model – different risky behaviors of computer users. Also, the extracted three-factor structure, with obtained communalities and factor loadings, shows satisfactory construct of validity, and can be used to measure the Promax factor on a sample of Serbian adolescents. However, considering the residual variability (specificity and measurement error) of 29.28%, further research and multivariate statistical analyzes of the extracted three-component model are necessary in order to empirically verify the stated assumptions about the coherence of this factor.

Table 4 shows percentages of variance and characteristic roots/principal components of the manifest variables regarding the knowledge about IT security.

Table 4. *Characteristic roots of the correlation matrix and the percentage of explained variance of the extracted factors of the Information Security Knowledge Scale*

Principal components	λ	%V	K%V
1.	2.02	29.41	29.41
2.	1.94	18.70	42.05
3.	1.66	18.30	51.08

Annotations. λ = characteristic root or eigenvalue Lambda*;* %V – percentage of the explained variance*;* K%V – cumulative percentage of the explained variance.

By inspecting the data matrix, it is noted that the factor analysis, based on the KK criteria, using the method of principal components, reduced 16 manifest variables into three characteristic roots (λ ≥ 1.00). They explain 51.08% of the total variability, with the first explaining 29.41% of the total variance, the second 18.70% and the third 18.30% of the total system variation. The communality matrix algorithm obtained indicates that the main extracted components are interpretable as they explain enough variation of the manifest variables.

In Table 5, the component model of factor analysis shows the condensed latent dimensions – standard factor loadings of 16 manifest variables of the Information Security Knowledge Scale.

Table 5. *Communalities and projections of factor cross-standard loadings of manifest variables in the Information Security Knowledge Scale*

Subscales			**Standardized factor loadings**		
	Items	h^2	F_I	F_{II}	F_{III}
Security of computer communication	SS_1	.56		.56	
	SS_2	.77		.68	
	SS_3	.60		.80	
	SS_4	.45	.47	.57	
	SS_5	.66		. 50	
Beliefs about security of computer data	US1	.82	66		
	US2	.73	.77		
	US3	.52	.84		
	US4	.43	.69		
	US5	.64	..57		
	OS_{18}	.88	.43		
Proper storage of computer data	VP1	.75	.49		. 49
	VP2R	.46			.62
	VP3	.85			.77
	VP4	.53			.56
	VP5	.72			.65
	VP6	.60	-.54		.45

Annotations. Principal components /factors: F_I, F_{II} i F_{III}; h^2 = Communalities after extraction – the amount of variance of an individual variable explained by an individual factor. Standard loadings lower than .40 are not shown.

The analysis of the assembly matrix shows that based on the obtained communality values, significant correlation coefficients and factor loadings of linear combinations of manifest variables, three hierarchical factors have been condensed, which include relevant information. The values of obtained communalities range between .43 and .85, which signals that it is not necessary to omit any item based on the criterion that implies low communalities. The first main component is theoretically, along with the largest segment of the variance of the manifest variables, defined as the higher-order Promax factor – *Security of computer communication* (F_I). The second, based on the maximum projections of six manifest variables, was interpreted as the Promax factor – *Beliefs about security of computer data* (F_{II}). Finally, the last, third main component was identified as the Promax factor – *Proper storage of computer data* (F_{III}). At the end of this review, it is concluded that the linear combinations of the main components (factors) of the three-dimensional model represent significant constructs in the diagnosis of "Information Security Knowledge". At the same time, the isolated three-factor structure, with the obtained communalities and factor loadings, signals the acceptable reliability of the used scale, which can be used to measure latent variables in the Serbian adolescent population. But, bearing in mind the remaining uninterpreted variance (specificity and measurement error) of 48.92% in the examined sample of adolescents, further empirical studies and multivariate statistical analyzes are needed to verify the tested hypothesis about the coherence of the extracted higher-order latent dimensions in the three-component model.

Table 6 shows the Pearson correlation coefficients between the latent dimensions of the risky behavior of computer users and the risky and delinquent behavior of adolescents.

Table 6. *Intercorrelations of the variables of the number of people who know the password and the frequency of renewing backups*

UZPK - SUBSCALES	**Risky and delinquent behavior**
Risky behaviors of computer users (RP)	.52**
Maintenance of personal computer systems (OS)	.19*
Sharing access data (PP)	.18*
Security of computer communication (SS)	.34**
Beliefs about security of computer data (US)	.10
The importance of properly storing computer data (VP)	-.05

**p* ≤. 05; ***p* ≤ .01.

Findings of moderate Pearson correlation coefficients between scores on subscales in the correlation data matrix demonstrate satisfactory criterion validity of the UZPK. The calculated correlation coefficients, although they range from .15 to .52, are statistically significant and directed in the expected positive direction, that is, they suggest the tendency of risky behavior, which is codependent with different viewpoints of risky behavior. The obtained correlations indicate that adolescents who are more prone to milder forms of risky and delinquent behavior also manifest a tendency towards everyday risky behaviors when using computers, not maintaining computer systems and sharing access data with other individuals. Also, a positive corelationship between mild risky and delinquent behavior and information security knowledge scale is observed. This means that young people who are more prone to milder risky and delinquent behavior believe that proper storage of computer data is not important to them.

Table 7 shows the interactions of the latent dimensions of the subscales of the UZPK and SRDP questionnaire.

Moderate intensity of the correlation of the measured constructs: second external criteria – self-assessment of the frequency and backup of security copies, as well as defining the number of people who know the user's computer password are expected. Defining a more frequent backup of security copies is interdependent with less risky behavior of the user's computer, with more efficient maintenance of computer systems and with less sharing of access data with other users, as well as greater importance of real computer data storage. Participants who more often use backup of security copies of personal data generally manifest less of all forms of risky behavior when using computers, and they more successfully understand the relevance of accurate supply of computer data. In addition, the opinion of the majority of participants who know the password interacts with the weaker maintenance of computer systems, with the determination of greater security of computer communication and with less importance of properly storing computer data. Adolescents who give their passwords to most people exhibit risky behaviors in the form of poor maintenance of computer systems and believe that Internet communication is safe and do not know how to properly backup and save computer data.

Table 7. *Intercorrelations of variables in the Users' Information Security Awareness Questionnaire with an estimate of the number of people who know the password and their more frequent sharing of user data with other users*

UZPK - SUBSCALES	Estimation of the frequency of renewing backups	Estimation of the number of people who know the password
Risky behaviors of computer users (RP)	-.35**	.10
Maintenance of personal computer systems (OS)	-.50**	.30**
Sharing access data (PP)	-.20*	-.28**
Security of computer communication (SS)	-.02	.19*
Beliefs about security of computer data (US)	-.09	05
The importance of properly storing computer data (VP)	-.43**	.18*

**p* ≤. 05; ***p* ≤ .01.

4. DISCUSSION

The goal of the research was to operationalize multidimensional hierarchical models of knowledge and risky and delinquent behavior of information system users on a Serbian adolescent sample using the UZPK and SRDP scales, the statistical program package for social sciences, SPSS 21, and define the metric characteristics of the instruments used in the research.

On the examined sample of adolescents, the reliability and convergent operational content validity of the variables of the Scale of Risky Behavior of Computer Users was checked by factor analysis, using the method of principal components with Promax rotation, whereby 70.72% of the total variance was explained by an extracted three-dimensional model of everyday risky behavior of computer users, maintenance of personal computer systems and receiving access data. Also, the factor structure of the Information Security Knowledge Scale was checked, where along with 51.08% of the total variability, its three-factor structure of higher-order factors was explained: the degree of security of computer communication, beliefs about the security of computer data and the importance of properly storing computer data. At the same time, the obtained acceptable coefficients of reliability of internal consistency for both scales reinforce the findings of the three-factor solutions of the factor analysis, as well as the confirmation of the first and second tested hypotheses (H_1 and H_2). At the same time, by testing the normality of the distributions of the Knowledge Questionnaire and the risk behavior of users of the information system and skewness and kurtosis coefficients, it was determined that the distributions do not deviate statistically from the Gaussian/theoretical probability curve. Such distribution of findings is expected because it is assumed that most adolescents know the basic rules of computer use.

The authors [15] emphasize that the assessment of each participant consists of valid variance, specific variance and error in measurement. Valid variance represents common variability, while specific variance has two fundamental generators: a different pattern of behavior on the basis of which each participant forms his attitude, and a tendency to express himself as favorably as possible. The obtained low values of the Pearson correlation coefficients in our sample between the variables of the Users' Information Security Awareness Questionnaire and Self-reported delinquency and risky behaviors questionnaire indicate that the specificities in the participants' judgments are considerable.

The good validity of the used measuring instrument UZPK and the independence of isolated higher-order factors are confirmed by low statistically significant correlations in the correlation matrix, ranging from 15 to .50, between the assessments of the measured constructs: risky behavior of computer users and risky and delinquent behavior of young people. Bearing in mind the fact that an identical problem has not yet been examined of a Serbian sample, the expectation is basically based on the tendency of risky behavior, which is codependent with the differentiated aspects of risky behavior of computer users. This suggests that adolescents who are more prone to milder forms of risky and delinquent behavior manifest everyday risky behaviors when using computers, they do not maintain computer systems and share access data with other individuals, which may also represent the current lifestyle of the adolescent population. In our sample, at the same time, a positive correlation was obtained between milder risky and delinquent behavior and the subscale of information security knowledge scale. Therefore, adolescents who assess that they are more prone to milder risky and delinquent behavior estimate that realistic backing up of computer data is not important to them. The relationship with other external measures (self-defining the frequency of renewing security copies and determining the number of adolescents who know the user's computer password) is also intuitive. Deciding on more frequent backing up of security copies interacts with less risky behavior of computer users, with more efficient maintenance of computer systems and with less sharing of access data with other users, as well as with greater importance of accurate computer data storage. Adolescents who back up security copies of individual data more often signal generally less of all forms of risky behavior when using computers, and also better understand the relevance of accurate storage of computer data. At the same time, the determining of a greater number of individuals who know the password is correlated with poorer maintenance of computer systems, with the opinion of greater security of computer communication and with less importance of actual storage of computer data. Adolescents who share their password with a large number of people manifest risky behaviors in the form of poor maintenance of computer systems, where they believe that Internet communication is safe, and do not know exactly how to back up and save computer data [16, 17, 18].

Keeping in mind the results obtained by factor analysis and the high reliability of the UZPK and SRDP scales, we can treat them as a unique instrument for measuring three-dimensional attitudinal constructs at a higher conceptual level, which are unambiguously valid and easily applicable instruments for adolescents.

The implemented procedure of defining the theoretical and practical validity of isolated three-factor models of knowledge and risky behavior of information system users suggests that they have acceptable metric characteristics. However, it can be recommended that the measurement procedure of UZPK and SRDP be confirmed on a larger number of different adolescent categories for their practical use. To this end, it is necessary to plan and define standards for Serbian adolescents so that researchers could more effectively compare different levels of risky behavior of computer users in order to organize additional education and improvement in the field of security of working with computer data in different stages in adolescence. Also, additional testing of the factor structure of the measured constructs is necessary to confirm the division of the Questionnaires into hypothetical scales and subscales. In addition, it is desirable to test the linear correlation of UZPK with some other tested and valid external procedures, e.g. realistic addition of individual data or violation of security measures during classes and free time of adolescents, as well as application of the Questionnaire in other speech areas, which would significantly increase its relevance and usability. [19, 20]. The general conclusion of the review of all previous research can be the identification of the latent structure of perceived knowledge and risky behavior of information system users and risky and delinquent behavior in adolescents, which enables a more intense influence of organizational psychology in this increasingly open and massive area of human work.

However, before reaching a conclusion, the research results should be considered in the context of certain methodological limitations. First, the research is based on self-perceptions of knowledge and risky behavior of information system users and risky and delinquent behavior [21]. Therefore, due to the real danger of not to getting a full insight into the attitude of the participants because of the subjective assessment of the participant, alternative methods of measurement should be analyzed using the objective assessments by other people (e.g. teachers, parents, etc.). Also, the study was conducted on a pertinent sample of adolescents, so the results cannot be generalized with complete reliability to various subpopulations with a larger number of adolescents of both sexes. With all of the above in mind, future research should define the measurement characteristics of the UZPK and SRDP in the entire territory of Serbia, with the addition of more items for the existing subscales, which would enable the assessment of the validity of individual subscales in heterogeneous age categories of participants of the adolescent sampled population.

5. CONCLUSION

Taking into account the fact that the perceived knowledge of adolescents about information security and the risky behavior of users of the information system and risky and delinquent behavior are the subject of numerous theoretical and empirical researches in the world, in this empirical study the metric characteristics of the UZPK and SRDP instruments and their three-factor factor structure were determined, which confirmed the tested hypotheses H_1 and H_2. In general, the applied measuring instruments proved to be reliable and valid. Using the principal component analysis method, based on the subscale items in the matrices of the Serbian sample, six higher-order factors were obtained: (a) "Habitual risk behaviors of computer users", (b) "Maintenance of personal computer systems", (c) "Receiving access data", (d) "Degree of computer communication security", (e) "Beliefs about security of computer data", and (f) "The importance of properly storing computer data", are consistent with earlier findings of foreign authors. The paper also presents the limitations of the research, the contribution of the research results and instructions for future research. Our sample is pertinent and limited to the school adolescent population (excluding other levels of education), and it would not be correct to generalize the results to other populations of participants. The research is transversal, and given that informatics is a very dynamic science, there is a possibility that the items or some of the analyzed items will be meaningless in the very near future.

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Biological Framework of Psychological Resilience: Literature Review

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Abstract: *Resilience, as a multi-dimensional psychological construct, is considered in the context of mental health. Many authors understand resilience as a psychobiological phenomenon which determines an individual's response to adverse life events or stress. The connection between psychological resilience and stress as a bio-psycho-social reaction is the topic of numerous empirical research studies and theoretical analyses. This paper focuses on the biological components and framework of psychological resilience. Based on the internet search in general research open access repositories (Google Scholar, DOAJ) and specialized repositories (MEDLINE and PSYCHINFO), the interest of the research community to investigate connections between biological factors and psychological resilience is confirmed. The following biological factors and components, which are most frequently considered and connected with psychological resilience, are: multiple phenotypic levels including stress response systems, neural circuitry function, and immune responses, in interaction with genetic factors; neurogenesis in the hippocampus or reactive up-regulation of ion channels in ventral tegmental area (involved in resilience against stressful conditions); temporal axis; genes encoding serotonin transfer; etc. By choosing specific terms as internet search filters, only a few papers were selected. The factors that form the biological framework of psychological resilience are systematized. An overview of the interventions likely to promote resilience and resilient brain function is included. The main conclusion emphasizes the importance of a holistic approach to psychological resilience as a construct supported by and affecting the social dimension as well as the biological dimension of personal functioning.*

Keywords: *psychological resilience; stress; biology of resilience.*

1. INTRODUCTION

Resilience is a positive psychological adaptation to changes and challenges. It is a multi-dimensional construct. And, it is both a capacity and an active process encompassing a person's flexibility in response to changing situational demands and the ability to bounce back from negative emotional experiences [1]. In the Oxford Advanced American Dictionary online the word 'resilience' is defined both as "the ability of people or things to feel better quickly after something unpleasant, such as shock, injury, etc." and "the ability of a substance to return to its original shape after it has been bent, stretched, or pressed" [2]. The psychological community understands resilience as a psycho-socio-biological phenomenon which determines an individual's response to adverse life events or stress.

The popularity of the concept of resilience in recent years is based on shifting the cultural focus on positive outcomes [3]. Psychological resilience is a topic of research in many sciences and scientific disciplines: different disciplines of psychology, biology and neurobiology, neurophy-siology, neuroscience, cognitive neuroscience, medical sciences, etc. Some of the authors used the construct neuropsychobiology of resilience [4]. A holistic approach to resilience science must include a neurobiological perspective [3]. Current scientific approach and technological tools and means are enabling a "true biopsychosocial approach to the study of resilience in humans" [5]. The research into the neuroscience of resilience is relatively new [6, 7].

However, in this paper, we consider the basic topic of resilience from the standpoint of positive psychological approaches and look for biological frameworks of established, manifested, and strengthened psychological resilience.

1.1. Psychological Resilience

According to the American Psychological Association, "resilience is the process and outcome of successfully adapting to difficult or challenging life experiences, especially through mental, emotional, and behavioral flexibility and adjustment to external and internal demands"[8].

Psychological resilience can be considered from two perspectives [1]:

- Resilience is the **process** of successfully adapting to difficult or challenging life experiences.
- Resilience is an **outcome** of successfully adapting to difficult or challenging life experiences.

Two crucial conditions for consideration some behaviour as resilient are: "(1) exposure to significant threat or severe adversity; and (2) the achievement of positive adaptation despite major assaults on the developmental process" [9].

Researchers have identified three related uses of the term resilience [1, 6, 10]:

1) Recovery is a form of resilience which refers to the return to a normal, pre-stressor level of functioning (health and psychosocial wellbeing).
2) Resistance is a form of resilience which occurs when a person displays minimum or no signs of disturbance (low distress, normal functioning) following a challenging event.
3) Reconfiguration (or redirecting) is a form of resilience which occurs when a person returns to homeostasis in a different formation with key aspects of that individual changing as a result of their experience.

Some of the indicators of a resilient person are the following [1, 11, 12, 13, 14, 15]: able to show positive adaptation in the face of adversity; able to rebound; able to function despite prolonged exposure to stressors and disadvantages; flexible; able to make and maintain supportive relationships; reflective; has problem-solving skills; able to plan; seeks to help; able to act independently; has goals; persistent; takes risks; optimistic; able to regulate his or her emotions and interact more effectively in social environments; has a higher sense of control and internal locus of control; the ability to withstand or recover quickly from difficult conditions. Resilience emerges through complex interactions of internal and external factors.

1.2. Resilience and Stress

The connection between psychological resilience and stress as a bio-psycho-social reaction is the topic of numerous empirical research studies and theoretical analyses. Resilience is analyzed as the outcome of successful stress adaptation [4]. Resilient individuals are changed by their own experiences. Consideration of resilience in relation to allostasis (adaptation through change) [6] or allostatic state (allostatic state is reflected by the adjustment or maintenance of physiological and behavioral systems in order to adapt to challenging or stressful situations) [16] and in relation to vulnerability are current topics as well.

Sometimes, the researchers use the words stress and resilience as one concept "stress resilience". The ability to manage own stress effectively enables the impact of stressors to develop resilience.

The effects of eustress and distress, and effects of the actual stress and chronic stress, and connections with resilience are not considered in this paper.

1.3. Biology of stress and resilience as psychological phenomena

The importance of the interdisciplinary approach to stress and resilience research is emphasized [17]. However, the researchers focused more on the stress than on the resilience. Early work has focused on the physiological stress response [16]. Resilience research has mainly focused on the contribution of psychosocial and environmental factors, with limited attention to the potential role of intraindividual biological factors [3].

A wide range of physiological and behavioural reactions developed as a response to stress, enable quick recovery or adaptation to the change. Borell [18] emphasized that the neuroendocrine and immune systems have been studied regarding stress effects at the cellular or neural level during the last decade. All these studies were often conducted in an isolated manner without considering that the neuroendocrine and immune systems are communicating with each other and are ultimately influenced by the perception of a stressor." Based on the analogy between the animal world and the human world, Borell's discussion on the neurobiological integration of stress emphasized a systematic and holistic approach to stress as a bio-psychosocial phenomenon based on the communication between the central nervous system, endocrine system, and immune system.

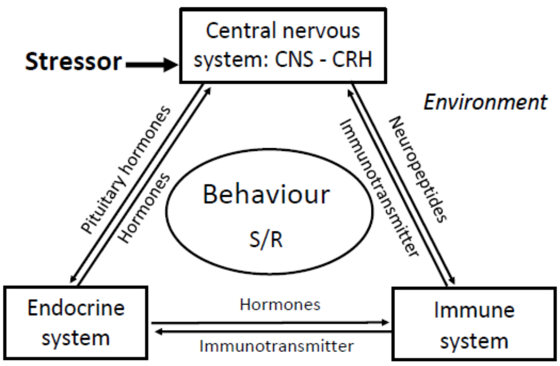

Figure 1. *Neurobiological integration of stressful or resilient behaviour (adapted according to [18])*

Current stress research considers the central nervous system, endocrine system, and immune systems as key systems for stress and resilience, and emphasises their interactions.

2. RESEARCH METHODOLOGY

The problem of the analysis: This paper focuses on the representation of the biological approach to psychological resilience in scientific and professional articles, other publications, and different types of work presentations, as well as the biological components and framework of psychological resilience.

The research goals:

- Overview of the presence of topics on the connection between psychological resilience and biological factors from the perspective of holistic approaches to sciences and scientific branches (example: biology of psychological resilience; neuroscience of psychological resilience).
- A systematic overview of the biological factors (causes and consequences) of psychological resilience based on the prior analysis.

A general browser was used to find and analyze the resources on the connections between psychological resilience and biological framework, in two general databases and two specialized databases: Google Scholar as general citation repositorium, DOAJ as general open access repositorium, and MEDLINE and PSYCHINFO as specialized repositories using the following terms (concepts) as filters (see Table 1). The internet search was performed on May 2, 2024, and control search June 11, 2024.

3. RESULTS

In the first step of this research, an examination of how many topics on biological frameworks of psychological resilience are represented in scientific periodicals available in online repositories was performed, and an overview of resources based on internet searches was given. In the second step of the research, there is an overview of biological components (factors, systems) related to resilience.

3.1. Repository search results

Based on the internet search in general open access registries and repositories (Google Scholar and DOAJ), and in specialized repositories (MEDLINE and PSYCHINFO), focusing on the articles (Table 1).

Table 1. *Number of sources with key terms searched in e-databases*

Phrases and words	Google	Google Scholar: articles	DOAJ: articles	MEDLINE: articles	PSYCHINFO articles
Biological framework of psychological resilience	24.800.000[a] (0)[b]	493.000 (0)	11 (0)	89 (0)	0 (0)
Biological basis of psychological resilience	15.500.000 (7)	518.000 (2)	8 (0)	97 (0)	174 (0)
Biological fundaments of psychological resilience	3.970.000 (0)	18.600 (0)	0 (0)	7 (0)	0 (0)
Biology of psychological resilience	213.000.000 (2)	389.000 (2)	8 (0)	72 (0)	151 (0)
Neurobiology of psychological resilience	1.210.000 (10.400)	104.000 (25)	7 (0)	32 (0)	61 (0)
Neuroscience of psychological resilience	26.400.00 (4)	281.000 (1)	52 (0)	44 (0)	278 (0)
Endocrinology of psychological resilience	1.190.000 (0)	67.100 (0)	4 (0)	26 (0)	31 (0)
Biology of resilience	76.000.00 (203.000)	2.120.00 (165)	378 (1)	137 (0)	152 (0)
Neurobiology of resilience	2.150.00 (81.500)	138.000 (1940)	96 (3)	51 (0)	61 (0)
Neuroscience of resilience	28.700.000 (53.500)	403.000 (236)	230 (2)	61 (0)	292 (0)
Endocrinology of resilience	7.630.000 (3)	98.800 (0)	11 (0)	30 (0)	32 (0)
	N[1] – number of results with some words/part of phrases (N)[2] – number of results with the whole phrases				

Based on the internet search in registries and repositories, focusing on the articles, the interest of the research community to investigate connections between biological factors and psychological resilience is confirmed.

The following biological factors and components, which are most frequently considered and connected with psychological resilience, are: CNS, brain, ANS, multiple phenotypic levels including stress response systems, neural circuitry function, and immune responses, in interaction with genetic factors; neurogenesis in the hippocampus or reactive up-regulation of ion channels in ventral tegmental area (involved in resilience against stressful conditions); temporal axis; genes encoding serotonin transfer; etc.

3.2. Results of searching by specific term

By choosing specific terms as internet search filters "biological basis of psychological resilience", "biology of resilience", "neurobiology of resilience", and "neuroscience of resilience" (in the title and in the text), only a few papers were selected in open access area (Table 2). For the content analysis 12 papers were considered.

Table 2. *The articles which included the phrase "biological basis of psychological resilience" or combination of words in open databases*

Title of the paper	Year of publishing	Google Scholar	DOAJ	Research Gate
The Biological Basis of Psychological Resilience as a Consequence of Active Processes. [19]	2012	+	no	no
The Neuroscience of Resilience. [6]	2018	+	no	+
Differences in Neural Recovery from Acute Stress Between Cortisol Responders and Non-responders. [16]	2018	+	+	+
Biological and Psychological Perspectives of Resilience: Is It Possible to Improve Stress Resistance? [15]	2018	+	+	+
Visual Analysis of Psychological Resilience Research Based on Web of Science Database. [20)	2023	+	+	+
Bringing a neurobiological perspective to resilience [3]	2021	+	no	+
The Biology of Human Resilience: Opportunities for Enhancing Resilience Across the Life Span. [5]	2019	+	no	+
Psychobiological Mechanism of Resilience and Vulnerability: Implications for Successful Adaptation to Extreme Stress. [21]	2004	+	no	+
Resilience in mental health: linking psychological and neurobiological perspectives. [22]	2013	+	no	+
Cognitive neuroscience of psychological resilience: State of research and unresolved issues. [4]	2021	+	no	+
The Molecural Basis of Resilience: A Narrative Review. [24]	2022	+	no	+
The Role of Epigenetics in Psychological Resilience. [25]	2021	+	no	+

4. AN OVERVIEW OF BIOLOGICAL CORRELATES OF THE PSYCHOLOGICAL RESILIENCE

Based on the content analysis of the articles searched from repositories and registry, the biological framework of psychological resilience is presented.

4.1. Neurochemical and neuroanatomic correlates of psychological resilience

The factors that form the biological framework of psychological resilience (causes and consequences), or neurobiological contributors to resilience [3], are systematically presented based on the holistic research articles and review papers.

Primary biological systems that are involved in stress responsivity and, by extension, resilience, are the following: the central nervous system, the endocrine system, and the immune system, as key organic systems connected with resilient behaviour. It is based on the organic and behavioural dimensions of stress which are considered in the research on resilience [3, 5, 6, 7, 15, 16, 17, 21, 22, 24].

According to [15] "the growing understanding of the neurobiological mechanisms of resilience should result in the development of novel interventions that specifically target neural circuitry and brain areas that enhance resilience and lead to more effective treatments for stress-induced disorders."

Neurocircuitries (any control mechanism that regulates neural activity), as mediators of the stress response and reward experience, are considered crucial in the neurobiology of resilience [22], and in the context of mental health.

The major neural systems that govern the stress response are the hypothalamus-pituitary-adrenal axis (HPA axis), the sympathetic nervous system (SNS) and the dopaminergic and serotonergic neurotransmitter systems [22].

Analyzing the neurobiological pattern for resilience, Charney [21] found "eleven possible neurochemical, neuropeptide, and hormonal mediators of the psychobiological response to extreme stress were identified and related to resilience or vulnerability: cortisol, DHEA, CRH, locus coeruleus norepinephrine system, neuropeptide Y, galanin, dopamine, serotonin, benzodiazepine receptors, testosterone, and estrogen (Table 3).

These neurochemical response patterns to stress help establish a framework for developing a measure of psychobiological allostatic load, and it may relate to resilience and vulnerability to the effects of extreme psychological stress [21].

Table 3. *Biological framework and response linked with resilience: neurochemical and/or endocrine responses - adapted to Charney [21]; additional overview [3, 16, 22]*

Neurochemical response to acute stress	Associations with Resilience
Cortisol	✓ Stress/induced increase constrained by negative feedback by means of glucocorticoid receptor and mineral corticoid receptors. ✓ Mobilizing energy, enhancing alertness, facilitating memory formation, and deploying the physiological resources needed to adequately respond to stress. ✓ Crucial in processes of memory consolidation, facilitating learning of emotional information. ✓ Has important regulatory function to amygdala.
Glucocorticoids (GCs), generally	✓ GCs plays very heterogeneous role in stress: they can serve permissive, stimulative, suppressive, and preparative functions. ✓ Crucial in processes of memory. ✓ Consolidation, facilitating learning of emotional information.
Dehydroepiandosterone (DHEA)	✓ High DHEA-cortisol ratios may have preventive effects regarding PTSD and depression. ✓ Inhibition of HPA axis.
CRH	✓ Reduced CRH release, adaptive changes in CRH-1 and CRH-2 receptors.
Locus coeruleus-norepinephrine system	✓ Reduced responsiveness of locus coeruleus-norepinephrine system.
Neuropeptide Y	✓ Adaptive increase in amygdala neuropeptide Y is associated with reduced stress-induced anxiety and depression.
Galanin	✓ Adaptive increase in amygdala galanin is associated with reduced stress-induced anxiety and depression.
Dopamine	✓ Cortical and subcortical dopamine systems remain in optimal window of activity to preserve functions involving reward and extinction of fear.
Serotonin (5-HT)	✓ High activity of postsynaptic 5-HT1A receptors may facilitate recover.
Benzodiazepine receptors	✓ Resistance to stress-induced down-regulation of benzodiazepine receptors.
Testosterone	✓ Increase in testosterone may promote increased energy and active coping and reduce depression symptoms.
Estrogen	✓ Short-term increase in estrogen may attenuate effects of stress-induced HPA axis and noradrenergic system activation.
Epinephrine (adrenaline)	✓ Infront the stress and challenge, epinephrine stimulates the nervous system to prepare the body for a quick response.
Norepinephrine	✓ Enhanced memory consolidation of emotional information and directly influence the activation of brain structures supporting memory. ✓ Decrease connected with the resilience, increase connected with the stress.

How can we describe the individuals with the highest index for psychobiological allostatic load and resilience?

According to the results of Charney's overview [21] a resilient individual will be described as person in the highest quartile for measures of DHEA, neuropeptide Y, galanin, testosterone, and 5-HT1a receptor and benzodiazepine receptor function and the lowest quartile for HPA axis, CRH, and locus coeruleus-norepinephrine activity.

Neuroendocrinological networks of resilience consist of the limbic-cortical network of the stress response, the meso-cortico-striatal network of reward processing, and the default mode network of interoceptive processing" [15].

The current state of research on the neurobiological framework of resilience focuses on the connections between psychological resilience and the stress and reward systems of the brain [22], how the brain regulates reward and motivation (hedonia, optimism, learned helpfulness), learns, remembers, and responds to fear (effective behaviour despite fear), and develops adaptive social behaviours (altruism, bonding and team work), and how these neural mechanisms relate to resilience and courage [21].

Current approaches describe how multiple biological systems work together in a complex, integrated manner to promote the body's adaptation to a threat or challenge [3], and to maintain resilience; some factors promote resilience in one domain, but may not promote resilience in another or all other domains [3]. Other biomarkers and components relevant to reaction to stress and establishing resilience involve: immune functioning, cellular aging, epigenetic modification of DNA, etc.

However, the most important and "principal" organ for identification of and (resilient) response to stress is the brain, as a target of stressful events [5]. The neuroanatomic basis of resilience is the topic of numerous research studies. Based on the methodology of research article selection (Chapter 2), only eight papers were used for the review of the neuroanatomic basis of resilience [3, 4, 5, 13, 15, 16, 21, 22].

Table 4. *Biological framework and resource linked with the resilience: neuroanatomic framework*

Neuroanatomic basis	**Associations with Resilience**
Brain regions	✓ Some of the key brain structures involved in the neurochemical response patterns following acute psychological stress.
Prefrontal cortex: medial prefrontal cortex lateral prefrontal cortex	✓ Stimulation promotes resilience. ✓ Selective activation enhances resilience. ✓ With amygdala have impact to quick attenuate learned fear and to function more effectively in dangerous situation.
Hippocampus, hippocampal complex, CA3 neurons in hippocampus	✓ It is modulated by the stress hormone. ✓ Important for spatial learning and memory. ✓ Most sensitive to stress, regulated HPA axis. ✓ Stimulation of the hippocampus decreases glucocorticoid secretion. ✓ Hipoccampus lesions increase basal glucocorticoid levels, especially during the stress recovery phase. ✓ Function to learn behaviour.
Amygdala	✓ Inhibition amygdala activity mediated by the medial prefrontal cortex have impact to quick attenuate learned fear and to function more effectively in dangerous situations. ✓ May reduce the strength of the original traumatic memory. ✓ Interacts with the hippocampus in mediating the effects of stress on the consolidation of contextual information. ✓ Interaction between amygdala and medial PFC are essential for successful emotion regulation. ✓ Emotional behaviour.
Hypothalamus HPA axis: Hypothalamic-pituitary-adrenalin axis	✓ Adequately response to stress. ✓ Lower ANS or HPA axis reactivity /often buffered from risk and show protection ✓ HPA axis enacts a more delayed, longer-term response to stress through a cascade of hormonal processes that culminates in the release of cortisol. ✓ HPA axis leads to the release of glucocorticoids.
Ventral tegmental área Potassium channel in the ventral tegmental area	✓ Regulating motivated behaviour. ✓ One of the components of brain reward circuits. ✓ Important mediator of active stress, a channel to enhance resilience.
Locus coeruleus	✓ The locus coeruleus–norepinephrine system globally. LC activated by stressors Modulates arousal, alerting and orienting functions. ✓ Have a powerful effect on the regulation of multiple memory systems. ✓ Reduced responsiveness of locus coeruleus norepinephrine system.
Nucleus accumbens	✓ Reward seeking, production resilience through self-care, and seeking social support.
Autonomic nervous system	
PNS Parasympathetic nervous system	✓ Reducing arousal and promoting restoration ("rest and digest"). ✓ lower ANS or HPA axis reactivity / often buffered from risk and show protection
SNS Sympathetic nervous system	✓ Mobilize the body to respond to stress through psychological activation. ✓ lower ANS or HPA axis reactivity. Often buffered from risk and show protection.

4.2. Selected molecular correlates of psychological resilience

It is believed that psychological resilience is moderately heritable, and influenced in equal parts by both environment and genetic factors [5], which would lead to the conclusion that the stable component of resilience is 50% heritable [24]. Ryan and Ryznar [24] analyzed the molecural basis of resilience. Many gene variants, oftentimes in association with corresponding protein biomarkers, are thought to be involved in development and modulation of resilience, their impact either positive or negative on the final outcome. They considered *PRTFDC1* gene, *DCLK2* and *KLHL36* genes, *NR3C2* gene, *NPY* gene, *FKBP5* gene, etc.

Phosphorybosil Transferase Domain Containing 1 (*PRTFDC1*) gene is regarded as a possible novel PTSD gene. It codes phosphorybosil transferase domain-containing protein 1, a member of a protein family important in purine salvage pathway, which allows for bases coming from in DNA and RNA catabolism to be converted back into nucleotides [24]. The brain is amongst those organs that cannot synthesize nitrogen bases de novo, and relies heavily on this pathway [25].

Certain alleles of *DCLK2* and *KLHL36* genes have also been connected to resilience. The former might be crucial for developing positive social skills and is thought to play a part in regulation of *NR3C2* gene, which has previously been associated with resilience [24].

It is important to note that while genomes across all somatic cells of an individual remain mostly the same throughout the life, the expression of genes varies immensely thanks to an intricate system of epigenetic markers, which include DNA[1] methylation, histone modifications, and non-coding RNAs (ncRNAs)[2]. These can be involved in both heritable silencing and activation. Epigenome is inherited mitotically and can be modified in response to a variety of changes in the environment, as well as during normal development and cell differentiation. The genome can directly affect the epigenome, thanks to the fact that changes in the genetic sequence can alter methylation sites and influence the efficacy of sequence-dependent functions of ncRNAs. Also noteworthy is the fact that the majority of research of the epigenetic component of resilience is focused on inheritance of adversity. In other words, epigenetic markers which correlate with diminished resilience are better known and researched than those that might be present in individuals with increased resilience [26].

The components of hypothalamic-pituitary-adrenal (HPA) axis can also be observed on the genomic scale. FK506 binding protein 51, coded by the *FKBP5* gene, inhibits the glucocorticoid receptor, which results in a decreased negative feedback inhibition of the HPA axis [24]. A series of studies of this gene were aimed at understanding the interactions between the genotype, epigenetic markers and exposure to childhood trauma [5]. The T-allele of rs1360780 polymorphism this gene shows delayed cortisol recovery after exposure to psychological stress, thus resulting in HPA axis dysregulation. The C-allele, on the other hand, allows for faster cortisol recovery. The intron 7 CpGs (DNA regions of cytosine followed by guanine in the linear sequence of bases) of T risk allele are also demethylated in individuals who report significant early trauma exposure. The protective C-allele might then also be activated through demethylation, positively impacting individual’s stress response. This differs significantly from the study of Holocaust survivors, who exhibit high methylation of *FKBP5* [24].

A single nucleotide polymorphism within the *NPY* gene, which codes for neuropeptide Y, has also been linked with psychological resilience. The T-allele of the said polymorphism (rs16147) correlates with increased resilience, whereas the C-allele is associated with poorer overall resilience (“anxiety and depressive symptoms after experiencing childhood adversity”) [24].

MicroRNAs (miRNAs) are small non-coding RNAs involved in gene expression. They inhibit messenger RNAs (mRNAs) by inducing their degradation or translational repression [27]. MiRNAs, a part of the intricate system of epigenetic regulation themselves, can be modified as a result of DNA methylation, histone modifications and chromatin remodeling. It is important to note that miRNAs have been found in all bodily fluids, and as such, they might have a widespread role in communication within the entire organism [27]. It has been shown that milder symptoms of anxiety disorder correlate with higher levels of certain miRNAs, namely miR-4505 and miR-663, which are present in blood. Another potential biomarker miRNA is miR-29c, found in peripheral blood lymphocytes of individuals exposed to stress through an arithmetic task. This miRNA has also been in correlation with increased survival rate in breast cancer through inhibition of particular genes involved in pathogenesis, which implies that it could play an important role in stress altogether, both physical and psychological [24].

4.3. Interventions to support resilience and biological feedback

APA emphasized that “psychological research demonstrates that the resources and skills associated with more positive adaptation (i.e., greater resilience) can be cultivated and practiced” [28]. Resilience also moderates the negative effects of stress and promotes adaptation, and it has been associated with increased psychological well-being [1, 29].

Current approaches to mental health are focusing on resilience rather than pathophysiology. This focus in many ways represents a paradigm shift in clinical-psychological and psychiatric research that has great potential for the development of new prevention and treatment strategies; the guiding idea is “Investigating health, not disease” [30].

In the research study of impact of psychological, social and biological mechanism on shaping resilience towards mental health [31], researcher suggested implication for action in enhancing children resilience. Based on this analysis, researchers recognized that these three types of mechanisms are all important for the development of resilience, but the social mechanisms are much more influential, and they can determine the role of biological and psychological mechanisms in resilience development.

There are a number of interventions likely to promote resilience and resilient brain function, including parenting and community-based interventions for children and adolescents, hardiness training, mediation and mindfulness approaches, and aerobic exercise [5].

[1] DNA — deoxyribonucleic acid.

[2] RNA — ribonucleic acid.

What is the impact of educational interventions on the biological phenomena linked to stress management and resilience?

Based on the understanding of the biological process that is connected with resilience, the overview of the treatment to enhance and promote resilience suggests using supportive factors (dyadic support, educational support) that have an impact on adaptive regulatory activity within the ANS and HPA axis, and stress and resilience physiology [3].

Recommended interventions (strategies and procedures) to enhance resilience [3, 5, 15, 32]:

- Psychological and behavioural therapy: it can be used to enhance resilience and mental flexibility and to reduce the symptoms of mental disorders; it should be kept in mind that psychotherapy generally takes place over a long period, and works slowly;
- Active adaptations largely impact resilience.
- Psychological cognitive therapies;
- Life skills education-based programme;
- Intensive mindfulness meditation training;
- Stress inoculation training;
- Enhancing early functional attachment relationship and parenting quality;
- A physically and emotionally safe and enriched environment creates the basis to down-regulate stress activation, and enhances neural proliferation towards the prefrontal cortical regions;
- Specific resilience enhancing interventions: promoting peer relationship and prosocial behaviours in adolescence; enhancing a person sense of control in early adulthood.

5. CONCLUSION

The main conclusion emphasizes the importance of a holistic approach to psychological resilience as a construct supported by and affecting the social dimension as well as the biological dimension of personal functioning. There are no uniform indicators of biological functions included in resilient functioning. Consideration of the biological framework of resilient functioning demands analysis of different contexts and collaborative interactions between them and resilient persons as a bio-psycho-social system.

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Encounters of Digital Technologies and Educational Psychology: Challenges of Interdisciplinarity

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Abstract: *Global crises call for innovative, interdisciplinary solutions; however interdisciplinary research and practices are still rare internationally and in Serbia. This paper reviews the literature on the challenges and benefits of interdisciplinarity, focusing on education and digital technologies. Its main contribution is presentation and analysis of the collaborative process between an educational psychologist and a computer science engineer in preparing a project proposal on computer-supported collaborative learning. Our methodology, based on collaborative analytic autoethnography, revealed that significant time was spent in conceptualizing the problem, goals and objectives. Besides "language" barriers, we also experienced methodological and epistemological challenges and had to disentangle ideas about the precedence of natural sciences and technology over social sciences. These processes, accompanied with many concerns and exhaustion have been resolved through persistence, mutual respect, interdisciplinary dialogues and reading circles. For future interdisciplinary endeavours to become transformative it is necessary to ensure broader participation of diverse stakeholders and to further reflect on the unresolved issue in the area of education.*

Keywords: *interdisciplinary; digital technologies; educational psychology; education; autoethnography*

1. INTRODUCTION

There are many crises globally, such as poverty, unequal access to education and healthcare, climate change, armed conflicts, and violence, all of which demand our attention and require innovative solutions. Scholars claim that these challenges can only be resolved through a holistic, problem-focused approach and thinking beyond disciplines [1]. Giroux considered pedagogy to be a central element of global change, with the capacity to embrace the potentials of diverse disciplines [2]. Therefore, it seems necessary to encourage the encounter of educational sciences with other disciplines that can help resolve these global challenges. This paper strives to review the literature on the challenges and benefits of interdisciplinarity in general, and in the fields of education and digital technologies in particular. Moreover, it addresses the process and results of collaboration between an educational psychologist and a computer science engineer while preparing a project proposal on computer-supported collaborative learning, as a form of collaborative autoethnography [3] that concretizes discussions about the challenges and gains of interdisciplinarity in education.

1.1. Benefits and challenges of interdisciplinarity

Interdisciplinarity refers to the interaction among two or more different disciplines, which may range from the simple communication of ideas to the mutual integration of organizing concepts and terminologies, procedures and methodologies, and research paradigms [4]. It can be understood as crossing disciplinary borders by mutual consent [5] between researchers of different disciplinary perspectives or within a researcher (interdisciplinary knowledge). Weak interdisciplinarity refers to the combination of different perspectives within one discipline (e.g., educational psychology and organizational psychology), while strong interdisciplinarity refers to the combination and integration of perspectives from different disciplines [5].

Suchman [6] asserted that an overly strong focus on one discipline may shift the attention of researchers to hierarchy and identity rather than content-related work. Similarly, some authors assume that disciplinary structures may serve as an instrument for exercising power, thereby limiting innovation, progress, and the relevance of science [7]. Nissani agreed that the main advantages of interdisciplinarity, besides addressing disciplinary weaknesses, include creativity and outsider perspectives [4]. Similarly, Gantogtokh and Quinlan [8] highlighted that the greatest opportunity for learning appears at the boundary of disciplinary, cultural, and social groups, where a so-called "third space" is created in which the meeting of different perspectives (amongst others) triggers the co-construction of learning [9, 10]. Therefore, it is not surprising that there is a relationship between interdisciplinarity and novelty, and thus, breakthrough discoveries [11].

Despite its strong benefits, interdisciplinarity is still rare in science and practice due to many challenges. Some of these challenges are conceptual and structural, such as structural or formal barriers between disciplines, differences in epistemologies, and resulting differences in objectives, methodologies, and conceptualization of what data is, as well as different "languages". Others are (inter)personal, such as a lack of motivation to adjust to other disciplines, accompanied by prejudices towards other disciplines (e.g., perceiving social sciences as less worthy than natural sciences) and resistance to novelty. Many challenges stem from institutional cultures and policy solutions, for example, funding schemes, hiring and merit systems, and peer review processes that disfavour interdisciplinarity, difficulties in publishing interdisciplinary work, and a lack of political support in developing interdisciplinary programs [12, 13, 14].

1.2. Benefits and challenges in collaboration between educational psychology and digital technologies

Learning and education have reached a level of complexity where it is necessary to adopt interdisciplinarity, with special attention paid to digital technologies. The COVID-19 pandemic has accelerated the comprehensive and intense use of digital technologies in educational contexts. However, there are still many challenges in integrating educational sciences and digital technologies, as their lines of research largely diverge. In addition to the common challenges mentioned earlier, Graesser and associates [15] pointed out that researchers in the fields of education, educational psychology, cognitive and neuroscience, machine learning, and artificial intelligence attend different conferences, publish in different journals, work in different university departments, and have very different learning research paradigms. Moreover, in the field of digital education, many computer science experts developing educational software and tools are not tied to academia but work in the private sector, which makes it additionally difficult for them to communicate and exchange ideas with scholars from educational sciences.

2. OBJECTIVES AND METHODOLOGICAL FRAMEWORK

In this paper, we strive to contribute to the discussions about the challenges and benefits of interdisciplinarity by specifically delving into the collaborative endeavour of one educational psychologist and one computer science engineer. Collaboration started in February 2024 when ideas about a potential application for an Erasmus KA2 project were exchanged. Knowing the priorities of the Call for projects and the needs of the Serbian educational system, it seemed reasonable to imagine a project proposal at the intersection of inclusive education and digital technologies. More specifically, we decided that our project should aim at enhancing the inclusiveness and digital transformation of the educational system through fostering Computer-Supported Collaborative Learning (CSCL). We opted for CSCL because it can enable better participation of diverse students and help them improve subject knowledge and digital competencies, as well as communication and teamwork competencies.

We strove to develop a project methodology that aligned with the values emerging from our aim and to foresee collaboration and a reflective stance as the main guiding principles of all project activities. This meant that we had to adhere to these values and principles even in the proposal writing, and not just use interdisciplinarity as a "meaningless academic buzzword" [16: p. 143].

In line with the project context and goals, our methodology was collaborative autoethnography [17] and thus – analytic autoethnography [18]. This method involves researchers recounting stories of their personal experiences to reflect on and better understand certain social processes. In our case, a practitioner (a computer science engineer working on the e-learning platform) and an academic (a scientist in the field of educational psychology) co-created knowledge and an interdisciplinary product – the project proposal. Data was not collected in a structured way, but in a form of notes after the meetings and at the end of the process of proposal writing. Notes were shared and discussed, and joint reflections were made about the emotions and insights that accompanied collaboration, as well as the barriers to and benefits of interdisciplinarity.

3. RESULTS AND DISCUSSION

Most of our joint endeavour was spent on the conceptualization phase, during which the research team developed an understanding of the interrelatedness of disciplines, their strengths and weaknesses, and the perspectives or scopes they offer [19]. This process is also known as "a combination of group divergent thinking activities across multiple domains of expertise that make task-level assessments of potential joint research activities, and tentative evaluation (convergent thinking) of potential outcomes from those activities" [20: p. 63].

Internal personal processes accompanying this phase included curiosity, enthusiasm, and high morale. As recognized in the literature; to be interdisciplinary, one needs to spend a lot of time with people who are genuinely interested in each other and each other's competence [19]. After the first meetings, these emotions were replaced by unease, concerns, confusion and a sense of being overwhelmed as the phase of divergent thinking prolonged. Further reading and mutual values and vision helped us put all these ideas into a coherent framework and start developing project goals, outcomes, and activities.

From the beginning, we experienced a well-recognized challenge of interdisciplinarity: "language" barriers. While the educational psychologist was aware that digital technologists are necessary for creating CSCL activities, this was not initially clear to the computer science engineer. Due to the broad use of certain terms in educational psychology in everyday life (such as learning motivation, collaborative learning, or inclusion) and the universal experience with schooling and education, the computer science engineer believed he knew enough about learning and motivating students. It took some time to realize that we had different understandings of commonly used terms and to address this challenge. Providing theoretical underpinnings (of human learning and development and teaching) was one of the greatest benefits for the computer science engineer. Introducing a conceptual structure of psychology made the computer science engineer think less about concrete, scattered activities that might be interesting to students and more holistically and purposefully about the program, its learning outcomes, and principles of learning.

Vivid debates were held on whether the digital tools should be adjusted to the planned program and activities or if we should adjust the activities to already developed tools. This likely stems from differences in epistemologies and the idea that natural science and technologies have an advantage over social sciences. For the computer science engineer, it might seem too time-consuming to change some features of the tools, and the educational psychologist might not be aware of the time and costs needed for such adjustments. We believe that when both parties no longer see this as an either-or question, the full potential of interdisciplinarity can be reached.

The idea that any innovation must be evaluated was also new to the computer science engineer. An uncritical stance towards technologies (and most recently, artificial intelligence) has already been recognized in the literature [21], so it was not surprising that the educational psychologist had to invest some time to highlight the need for monitoring and evaluation (ideally through quasi-experimental design) to the computer science engineer. Before interdisciplinary discussions even very technically simple means of evaluation (collecting feedback from educational tool/platform users), collecting qualitative data and participatory research were not covered in the computer science engineer's focus area.

Many rounds of interdisciplinary dialogues [22], including other specialists, helped us finalize a truly interdisciplinary project proposal. The exchange of literature and further discussions, referred to as "reading circles" by Schmitt and associates [23], were useful. Nevertheless, we cannot say that we moved beyond "extension" in our attempts to integrate our disciplines [24], and more effort, as well as a more challenging and original project topic, is likely needed for real transformation.

4. CONCLUSIONS

Despite limited data, our research can be considered pioneering in the Serbian context, addressing the issue of collaborative endeavours between computer science engineers and educational psychologists. The challenges encountered in such a collaboration were similar to those already identified in the literature — differences in theoretical and methodological underpinnings, terminology, objectives, and purpose predominated. However, through persistence, genuine interest in learning from each other, reflective stances, interdisciplinary dialogues (and discussions), and "reading circles," this collaboration resulted in a written proposal for a competitive Erasmus call and many new ideas about future joint initiatives. The lack of institutional barriers, which seem to be very strong in many cases [23], also helped, as the Call for proposals required a diversity of institution types (NGOs, HEIs, schools) and experts (in science, practice, and policy) and actually favoured proposals with interdisciplinary and multistakeholder teams.

We conclude that the collaboration between the educational psychologist and the computer science engineer sowed the seeds for future, more intense interdisciplinary encounters. For such interdisciplinarity to be more socially relevant and effective, and to bring about real transformation, it would be useful to include wider participation from actors outside academia (e.g., teachers, students, citizens, and the economy). We should engage in 'futures thinking' [25] to reimagine and create our own educational futures more profoundly, clearly, and justly, so it can help resolve global challenges.

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Empowering Digital Resilience: Exploring the Role of School Psychologists

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Abstract: *In an increasingly digital world, students face a variety of online challenges, which necessitates a proactive approach to foster digital resilience. This research seeks to gain insight into the crucial role of school psychologists in promoting digital resilience within educational settings. Thirty-two school psychologists working with students in grades ranging from preschool to high school, from 16 different U.S. states, completed an online questionnaire. An exploratory study revealed that although school psychologists are aware of the significant impact of digital challenges on students, many are not utilizing support mechanisms to help students develop digital resilience skills. Notably, 68.8% of school psychologists have never implemented interventions for digital resilience. The study also found a statistically significant difference in perceptions of how digital challenges affect general education students versus special education students, with the latter being more adversely affected. The majority of school psychologists do not believe digital resilience is adequately addressed in their educational environments. However, they find strategies to be moderately feasible and are highly likely to collaborate with key stakeholders to promote digital resilience in students. By providing school psychologists with practical recommendations and actionable insights, this research aims to create a safer and healthier digital environment for students, ultimately enhancing their well-being and success in the digital age.*

Keywords: *digital resilience; school psychologists; education; student well-being; online challenges*

1. INTRODUCTION

The aim of this study is to gain insight on school psychologists' possible perspectives and practices concerning digital resilience among students in educational settings. By the age of nine, most American children are using electronic devices to connect with their friends, follow influencers, and learn about their interests [1]. A national survey of American youth found that elementary age students (ages 8 to 12) spend an average of four hours online per day, and high school students spend up to 8 hours online per day [2]. Digital environments offer both good opportunities such as social connection, entertainment, and information access, as well as negative risks such as cyberbullying and privacy violations [3,4,5,6,7,8]. Cyberbullying is of significant concern because there is a consistent relationship between cyberbullying and depression among children and adolescents [9]. The traditional method for educating children about technology has primarily emphasized minimizing their online time. For instance, students are often instructed to monitor and reduce their screen time, while parents are advised to postpone their children's exposure to technology [15, 16]. Although these strategies might shield children from digital risks, they could also limit their access to the benefits of digital technology, such as maintaining connections with peers during significant transitions (e.g., changing schools, [12]) and challenging situations (e.g., the COVID-19 pandemic, [13]). Moreover, these approaches concentrate on avoiding digital challenges rather than equipping youth with the skills to manage these challenges effectively when they arise.

Thus, equipping children with a particular type of resilience that focuses on enabling them to cope with digital challenges in a constructive manner, can be defined as digital resilience, and is also important [14]. Although digital risks are prevalent and negatively impactful, studies indicate that well-designed educational interventions have potential in building digital resiliency among students [10]. Schools play a crucial role in supporting the holistic development of students. School psychologists, with their specialized training in both psychology and education, are uniquely positioned to promote mental health and well-being in schools [11]. In an era where digital technologies play an increasingly integral role in students' lives, understanding how school psychologists perceive and address digital challenges is essential for promoting students' well-being and academic success. Through this study, we aim to explore the following objectives:

- **Assess Awareness:** Evaluate school psychologists' awareness of digital challenges faced by students.

- **Identify Practices:** Gain insight on current practices and interventions used by school psychologists to foster digital resilience.
- **Measure Perceptions:** Examine school psychologists' perceptions of the impact of digital challenges on general and special education students.
- **Evaluate Feasibility:** Determine the feasibility and likelihood of implementing digital resilience strategies in schools.
- **Provide Recommendations:** Offer practical recommendations for school psychologists to effectively promote digital resilience.

By addressing these objectives, this study aims to provide valuable insights into the role of school psychologists in promoting digital resilience and supporting students' well-being in the digital age. Through a comprehensive examination of school psychologists' perspectives and practices, we aim to contribute to the development of

evidence-based strategies for fostering digital resilience among students and enhancing digital well-being within educational settings. To explore this, a structured survey was designed to gather insights from school psychologists regarding their observations, beliefs, and practices related to digital resilience among students.

1.1. The Current Study

In the following sections, a detailed analysis of the survey findings are presented, highlighting key themes and implications for school psychology practice. The survey questions were meticulously crafted to capture various dimensions of school psychologists' perspectives, ranging from their observations of digital challenges faced by students, to their utilization of support mechanisms aimed at fostering digital coping skills. Each question was carefully designed to elicit measurable responses that could shed light on the effectiveness of current interventions and inform recommendations for enhancing digital resilience education within educational settings.

2. METHODOLOGY

2.1. Participants and Procedure

Thirty-two school psychologists working with students in grades ranging from preschool to highschool completed an online questionnaire in May and June of 2024. The participants anonymously volunteered to complete the survey after a call for survey participants was posted onto various virtual forums for school psychologists. This method was chosen to ensure a wide range of participants who practice in various regions across the U.S. states. Due to the diverse field of school psychology, and variances of common practices between states, it was essential that participants live in a wide range of states. It was also important to gather participants who worked with various ages of students. This ensured that the results would not be skewed and varying common practices would not become a limitation. The participants in this study were all practicing school psychologists, ranging from 16 U.S. states. Socio-demographic characteristics of the sample are reported in Table 1.

Table 1. *Demographic characteristics of the sample*

Variables	n(%)
Years of Experience	
Early Career (0-4 years)	17 (53.1%)
Mid Career (5-19 years)	8 (25%)
Late Career (20+ years)	7 (21.9%)
Age Groups Served *some participants served multiple age groups	
Preschool	8 (25%)
Elementary	26 (81.3%)
Middle School	20 (62.5%)
High School	13 (40.6%)
Post Secondary	0 (0%)
Location (State)	
California	4 (12.5%)
Colorado	1 (3.1%)
Connecticut	1 (3.1%)
Iowa	1 (3.1%)
Kansas	13 (40.6%)
Louisiana	1 (3.1%)
Maine	1 (3.1%)
Maryland	1 (3.1%)
Minnesota	1 (3.1%)
Nebraska	1 (3.1%)
New Jersey	1 (3.1%)
New York	1 (3.1%)
Pennsylvania	1 (3.1%)
Rhode Island	1 (3.1%)
Texas	2 (6.3%)
Washington	1 (3.1%)

2.2. Measures

The online survey was composed of the following questionnaire:

a) A questionnaire created specifically for this study investigating school psychologist’s perspectives (14 items) and practices (6 items) concerning digital resilience among students in educational settings. The selection of these 14 examples of perspectives and 6 practices was based on a comprehensive literature review and consultations with experts in the field of educational psychology and digital resilience. The aim was to cover a broad spectrum of relevant issues and interventions that school psychologists might encounter or implement in their practice.

b) The majority of the questions were Likert scale style, asking participants to rank on a scale their level of agreement, opinion of effectiveness, frequency of practice, etc. on various items. Five point scales were utilized, ranging from less severe (1) to most severe

(5), or strongly disagree (1) to strongly agree (5).

c) There was one open-ended question which was not required, to provide participants an opportunity to provide free-form, unrestricted responses. These provided qualitative insights which were included (see Findings 3.4).

2.3. Statistical Analyses

Descriptive statistics, which include means (average values), standard deviations (measurements of variability), frequencies (counts), and percentages, were calculated for the demographic data. For the Observation and Awareness section (see Findings 3.1) of the survey, we conducted an item analysis, reporting the means, standard deviations, frequencies, and percentages. We also reported total scores and scores for subscales (as means and standard deviations), along with internal reliability using Cronbach's alpha, which measures the consistency of the survey items. This analysis is crucial because it ensures that the results obtained from the instrument are reliable and can be replicated.

For the Perception of Effective Strategies (see Findings 3.2) and Utilization of Support Mechanisms (see Findings 3.3) sections, we used Friedman's scale analyses. Friedman's test is a non-parametric statistical test that detects differences in treatments across multiple test attempts. This test is particularly useful when the assumptions for parametric tests (e.g., normal distribution of data) are not met. By using this test, we can determine if there are statistically significant differences between responses and perceptions.

Additionally, we conducted a Wilcoxon Signed Ranks Test to compare the impacts on general education and special education students. The Wilcoxon Signed Ranks Test is a non-parametric test used to determine if there are statistically significant differences between two related samples. This test helps us understand if the impact of digital challenges differs between general education and special education students.

3. FINDINGS

3.1. Observations and Awareness of Digital Challenges

Research on resilience aims to understand why some individuals adapt more effectively to challenging situations than others. Various factors, including individual traits, relational dynamics, and environmental influences, impact how people cope with stressors [16]. For instance, students may exhibit different reactions to the same cyberbullying incident, such as receiving derogatory messages about their appearance [17, 18]. Children are especially susceptible to these harmful effects if they lack support, withdraw from social interactions, or engage in self-harm [19, 20, 21]. On the other hand, resilient students may have protective factors that help them cope, such as self-advocacy skills, emotional support from friends, and assistance from trusted adults who can provide reassurance or mediate conflicts [23]. Therefore, it was vital in this research study to gain an understanding of school psychologists' observations and awareness of students facing digital challenges.

The objective of this section was to assess school psychologists' observations and awareness of digital challenges faced by students. This section included questions about the prevalence and severity of digital challenges, such as cyberbullying, excessive screen time, and misinformation, as well as the impact of these challenges on students' academic performance and well-being.

The reliability analysis of the survey questions yielded a Cronbach's Alpha of 0.773, indicating acceptable internal consistency. This suggests that the responses are reliable and the school psychologists have a consistent understanding of the digital challenges students face.

Table 2. *Observations and Awareness*

Item	Mean (1 to 5, 5 being most severe)
Do students in your educational setting encounter digital challenges such as cyberbullying, excessive screen time,or misinformation online?	m = 4.28
How severe do you perceive the recent digital challenges faced by students tobe?	m = 3.97
How significantly dothese digital challenges impact students' academic performance and overall well-being?	m = 3.94
To what extent do youagree with the statement: "Digital resilience is a crucial factor for promoting students' well-being ineducational settings"?	m = 4.19

School psychologists observed that students frequently encounter digital challenges. The perceived severity of digital challenges was moderately high. The impact of digital challenges on students' academic performance and overall well-being was also rated moderately high. There was strong agreement on the importance of digital resilience for promoting students' well-being.

The inter-item correlation matrix supports these findings, showing moderate to strong correlations between the survey items. This further indicates that the school psychologists have a good awareness of the digital challenges students face and consistently perceive their impact and importance.

The results demonstrate that school psychologists are well aware of the digital challenges encountered by students and recognize the importance of addressing these issues to promote students' well-being and academic success.

3.2. Perceptions of Effective Strategies and Interventions

Providing children with the necessary skills to navigate the digital world effectively can enhance their resilience. Interventions designed to improve digital skills have successfully increased their ability to critically and responsibly engage with online information, as well as boosted their overall well-being [24, 25]. Although research on elementary school students' digital skills in relation to digital resilience is limited, specific interventions that teach skills like engaging with digital texts and critically analyzing online advertisements have shown to improve children's educational outcomes [26, 27]. Educational interventions can improve students' ability to respond adaptively to digital challenges and safely navigate the digital world - or exhibit digital resilience [14]. Within the scope of school psychology, four different styles of interventions were considered to assess how school psychologists interpret the potential effectiveness of the strategies; 1) Providing digital resiliency education to students (e.g. workshops or seminars on digital citizenship, online etiquette, digital footprint management, safety and privacy, and reasonable social media use); 2) Providing digital resiliency education to parents (e.g. seminars on digital resilience, brochures/newsletters); 3) Facilitating open discussions about digital challenges; and 4) Offering counseling or support services for students.

This section analyzes school psychologists' opinions on the effectiveness of different strategies and interventions designed to promote digital resilience among students. School psychologists rated the effectiveness of various strategies and interventions. The Friedman test was used to determine if there were statistically significant differences in their ratings. The survey included the following strategies:

1. **Providing digital resiliency education to students** (e.g., workshops or seminars on digital citizenship, covering topics such as online etiquette, digital footprint management, safety and privacy, and responsible social media use)
2. **Providing digital resiliency education to parents** (e.g., seminars on digital citizenship, brochures/newsletters)
3. **Facilitating open discussions about digital challenges**
4. **Offering counseling or support services for students facing online harassment**

Table 3. *Perceptions of Effective Strategies and Interventions*

Strategy	Mean (1 to 5, 5 beingmost effective)	Standard Deviation
Digital resilience education to parents	m = 3.65	SD = 0.798
Digital resilience education to students	m = 3.94	SD = 0.964
Facilitatingopen discussion	m = 4.13	SD = 0.670
Offering counseling orsupport services	m = 4.03	SD = 0.875

The Friedman test indicates that there are statistically significant differences in the perceived effectiveness of the strategies (p = 0.003).

In addition, the survey question was asked, "Have you noticed any improvements in students' ability to navigate digital challenges after implementing interventions for digital resilience?". The results were as follows:

- 68.8% answered "Have not implemented any interventions"
- 21.9% answered "Yes"
- 9.4% answered "No"

The results demonstrate that school psychologists perceive significant differences in the effectiveness of various strategies for fostering digital resilience among students. The strategy rated as most effective is facilitating open discussions about digital challenges, followed closely by offering counseling or support services. Both of these strategies received higher mean ranks compared to providing digital resiliency education to students and parents. Additionally, the majority of school psychologists have never implemented any type of digital resilience intervention.

3.3. Utilization of Support Mechanisms

Participants were asked about how often they employ various support mechanisms to assist students in developing digital coping skills across different age groups, considering recommendations from relevant studies [28,29]. Based on common support mechanisms that school psychologists facilitate, the following types were rated; 1) Counseling sessions (e.g. one-on-one, group); 2) Group workshops or seminars on digital resilience; 3) Collaboration with teachers to integrate digital resiliency into the curriculum; and 4) Collaboration with parents to provide digital resilience education.

The Friedman test was used to compare the mean ranks of these different support mechanisms. Here are the key findings from the analysis:

- **Counseling sessions** had a mean rank of 3.02, indicating it was the most frequently utilized support mechanism.

- **Group workshops or seminars on digital resilience** had the lowest mean rank of 1.94, suggesting it was the least frequently used.
- **Collaboration with teachers and Collaboration with parents** had similar mean ranks of 2.52 and 2.53, respectively, indicating moderate usage.

Statistical significance was found in the utilization of these support mechanisms, with a Chi-Square value of 19.274, degrees of freedom (df) of 3, and an asymptotic significance (Asymp. Sig.) value of 0.000. This indicates that there are significant differences in how frequently these support mechanisms are employed by school psychologists.

Table 4. *Utilization of Support Mechanisms*

Support Mechanism	Mean (1 to 5, 5 being utilized often)	Standard Deviation
Counselingsessions	m = 2.28	SD = 1.276
Group workshops or seminars	m = 1.28	SD = 0.683
Collaborationwith teachers	m = 1.84	SD = 1.167
Collaborationwith parents	m = 1.81	SD = 1.091

These results highlight that counseling sessions are the most utilized support mechanism. However, it was found that there was an overall low frequency of utilization of support mechanisms. This further emphasizes that school psychologists are not currently providing interventions and supports for digital resilience (see Findings 3.2).

3.4. Recommendations for Practice

School psychologists were invited to share their recommendations for enhancing digital resilience education within educational settings, informed by their professional experiences and the synthesized findings from relevant literature.

In analyzing the responses to the survey question, "Do you believe digital resilience is being adequately addressed in your educational setting?" it was found that a significant majority of participants expressed concern over the current state of digital resiliency being addressed in their educational settings. Specifically, 81.2% of respondents indicated that they either "strongly disagree" or "disagree" with the statement. This indicates a prevalent perception among school psychologists that digital resilience is not being sufficiently addressed within their educational environments. This finding highlights a critical need for enhanced focus and resources dedicated to promoting digital resilience among students.

Regarding the feasibility of implementing digital resilience strategies in their educational settings, the responses were predominantly neutral. A significant portion of participants, 59.4%, selected a mid-point response between "strongly disagree" and "strongly agree." This neutrality suggests that while school psychologists recognize the potential importance of these strategies, they may have reservations or uncertainties about their practicality or effectiveness within their specific educational contexts. This insight underscores the need for further investigation into the barriers and facilitators affecting the implementation of digital resilience initiatives.

Regarding the likelihood of collaboration with other stakeholders (e.g., educators, parents) to promote digital resilience among students, the majority of participants expressed a positive outlook. Specifically, 46.9% of respondents selected "agree," indicating a strong inclination towards collaborative efforts. The second highest response, at 18.8%, was neutral, falling between "strongly agree" and "strongly disagree." This data highlights a general willingness among school psychologists to work with others to enhance digital resilience, while also pointing to some ambivalence that could be explored further to understand potential obstacles to such collaboration.

Two participants provided written responses to the survey question regarding areas or topics related to digital resilience that require further attention or research. One participant highlighted the need for better methods to help students differentiate between real and fake social media profiles, emphasizing the importance of online authenticity and safety. Another participant suggested that there is a critical need for increased awareness about what constitutes child pornography and the trafficking of such material, especially given the ubiquity of camera phones. Additionally, this participant identified social media threats and the role of schools in addressing these threats as significant areas requiring attention.

3.5. Differences in Students with Disabilities and Willingness for Collaboration

Students with disabilities frequently encounter unique challenges within the educational environment, affecting their academic, social, and emotional well-being. Given that school psychologists play a crucial role in supporting these students, it is essential to understand their perspectives on whether digital challenges disproportionately impact students with disabilities. This insight is vital for developing effective interventions and support strategies tailored to the unique needs of these students.

The survey asked school psychologists to rate how much digital challenges impact general education students versus special education students in their educational settings. The mean ratings indicate a significant perception that special education students are more impacted by digital challenges compared to their general education peers.

Table 5. *Impact on general education vs. special education students*

Impact Severity	Mean (1 to 5, 5 being most severe)	Standard Deviation
Impact ongeneral education students	m = 3.94	SD = 0.759
Impact onspecial education students	m = 4.22	SD = 0.832

A Wilcoxon Signed Ranks Test was conducted to determine if there were statistically significant differences between the impacts on general education and special education students. The results are as follows:

- **Negative Ranks**: 1 (Mean Rank = 6.00)
- **Positive Ranks**: 10 (Mean Rank = 6.00)
- **Ties**: 21

The test statistic results were:

- **Z**: -2.714
- **Asymp. Sig. (2-tailed)**: 0.007

The significance level ($p < 0.05$) indicates that there is a statistically significant difference in the perceptions of school psychologists regarding the impact of digital challenges on special education students compared to general education students. Special education students are perceived to be more greatly impacted by digital challenges.

Willingness for Collaboration

The survey also assessed school psychologists' willingness to collaborate with other stakeholders, such as educators and parents, to promote digital resilience among students. The majority of school psychologists expressed a high likelihood of collaborating with key stakeholders to address these challenges and enhance digital resilience education within their schools. This willingness to collaborate underscores the importance of a holistic approach involving various parties to effectively support students, particularly those with disabilities, in navigating digital environments.

4. DISCUSSIONS

This study aimed to evaluate the awareness, practices, perceptions, feasibility, and recommendations concerning digital resilience among school psychologists. The findings provide valuable insights into these areas.

Assess Awareness

The results indicate that school psychologists are generally aware of the significant digital challenges faced by students, such as cyberbullying, privacy breaches, and exposure to inappropriate content. This awareness is crucial, as it forms the foundation for any effective intervention aimed at promoting digital resilience.

Identify Practices

Despite the awareness, the study reveals a gap in the implementation of interventions designed to foster digital resilience. Most school psychologists reported rarely or never using specific strategies to address digital challenges. This gap underscores the need for more comprehensive training and resources to equip school psychologists with practical tools and techniques.

Measure Perceptions

School psychologists perceive that digital challenges impact special education students more adversely compared to their general education counterparts. This perception highlights the need for tailored interventions that address the unique vulnerabilities of special education students, ensuring they receive the support required to navigate digital environments safely.

Evaluate Feasibility

The feasibility of implementing digital resilience strategies in schools was rated as moderate. While school psychologists are willing to collaborate with stakeholders, practical constraints such as time, resources, and training need to be addressed to make these strategies more accessible and implementable.

Provide Recommendations

Based on these findings, several recommendations can be made:

- **Training Programs:** Develop and offer specialized training programs for school psychologists focused on digital resilience strategies.
- **Resource Development:** Create comprehensive resources, including toolkits and guidelines, to support the implementation of digital resilience interventions.
- **Collaborative Efforts:** Foster collaboration between school psychologists, teachers, parents, and policymakers to create a unified approach to digital resilience.
- **Tailored Interventions:** Design and implement specific interventions that cater to the needs of both general and special education students.

Implications for School Psychologists and Educational Practices

The findings have significant implications for school psychologists and educational practices. By enhancing their awareness and providing practical tools, school psychologists can play a pivotal role in promoting digital resilience. This proactive approach can lead to safer digital environments and improved mental health outcomes for students. Additionally, educational institutions must prioritize digital resilience as part of their overall strategy to address students' well-being.

Future Research

Future research should explore:

- **Longitudinal Studies:** Conduct longitudinal studies to assess the
- long-term effectiveness of digital resilience interventions.
- **Comparative Analyses:** Compare the efficacy of different digital resilience strategies across diverse student populations.
- **Integration with Curriculum:** Investigate the integration of digital resilience education within the school curriculum and its impact on student outcomes.
- **Technological Advancements:** Examine how emerging technologies can be leveraged to support digital resilience efforts

5. CONCLUSIONS

In conclusion, this study highlights the crucial role of school psychologists in fostering digital resilience among students. While there is a strong awareness of digital challenges, there is a need for more consistent and effective practices to address these issues. By implementing the recommended strategies and focusing on collaborative efforts, school psychologists can significantly contribute to creating a safer and more supportive digital environment for all students. Future research should continue to build on these findings, exploring innovative approaches and long-term impacts to ensure the continued well-being and success of students in the digital age.

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Session 8:

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Gamification in Primary Education: What It Is, Benefits and How to Use It

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Abstract: *In the field of education in recent years, two topics stand out as dominant: online teaching and gamification. Gamification is increasingly detected as an important element in the development of learning methods, e-learning and digitalization. Game-based learning is an innovative form of education that incorporates educational computer games. Various forms of computer games are widely used in education.Gamification also includes software for educational games, learning aids, teaching improvement and student assessment.However, most teachers are very cautious and distrustful of exploring this concept of learning and its application in teaching. The paper focuses on the basic questions of this topic - what exactly is gamification in education, why is it such a growing trend, and how to apply it all in regular teaching, online and school classes. This article discussesthe effects and implications of gamification in primary education with the aim of providing a critical point of view on its use. Positive and negative effects are discussed, as well as various factors that influence the effectiveness of gamified learning. In addition, gamification is also scrutinized from a modern perspective, including points of consideration such as the current state of technological development.*

Keywords: *Gamification; Online Learning; e-Learning; Education*

1. INTRODUCTION

Play is a fundamental human activity that fosters curiosity and facilitates skill acquisition and behavior change. Numerous fundamental researches in the field of psychology, as well as affective neuro-science, have revealed that play is not only entertainment and useless waste of time for the purpose of entertainment, but also a developmental need, which is characteristic of all mammals [1]. Researches showed that handling emotions is learned through play, in addition to the fact that play significantly affects the development of both physical and social skills of an individual [2]. It can be argued that play is an evolutionary product. Games can be defined as rule-based systems of meaningful choices towards desirable goals. Games such as sports and board games have been the staple of ancient human civilizations [2].

When you look at the importance of games, as a part of development, but also of other human activities, it becomes meaningful and clear that a functional way must be found to include games as a part of business and educational systems [3]. The idea of using games, as a form of functioning in non-game conditions, is not new. However, a systematic approach to the problem of applying that idea is more recent. Thus, the concept of gamification appeared for the first time in the early 2000s. The term gamification has gained great interest and popularity only since 2010, and the very concept of gamification was introduced in 2002 by the British developer Nick Pelling [4]. Gamification stems grammatically from the verb gamify, which was presumably first used by Richard Bartle in his work on the first Multi-User Dungeon (MUD), one of the first computer-generated gameful and social virtual worlds [5].

2. GAMIFICATION: CONCEPT, IMPORTANCE AND IMPACT

A number of definitions of gamification can be found on Internet and in literature. In short, gamification would be the application of principles from games to new non-gaming environments. The two most important goals to be achieved through gamification are: motivation for a specific activity and achieving a goal (achievement) from the game [6].

Although gamification started to appear as a topic only fifteen years ago, in less than a decade it found wide application in literally any aspect of life, i.e. everything can be gamified. The integration of gamification techniques into various sectors of the economy and society has been a notable trend in recent years. The systematic review revealed that the domain of education and training is emerging as the primary area where gemification is being implemented and intensively researched [7].

Within the educational environment, gamification's potential for transformative impact extends beyond simply making learning "fun". Research suggests that well-designed gamified learning environments can foster a range of cognitive and emotional benefits, such as improved problem-solving abilities, collaborative skills, and resilience [8]. Gaming is above all potent in fostering self-motivation, thereby contributing to long-term engagement and learning gains through play [9], [10]. Gamification is one of the most current issues in the field of education, certainly because it is increasingly being detected as an important element in the development of learning methods, e-learning and digitization.

Education experts define gamification as the application of typical elements and principles of games in a teaching context to encourage participation, increase commitment and effort, and improve results. Although it seems to teachers that games first found application in the classroom, the truth is that they have been used for some time in various other segments of life, from business (marketing games) and travel (earning points for discounts), to surgeon training (AI trainings), to motivating cashiers in supermarkets (who gets items through the cash register faster). Already this spectrum of examples of successful application in different fields is enough to convince the teaching staff to give gamification a chance in the classroom.

However, most educators are very cautious and distrustful of exploring this concept of learning and its application in teaching. Plantak Vukovac and associates (2018) published their research on gamification in elementary schools. The research included a survey of teachers about the practical application of gamification in their teaching practice. In addition, the general attitudes of teachers towards gamification, as a form of teaching environment and teaching practice, were examined. The results showed that only one third of the surveyed teachers were even familiar with the concept of gamification. The other teachers were not familiar with the concept of gamification, in terms of what it entails, how it is implemented and which methods of work, lesson planning, instruction organization are most suitable for gamified teaching. Also, most of the teachers involved in the research, have never participated in professional development on gamification. With this kind of research, the authors pointed out a big gap in the educational system, where teachers reported a lack of knowledge when it comes to gamification, a lack of time to create such an educational environment, but also a lack of interest in improving teaching methods [11].

Perhaps educators' reticence towards gamification in education can be justified by a relatively demanding teaching approach, extensive preparation and thorough planning of teaching in such an environment. As an instructional approach, it extends to different disciplines (science, technology, engineering, mathematics, arts), with each employing distinctive mechanics and reward systems adapted to the learning outcomes of the discipline [12]. Indicative examples include point-based grading systems [13]; leaderboards for academic achievements [14]; and even more intricate constructs, such as game-based learning platforms that simulate real-world scenarios [15]. Gamification has also infiltrated e-learning and professional training environments, where interactive online courses often use game elements to improve student engagement. Namely, for an even more practical presentation of gamification in an educational environment, it is best to say that it is a system that can include elements such as points, badges, levels, challenges, a table with positions, etc. In addition, there is the dynamic of games, which implies competition, speed, patience, rewards, pride, building status, satisfaction with achievements. If education is viewed as preparing and equipping young people for life after school, aren't these competencies exactly what they will encounter or strive for in real life?

Gamification certainly makes the teaching process more fun and, if it used with purpose and understanding, can bring many benefits. Namely, it should be kept in mind that gamification is a tool, not a solution for reaching the goal (which is the development of knowledge and skills among students). It should be complementary to traditional learning, to facilitate and supplement it, motivating students to come to knowledge independently or give it a useful value, through discovery. It is a big misconception that it is enough to give a student a tablet or a computer and find an educational game. Gamification can motivate and direct the learner, but that direction can also be towards the wrong goal. Student motivation can be superficial and external, and will not produce deeper results, so it is crucial for the teacher to connect the elements of the game with substantive knowledge or skills. In addition, students can be focused only on winning the game as a goal, thus neglecting the goal that should be in focus, which is learning and mastering a subject. That is why it is important for the teacher to be a game-master, to be able to manage the process and time, directing the students towards the right outcome [16]. It can be concluded that gamification can and will give results only if the teacher knows well the subject he is teaching and its use value, the laws and benefits of games and prizes, then if he has motivation and wants as many students as possible to like and discover his subject and has enough support, resources and freedom to implement own ideas.

Gamification in education is important because it can overpass the great gap between the two extremes - students are generally unmotivated to learn, and they easily access playing various computer and mobile games. Gamification was conceived as an instrument that can replace this state of affairs, and therefore represents one of the greatest innovations in education.

3. GAMIFICATION TEACHING MODE IN PRIMARY SCHOOL

The elementary school stage is a critical period for fostering students' basic literacy. For most subjects in primary school, the connotation of basic literacy is multifaceted and should include the following main contents:

- Awareness of the subject topics covered – elementary school students should understand and master some basic subject matter theoretical knowledge, develop a holistic understanding of the topics, actively think and study the subject issues and gradually improve competences and knowledge in that area;
- They should develop logic and thinking – primary school students should think actively during the entire learning process. Through systematic learning, with continuous mastery of knowledge and skills, they need to learn from each other and learn by analogy when solving problems, in order to continuously improve ability to think logically;
- Communication – primary school students need to expand own understanding and understanding of subject areas, to communicate and apply relevant knowledge, such as using expert language and correct terms;
- Practical applications – after the theoretical learning of knowledge and facts in the classroom, attention should also be paid to extracurricular practical applications. The combination of theory and practice should be emphasized in order to encourage students to flexibly apply the acquired knowledge to solve practical tasks and problem situations, which helps to improve the comprehensive development of students' abilities [17, 18].

Primary school children have a strong curiosity and are interested only in relatively new things, which is a reference for designing teaching activities for teachers. Primary school teachers should pay attention to understanding students' psychological characteristics and they should attract and encourage students to learn actively in training activities. Only when students develop an interest in learning, the basic conditions for promotion basic competencies can be provided [17]. In the process of creating a gamified teaching model, teachers should take into account and include the psychological characteristics of students, by introducing game activities to stimulate students' interest in knowledge [19]. Driven by curiosity, students will show motivation to explore unknown fields in the game. This can stimulate students' interest in learning and develop their intelligence by introducing elements of play into the lesson. It can also go a long way in cultivating good logical thinking skills [20]. In traditional instruction, teachers should actively explore and implement teaching reform and design game activities based on students' psychological needs, so as to encourage students to show strong interest in learning and fully reflect the great value of gamified teaching.

The important thing related to the gamification process is that it isn’t only reserved for an online teaching, but the teacher can always create own scenario for a live educational game in the classroom. But the prerequisites needed for successful gamification are the same for both live games and online content.

3.1. Key Components of Gamification

Effective gamification assumes four basic components: goal setting, feedback and reinforcement, progress tracking, and social interaction. Only when all these four elements are unified together, they provide the structure for a gamified experience [5, 21].

Goal setting – Goal setting is an important part of gamification, as it gives students a clear objective to work towards. Goals should be defined so that they are achievable. As well as that resources are available to students to achieve such set goals. Practice shows that it is more effective to set several smaller goals, which are more accessible, than one global one, the achievement of which requires more effort and more long-term work [22]. By setting achievable goals, students are motivated to work hard and stay engaged in the learning process. For example, one of the goals can be that the student submits his homework on time. The second goal is to have that task done properly and correctly

Feedback and reinforcement – Feedback and reinforcement are also crucial components of gamification. During work, everyone likes to be updated and informed about whether they are working in the right way, correctly and whether they are progressing in the right direction. Knowing about the correctness of the work is an additional motivation to continue with the work. Also, knowing about a possible error during work, provides a chance to change the approach to the problem and to make the necessary corrections. By providing students with regular feedback on their progress, teachers can help them stay motivated and engaged [22].

Reinforcements, such as rewards and recognition, can also help encourage students to keep working toward their goals [5]. In the example of assigned homework, the feedback is whether or not students receive credit and points for turning homework in on time. Or how many points they get for doing their homework correctly.

Progress tracking – By tracking their progress toward their aims, students can see how far they've come and stay motivated to keep going [22]. Monitoring progress also allows the identification of areas where students may be struggling. This made it possible to provide additional support to students as needed. Using the homework assignment example, progress tracking occurs when students can see on the scoreboard how many points they have and how close they are to receiving the next award.

Social interaction – Social interaction is the final key component of gamification. Pedagogy and educational sciences have long recognized social interaction and social inclusion as an extremely important factor in education. The purposefulness of learning and the importance of acquired knowledge, as well as the possibility of their application in the social environment, are crucial factors of motivation to learn [5]. By including social elements like collaboration and competition, it can be created a more engaging and interactive learning experience. Social interaction can also help students develop important social and communication skills, which are essential for success in the classroom and beyond. In homework example, the social interaction is when students can show their rewards to other students and everyone can see who is closest to the next prize on the leaderboard.

What is each game based on? What keeps students glued to their computer or smartphone when they play a game are actually the three fundamentals of any gameplay: challenges, rewards, and progress [5, 23].

Challenges – represent expectations that the student should achieve. Sometimes it's learning a new lesson, reviewing material, or taking a test. Almost all popular games have these aspects: sometimes your task in playing is to solve a puzzle on the current level, sometimes it is a transition to the next (more demanding) level of play, sometimes it is the fulfillment of a daily, weekly or monthly task. All these components are irresistibly reminiscent of homework at school, and yet students prefer to play games rather than schoolwork.

Rewards – follow the challenges. In the world of games, these are usually virtual coins, upgrades or items that make the game easier. In the world of education, these can be instruments in teaching that will facilitate, speed up, or be necessary in the work.

Advancement – is the main driver of motivation. In games, every attempt is scored. Of course, more successful attempts than unsuccessful ones. Progressing through the game is usually characterized by passing the level or solving all the provided tasks [23].

From the above, it can be seen that the process of learning through gamification is essentially the same as in classical teaching - there is a goal that needs to be achieved, progress is monitored and finally information is obtained about what has been achieved. The difference is in the methods and approach to the problem - the goals are partially fragmented; progress monitoring is online and more effective; the feedback and reward system is more transparent for all participants and is adapted to the more modern requirements of students who are digital natives.

3.2. Gamification Techniques in Classroom

Gamified learning is designed to have a positive impact on students by incorporating game elements into training strategies. Of course, there are various steps in implementing gamification in the learning process that can be implemented in the classroom, including integrating educational video games into the curriculum, encouraging independent learning in the gamification of homework, gamification in scoring, implementing a wider class reward system, ensuring that lessons be interesting from the beginning, making gamification part of the evaluation, choosing gamification in the form of multiple choice, giving rewards like badges, etc. However, the application of gamification requires that the system or platform be successful [24]. There are several techniques and approaches to gamification of teaching and learning, and some of them, which are the most common in primary schools, are briefly presented here [25].

Game-Based Learning [25] – is a gamification technique that incorporates game design elements into everyday educational activities. By creating games that reinforce skills and concepts, educators make learning more engaging and fun for students. Game-based learning is particularly effective for younger students, as it provides a structured and immersive learning experience. A good example is the use of interactive quizzes while processing material with students; thus, students would be given instant feedback and at the same time learning becomes a fun activity.

Points, badges, and leaderboards [25] – are popular gamification elements that encourage active learning among students. These elements influence the competitive spirit of students, encouraging them to strive for better results. When designed effectively, these tools help students develop a growth mindset, where they see mistakes as opportunities to learn. For example, a system where students who complete assignments on time are awarded a special badge that rewards their engagement can encourage other students to complete their assignments on time so that they too can receive a badge the next day.

Collaborative and Competitive Elements [25] – Gamification can also include elements of collaboration and competition, which can take advantage of the social nature of learners to achieve learning outcomes. Collaborative activities include cooperative learning, group projects, and group challenges. These activities not only make learning more fun but also help students develop important teamwork and communication skills. Competitive elements include head-to-head competitions and team challenges. These gamification elements not only make learning more fun, but also help students develop important social and emotional skills, such as competitive spirit and teamwork.

Actually Using Educational Games [25] – Gamification is essentially about taking the best elements of (video) games and using them to help students learn better. But if there are games already made that use these elements to help students learn, they can also make great additions to the classroom!

For example, Kodable is an educational app that helps primary students (in USA) learn the basics of computer science in a fun and engaging way [26]. Kodable levels offer helpful-hints, when students need them, and provide immediate feedback to help reinforce learning and build resilience. After completing levels students also receive positive support by leveling-up, collecting rewards, and gaining points they can use to upgrade their playable character. Together these elements motivate students to continue playing and learning.

Overall, gamification techniques can be an effective way to engage students in the learning process. By incorporating game design elements into educational classroom activities, learning can be made more fun and engaging while helping students develop important skills that will serve them well throughout their academic and professional careers.

In all presented gamification techniques, a common factor can be observed, which is that gamification turns lessons and lectures into fun and, in this way, releases greater potential for students to acquire new knowledge, skills and abilities [25].

Prerequisites for successful gamification are: fairness, clear and defined rules, interestingness, transparency, competitive spirit, specific tasks, sustainability and elements of advancement.

4. BENEFITS OF GAMIFICATION IN EDUCATION

If the advantages and benefits brought by gamification in education are considered, perhaps the most important thing is to point out the items that, viewed from the pedagogical aspect, are the most important in an educational process.

Thus observing, it must be pointed out at:

Increased student engagement - Gamification can help students engage more in learning, leading to better results. A Yee study from 2006 [27] found that achievement, students who want to excel, social factors, and immersion, students who want to discover new aspects of the game, are the three motivating factors that lead students to play games again and again. These same motivational factors, when used in the classroom, can increase student engagement by encouraging them to continue engaging with your materials and activities.

Improved learning outcomes - All of the previously discussed sources show that when games target students' critical thinking and problem-solving skills, they can improve students' information processing and retention skills. Therefore, introducing game elements into the classroom, and especially into educational material, can help students not only process that material better, but also remember it better [28].

Improved critical thinking and problem solving skills - Gamification can help students develop critical thinking and problem-solving skills by providing opportunities to apply knowledge in real-world scenarios. Experience shows that skills acquired from video games can be transferred to other fields. This means that using gamification in the classroom can better prepare students to apply the acquired knowledge outside the classroom or in other contexts [28].

Personalized learning experiences - Gamification also enables personalized/adaptive learning, where students can learn at their own pace and at their own level. By providing feedback and tools to monitor progress, gamified experiences help students stay on track and focus on achieving their learning goals [28].

5. CONCLUSION

Gamification is a powerful tool that can help students learn better, more efficiently and in a more interesting way. By using game elements, it is possible to create a more interesting and effective learning experience for students. With the many digital learning tools available today, gamification is becoming more accessible to schools of all sizes and levels. By understanding the key components of gamification and applying effective gamification techniques, it is possible to create a more engaging and rewarding learning experience for students.

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The Effects of Implementing Educational Software in Subject-Specific Mathematics Instruction

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Abstract: *In a modern educational context, educational software is becoming a key tool for enhancing mathematics teaching. Our study explores the effects of implementing such software on students' achievements. The motivation for this research stems from the results of the PISA testing, which indicated below-average knowledge among our students. An analysis of factors influencing student achievements was conducted using the Adaptive Neuro-Fuzzy Inference System (ANFIS) method, confirming the importance of educational software in improving students' mathematical skills. Subsequently, an experiment was conducted over three school years, involving two groups of students. The first, experimental group utilized educational software as the primary tool for learning mathematics, while the second, control group continued with traditional teaching methods. Through carefully designed experimental protocols, data on student achievements were collected via various mathematics knowledge tests, as well as their satisfaction with both traditional teaching methods and interaction with the software. The research results demonstrate that students using educational software achieve significantly better results on mathematics knowledge tests and are more satisfied with their learning compared to the group taught using traditional methods. This study highlights not only the positive impact of educational software on mathematics achievements but also the need for further research and practice in integrating technology into teaching to achieve optimal educational outcomes.*

Keywords: *Educational software; Mathematics; PISA testing; ANFIS method.*

1. INTRODUCTION

Learning mathematics can be difficult for various reasons; however, it is important to note that with the right approach and persistent work, most people can learn mathematics. This includes understanding basic principles, setting clear goals, practicing regularly, and seeking help when necessary. Additionally, finding ways to connect mathematics with the learner's interests or everyday life can make the learning process easier and less frustrating. Improving achievement in mathematics requires dedication, strategy, and perseverance.

Educational software can help students develop their mathematical skills, enhance their understanding of concepts, and achieve better results in mathematics [1, 2]. Educational software can be a useful tool for improving mathematical achievement in several ways [3, 4, 5, 6, 7]:

Interactive lessons: Software can provide interactive lessons that allow students to learn mathematics in a fun and engaging way. These lessons can include animations, videos, graphics, and other interactive elements that help students better understand concepts.

Customized content: Many educational software programs provide customized content that adapts to the knowledge level and abilities of each student. This way, students can work on their weaknesses and challenges at their own pace.

Exercises and tasks: Software can provide exercises and tasks for practicing mathematics. These exercises can be interactive and provide immediate feedback on the accuracy of answers, allowing students to see where they are making mistakes and learn from them right away.

Progress monitoring: Educational software can track student progress and provide detailed analyses of how they are performing in specific areas of mathematics. Based on these analyses, teachers and parents can provide additional support and guidance to students.

Motivation: Software can use motivational elements such as rewards, scoring, or ranking to encourage students to engage and continue learning mathematics.

Practical applications: Software can provide practical applications of mathematics that help students see how mathematical concepts are used in the real world. This can increase student motivation by providing a meaningful and relevant learning experience.

2. STATISTICAL ANALYSIS OF STUDENT ACHIEVEMENTS IN MATHEMATICS PISA TESTING

The Programme for International Student Assessment (PISA) has been implemented in the Organization for Economic Co-operation and Development (OECD) since 1997 and is one of the largest international research projects in the field of education. Student testing is organized every three years and the main goal is to enable the participating countries to adopt new strategies and improve education based on the obtained results.

The state of Serbia has been participating in the PISA testing since 2003, but it was skipped in 2015. PISA evaluates 15-year-old students, i.e. first or second grade high school students, in three areas: science, mathematics, comprehension and interpretation of texts, because this age limit is the limit of compulsory education in many countries. Mathematical literacy is the capacity of an individual to identify and understand the role that mathematics plays in the modern world, to formulate, apply and interpret mathematics in different contexts, to perform well-founded mathematical assessments using mathematical concepts, procedures, facts and "tools" to describe a certain phenomenon, explain and anticipate, to engage in mathematics so as to meet his current and future needs as a constructive, interested and reflective citizen [8].

The analysis of mathematical literacy, for the needs of PISA testing, was performed from three interrelated aspects: mathematical concepts, mathematical contents and mathematical situations. The number of points won by Serbian students is significantly below the OECD average, which can be seen in Table 1. The best average was achieved in the PISA 2012 test and it is 449 points, which is 45 points less than the OECD average or, according to rough estimates, for one level.

The number of countries participating in the PISA test is constantly increasing. Serbia did not participate in the PISA test in 2015, when 72 countries were tested, and there were 85 countries in the 2022 test, including Serbia. Table 2 shows that Serbian students are ranked rather poorly.

Table 1. *Average number of points in the PISA test*

year of testing	**2003**	**2006**	**2009**	**2012**	**2018**	**2022**
number of points Serbia	437	435	442	449	448	440
number of points OECD	500	498	501	494	494	472

Table 2. *Ranking of Serbia in PISA tests*

year of testing	**2003**	**2006**	**2009**	**2012**	**2018**	**2022**
number of countries	41	57	62	65	78	85
ranking of Serbia	34	41	45	43	46	42

3. PREDICTION OF ACHIEVEMENT FACTORS

3.1. Subject, objective and hypothesis

The subject of this research is the assessment of mathematics teaching performance from the perspective of introducing educational software into the teaching process. The aim of the research is to predict the factors influencing students' achievement in mathematics from the perspective of introducing educational software and to determine the effects of the application of educational software. It is hypothesized that the experiment will confirm the positive effects of applying educational software on students' achievements.

3.2. Description of the Data Processing Procedure

The data processed were collected over three school years in the Rasina District of the Republic of Serbia, which comprises 38 primary schools. Official statistical data from the schools at mid-term and end of the school year, as well as a survey conducted on a random sample of students and teachers, were utilized.

For data processing in this research, the Adaptive Neuro-Fuzzy Inference System (ANFIS) was employed. The structure of the ANFIS adaptive neural network comprises five layers and corresponds to the Sugeno model phase. The rule base of the ANFIS structure consists of phase IF-THEN rules. Data processing was conducted using the Matlab software package employing tools for neuro-fuzzy logic. Before data processing, i.e., training, the following steps were undertaken:

- Load the dataset containing input and output variables—this dataset represents a series of columns with numerical values, with the output variable located in the last column.
- Load the initial model structure—FIS Sugeno type with one output (ANFIS) was used.

- Select the optimization method for training the membership function parameters—hybrid method combining the least squares method and the gradient descent backpropagation method was used.
- Determine and enter the number of epochs and error tolerance as the output criterion for training—training stops when the specified number of epochs is completed or when the training goal is met.

After completing the FIS training, validation is performed using test data, which differs from the data used for training. Additionally, processing of all data is performed collectively. All obtained results are graphically represented and available in files.

The ANFIS network is trained for each input separately to determine:

- Mean error value (ME)
- Standard deviation (SD)
- Mean squared error (MSE)
- Root mean squared error (RMSE)
- Coefficient of linear correlation (R)

To demonstrate the hypothesis, data obtained for the root mean squared error (RMSE) value will be used. The influence of each input on the output can be determined based on the RMSE for each input. The input with the lowest training RMSE has the greatest influence or relevance on the output. Testing the RMSE is used to monitor overfitting between data in the training and testing processes. Besides determining the influence of individual inputs on the output, the combined influence of multiple inputs on the output value can also be determined in the same way. This section presents the results of the impact of one, two, and three input variables on the output.

3.3. Description of Variables

Learning mathematics is generally a very challenging task for many students. The aim of this part of the research is to assess factors that can improve the process of learning mathematics and enhance students' achievements. The average mathematics grade at the end of the school year is the output variable of the model, obtained as the arithmetic mean of final grades per class, and used as an indicator of students' achievements throughout the school year. This indicator represents a reliable value that depends on many different independent variables, some of which are presented in this study. These variables are:

Input 1: Average grade on the initial test - represents the average grade, per class, of the mathematics entrance test conducted at the beginning of each school year in all grades and is at the state level by grade.

Input 2: Average number of absences per student - represents, in total, per class, the average number of justified and unjustified absences per student at the end of the school year per grade.

Input 3: Number of students motivated to learn mathematics - represents the percentage of students, per class, who are motivated to learn mathematics, acquire new knowledge, and improve current knowledge.

Input 4: Number of students studying for grades - represents the percentage of students, per class, who study mathematics only to get a better grade, i.e., a grade with which they would be satisfied directly or indirectly (because of the average, parents, society, etc.).

Input 5: Number of students studying independently in a traditional way - percentage of students, per class, who individually, outside the classroom, study from literature and books or with expert assistance, in a traditional manner.

Input 6: Number of students studying independently using educational software - percentage of students, per class, who individually, outside the classroom, study using educational software or some platform for learning mathematics.

Input 7: Number of students regularly attending supplementary or additional classes - percentage of students, per class, who mainly focus on attending supplementary or additional classes provided by the curriculum and regularly attend such classes.

Table 3 shows the input parameters, with their minimum and maximum values, and the output parameter.

Table 3. *Range of Parameter Values*

INPUTS AND OUTPUT	**min - max**
Input 1	2.34 – 2.98
Input 2	2630 – 7156
Input 3	0.27 – 0.46
Input 4	0.50 – 0.81
Input 5	0.73 – 0.86
Input 6	0.08 – 0.24
Input	0.18 – 0.41
Output	*2.39 – 3.14*

3.4. Presentation of Obtained Results

Table 4 presents the mean error value, standard deviation, mean squared error, and root mean squared error for training data, test data, and all data combined, for the input with the greatest influence on the output variable.

Table 4. *The Influence of a Single Input on the Output - Student Achievement*

The Input with the Lowest Error	
Input num. 1	
Training - Error	*RMSE= 0.041169*
Test - Error	*RMSE= 0.045160*
All Data - Error	*RMSE= 0.041786*

Input 1 has the lowest RMSE, which means that the average grade on the initial test has the greatest influence on the output variable, i.e., on the average grade at the end of the school year, which serves as a measure of student achievement. In addition to the individual influences of inputs on the output, an assessment of the combined influences of two inputs on the output was also conducted. It was found that input 1 and input 6 in combination have the lowest RMSE, indicating the greatest influence on the output variable. This means that the average grade on the initial test and the number of students studying independently using educational software, combined, have the greatest impact on the average grade at the end of the school year.

The values of all training, testing, and combined data errors for the two most influential inputs combined, input 1 and input 6, on the output variable, as well as the reliability coefficient of the obtained model, are presented in Table 5.

Table 5. *The Influence of Two Inputs on the Output - Student Achievement*

The Input with the Lowest Error	
Input num. 1 - 6	
Training - Error	*RMSE= 0.023292*
Test - Error	*RMSE= 0.034231*
All Data - Error	*RMSE= 0.025218*

At the end, the influence of three combined effects of input variables on the output variable is presented. Inputs 1, 2, and 6 have the lowest RMSE, so their combined influence on the output is the greatest, i.e., the average grade on the initial test, the number of absences, and the number of students studying independently using educational software have the greatest impact on the average grade at the end of the school year.

The errors of training, testing, and all data combined during the processing of the three most influential input variables on the output, as well as the reliability coefficient of the obtained model, are presented in Table 6.

Table 6. *The Influence of Three Inputs on the Output - Student Achievement*

The Input with the Lowest Error	
Input num. 1 - 2 - 6	
Training - Error	*RMSE= 0.017032*
Test - Error	*RMSE= 0.176760*
All Data - Error	*RMSE= 0.069908*

4. EVALUATION OF OBTAINED FACTORS

Considering the aim and objective of this research, the method of experiment with parallel groups conducted in school conditions was used. Namely, it involved classes of the same grade, as two parallel groups, in which the research was conducted using the experimental method. Within this research model, multiple factors influencing the implementation of teaching in the formed groups are examined, and based on the obtained results, the effectiveness of the applied procedures is determined.

The research was conducted in five elementary schools in the Rasina District. The research process lasted for three years, during which the same groups of students were monitored. For the purposes of the research, two groups were formed: experimental and control. In each school individually, the same teacher conducted classes for both groups, and the groups were formed from two homogeneous classes based on achievements in the previous school year, in this case, in the fifth grade. The experimental group consisted of five classes, totaling 124 students, and the control group consisted of five classes, totaling 127 students. The number of students in each group remained constant during the research. Hybrid teaching was conducted in the experimental group as one of the methods of e-learning. Namely, classes were conducted in a way that involved a combination of traditional teaching and teaching using educational software for mathematics. The educational software "MATIŠ" was selected for the research, accounting for approximately 60% of the time allocation during the implementation of all areas of the curriculum. In the control group, teaching was conducted in a classical, traditional manner with occasional use of ICT, in the form of presentations.

Data collection was carried out through observation, testing, and surveys.

4.1. Results of Statistical Data Analysis

Statistical Data Analysis yielded average grades per knowledge levels. The knowledge levels in relation to the average grade are presented in Table 7.

Table 7. *Levels of Knowledge*

Levels of Knowledge	Basic Level	Intermediate Level	Advanced Level
Grade Range	1–2.49	2.5–4.49	4.5–5

Average grades per knowledge levels of students in the experimental and control groups were compared. Similar results were obtained for both groups in the fifth and sixth grades. In the seventh grade, the average grades of students in the experimental group were slightly higher. The differences were 0.17 for the basic level, 0.10 for the intermediate level, and 0.14 for the advanced level. In the eighth grade, these differences increased, with 0.18 for the basic level, 0.26 for the intermediate level, and 0.20 for the advanced level.

The data analysis also yielded the number of students in the experimental and control groups who achieved certain knowledge levels. In the fifth grade, this number was equal due to the balanced group selection. In the sixth grade, the number of students in the experimental group who achieved the basic level decreased by 18, while the number of students who achieved the intermediate level increased by 17, and the number who achieved the advanced level increased by 2. In the seventh grade, the number of students achieving the basic level decreased by 1, increased by 1 for the intermediate level, and remained unchanged for the advanced level. In the eighth grade, the number of students achieving the basic level decreased by 3, increased by 1 for the intermediate level, and increased by 2 for the advanced level.

Regarding the control group, there were no significant changes in the sixth and seventh grades, while in the eighth grade, there was a slight change with a decrease of 4 students achieving the basic level, an increase of 4 for the intermediate level, and no change for the advanced level.

When comparing initial and yearly test scores, the results showed that in the experimental group, the average scores on the yearly and initial tests in the following grade were generally consistent, while in the control group, there was a significant difference. Furthermore, comparing the experimental and control groups, students who learned mathematics using educational software achieved better results on both types of tests, with scores ranging from 6.02 to 12.13 on the yearly test and from 1.01 to 14.21 on the initial test.

On the final exam, which covers the entire elementary school curriculum, students in the experimental group averaged 13.45 points, showing better results than the control group, which averaged 10.18 points. Additionally, this result is 2.99 points higher than the national average score of 10.46 points.

4.2. Discussion of the obtained results

From the obtained results, it can be seen that the achievements of the experimental group are better than those of the control group. This is evident from the fact that in the experimental group, the number of students who remained at the basic level is significantly lower than the number in the control group. Specifically, students who learned mathematics using educational software made significant progress, with 25 students from the basic level advancing to the intermediate level, and 6 students from the intermediate level qualifying for the advanced level of knowledge. In the control group, the number of students at each level did not change significantly. At the level of elementary mathematics knowledge at the end of primary education, 25.2% of students remained in the control group, which is significantly higher compared to the experimental group where this percentage is 10.5%. At the intermediate level of knowledge, the control group has 55.9% while the experimental group has 65.3%, and at the advanced level, the control group has 18.9% while the experimental group has 24.2% of students.

Despite the fact that the average grades at each level are almost balanced (with a slight advantage for the experimental group), based on the presented data, it can be concluded that the use of educational software in mathematics classes contributed to students achieving better results, as reflected in their average current grades.

Others came to similar conclusions. Learning with educational software activates many more senses than learning in the traditional way [12]. All these senses enable better adoption of teaching contents, as well as much faster and easier recall of some taught content that has not been used for a long time [13]. Most educational software also has a variety of additional content to help children develop their mathematical thinking [14].

5. CONCLUSION

The success of educational software in improving mathematics achievement often depends on its proper implementation in the classroom, teacher support, and the quality of the software itself. When used effectively, educational software can be a powerful tool for enhancing mathematical skills and student achievement. This was the focus of the present study. The research results demonstrate that students who used educational software achieved significantly better results on mathematics knowledge tests and expressed greater satisfaction with their learning compared to the group using traditional teaching methods. This study highlights not only the positive impact of educational software on mathematics achievement but also the need for further research and practice in integrating technology into teaching to achieve optimal educational outcomes.

The results and conclusions of this work represent a special contribution to the methodology of teaching mathematics, which can be modernized and modernized in this way, and the teaching process itself can be improved, teachers can make it easier to plan lessons, and students can adapt teaching methods so that the best results can be obtained.

The scientific contribution of this work is that, in this way, by applying the Adaptive Neuro-phasic Interference System, the factors for the improvement of teaching can be predicted from any aspect and any subject, regardless of its specificities.

The practical contribution of this work is reflected in the fact that the results and discoveries in this work can be used when creating the curriculum for the subject of mathematics.

The limitations of this research are the small number of respondents, as well as the localized location of the research. The chosen ANFIS method has only recently been used for this area of research. The factors examined were derived from the author himself.

Guidelines for further research would refer to an increased sample of respondents, a larger territorial area as well as the symbiosis of several researchers in order to determine the factors being examined as objectively as possible.

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Training Tasks and Test in Micro- and Nanosystem Technique in the Specialty of Mechatronics at TU Gabrovo, Bulgaria

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Abstract: The article presents tasks and test for exercises in the training of micro- and nanosystem technology in the specialty Mechatronics at TU Gabrovo, Bulgaria. Test questions include topics on the history of nanotechnology, terminology, methods of creating and manipulating of MEMS, components and nanostructures, types of micro- and nanosystems, functional materials, polymers and their effects, indices and description systems, technological capabilities and application of components and microchip manufacturing. The tasks are for exercises on the topic of how big is the percentage of defectively made and the efficiency of chips, equations and calculations of reaction parameters, technological possibilities when creating specific components and systems.

Keywords: *tasks, test, micro- and nanosystem engineering*

1. INTRODUCTION

Task setting: Micro- and nanotechnology training includes lectures on the discipline from [1, 2], the exercise guide to it with tasks and an exam test. For this purpose, study programs for the discipline of the same name were prepared in 2017. and updated in 2020 for the disciplines Avant-Garde Technologies and High-Energy Technologies with a schedule of 30+15 hours and 15+8 hours for full-time and part-time studies, respectively [3, 4, 5]. The subject of the report is the exercise tasks and test.

2. EXHIBITION

Task 1.

A 4" silicon pad with a diameter of 100 mm stands for 1 minute in a closed container with cleaning class 10 under the influence of a laminar moving air jet with a velocity of V = 0.5 m/s. How many 0.5 μm particles does the jet subsequently clear from the base surface, with all caught and remaining on it?

- speed $V=0{,}5$ [m/s]
- time $t=1$ [min]$=60$ [s]
- area $A=\pi*d^2$; $d=100$ mm
- purification $R_{10}=10$ [particles/m^3]|v.$R_{10}=83{,}22$
  $v=V*t*A=0{,}5*60*(0{,}05)^2*\pi=0{,}236\ m^3$
- pollution=quantity_particles=64,5=1,06 [particles]; 61 area cm² (1)

Task 2.

61 chips with an area of at most 1cm x 1cm can be obtained from one 4" pad. What is the percentage of defective chips if all dust particles cause 1 error, and in the whole production it is necessary to put 5 critical steps in the mask. To what extent can the same dedusting be applied to each mask?

Task 3.

An important characteristic for any production process is the efficiency (efficiency) of the Y chips. In micro-technical production, it is defined as the ratio of quality chips to the total number of integrated circuit chips (substrates) according to the Poisson equation:

$$Y=\left[e^{-D*Ach}\right]^m$$

$$D=\frac{n}{S} \text{ - frequency of defects} \qquad (2)$$

where n is the amount of particles, number; S - the surface of the integrated circuit, Ach - area of the chip, m - number of operations in the process. How great is the efficiency (efficiency) of chip Y under the boundary conditions of problem 1? Compare the results.

Task 4.

As a rule, in a micromechanical chip only 10% of the structures are critical, i.e. here pollution leads to marriage. Calculate the achievable efficiency of chip Y!

Task 5.

Calculate, in comparison with equation (2), the efficiency of chip Y in a CMOS process with a chip area of 1 mm x 1 mm and 15 critical mask steps.

Task 6.

Electroplating of Ni-nickel layer. In a bath of electrolyte-nickel sulfate, a flat conductive substrate material is fixed on the cathode, which must be electroplated with a homogeneous nickel layer. Formulate the reaction equation for the nickel coating on the cathode!

Nickel is a silver-white metal with a yellowish tint. It has atomic number №28, atomic mass -58.69, relative density - 8.85 g/cm^3, melting point 1452 - 1455°C, electrochemical equivalent C=1.0947 [g/Ah], normal electrode potential +0.25 [V], appears in the I, II, III and IV valence, the microhardness of the galvanic coatings is 140 – 550 daN/mm^2. The smallest thickness of nickel coatings according to Standart BDS 3009/73 is indicated in table 1.

Table 1. *Minimum thickness of galvanic nickel coatings*

Minimum coating thickness [μm]			
Operating conditions	One layer	Very layered	Top layer **Ni**
light	7 - 12	12 - 15	5
medium	12 - 24	24 - 30	10
heavy	30 - 48	30 - 48	15

Nickel is one of the most widely used metals. It has a number of properties: reflectivity, hardness, wear resistance, electrical conductivity, thermal conductivity, as well as magnetic properties. Table 2 lists some commonly used metals and their specific mass [g/mm^2]. Table 3 shows the dependence of the nickel deposition rate on the current density.

Table 2. *Dependence of the mass of the coating on its thickness*

thickness	chrome	cuprum	nickel	silver	gold
1	6,95	8,93	8,85	10,50	19,30
2	13,90	17,86	17,70	21,00	38,60
3	20,85	26,79	26,59	31,50	57,90
4	27,80	35,72	35,40	42,00	77,20
5	34,75	44,65	44,25	52,50	96,50
6	41,70	53,58	53,10	63,00	105,80
7	48,65	62,51	61,95	73,50	135,10
8	55,60	71,44	70,80	84,00	154,40
9	62,55	80,37	79,65	94,50	173,70
10	69,70	89,30	88,50	105,00	193,00
11	76,45	98,23	97,35	115,50	212,30
12	83,40	107,16	106,20	126,00	231,60
13	90,35	116,09	115,05	136,50	250,90
14	97,30	123,02	122,90	147,00	270,20
15	104,25	133,95	132,75	157,50	289,50
16	111,20	142,88	141,60	168,00	308,00
17	118,15	151,81	150,45	178,50	328,10
18	125,10	160,74	159,30	189,00	347,40
19	132,55	169,67	168,15	199,50	366,70
20	139,00	178,60	177,00	210,00	386,00

Table 3. *Dependence of the nickel deposition rate on the current densit*

Current density [A/dm^2]	Nickel layer deposition rate [μm/h] at current availability [%]					
	50	**60**	**70**	**80**	**90**	**95**
0,5	3,1	3,7	4,4	5,0	5,6	5,9
1	6,3	7,4	8,7	10,0	11,2	11,8
2	12,5	14,9	17,6	20,0	22,4	23,6
3	18,8	22,3	26,2	29,9	33,6	35,4
4	25,1	29,8	34,9	39,9	44,8	47,2
5	31,4	37,2	43,7	49,8	56,0	59,0

The deposition of electroplating requires calculations to determine the time required to deposit the metal, the mass and thickness of the deposited metal, the magnitude and density of the current, and its usability. These calculations are calculated using the following formulas:

1. Mass of metal to be deposited:

$$m = 10*S*d*H, [g] \qquad (3)$$

2. The thickness of the coating obtained at a given current density and duration of electrolysis:

$$H = \frac{Dk*C*\eta*t}{d}, [\mu m] \qquad (4)$$

3. Time to deposit metal of a certain thickness at a given current density:

$$t = \frac{60*d*H}{Dk*C*\eta}, [\min] \qquad (5)$$

4. The current, required to obtain a coating of a certain thickness in a regulated time, is:

$$I = \frac{S*d*H}{C*\eta*t}, [A] \qquad (6)$$

5. Current usability:

$$\eta = \frac{60*H}{C*I*t} = \frac{H*d}{Dk*C*t}, [\%] \qquad (7)$$

where m [g] is the mass of the deposited metal, S [dm^2] – the surface to be coated, d [g/cm^3] – the relative density of the deposited metal, C [g/Ah] – the electrochemical equivalent, Dk [A/dm^2] – the cathodic current density, η [%] - the usability of the current, I [A] - the strength of the current, t [min] - the duration of electrolysis.

Task 7.

Derive the equation for the deposited mass (coating mass) on the substrate material from Faraday's first and second laws!

The chemical equation for the nickel plating reaction is:

$$NiSO_4 \leftrightarrow Ni^{++} + SO_4^{--} \qquad (8)$$

- According to the first law:

$$m = \frac{A*I*t}{96500*n}, [g] \qquad (9)$$

- According to the second law:

$$m = 10*S*d*H = 10*S*Dk*C*\eta*t = 10*I*C*\eta*t\ [g] \qquad (10)$$

Task 8.

Derive the rate of the plating process as a function of current density!

According to table 3. at 80% current utilization, the relationship between deposition rate and current density is linear in close approximations (shown in Fig. 1).

The coating thickness is:

$$H = \frac{I*C*\eta*t}{S*d}, [\mu m] \quad (11)$$

The speed of the process is defined as the thickness of the layer per unit of time:

$$V = \frac{H}{t} = \frac{I*C*\eta}{S*d}, \left[\mu m / \min \right] \quad (12)$$

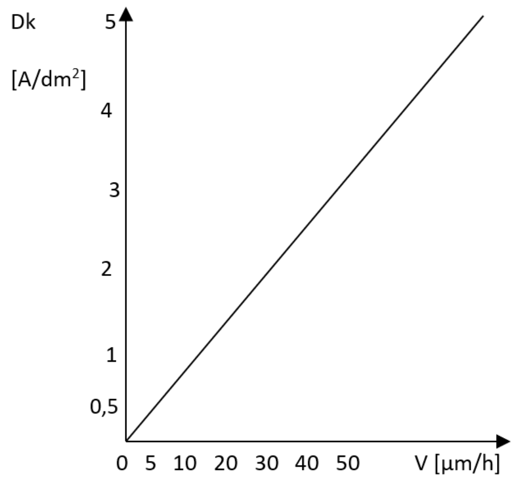

***Figure 1**. Dependence between current density and deposition rate*

Task 9.

Calculate the required nickel plating exposure times for: a) 2: b) 4 and c) 6 [A/dm²], if a nickel layer of 8 µm is to be electroplated on the carrier, and the current efficiency amounts to 95% (hint: M(Ni)=58,71g/mol).

Nickel layer thickness H=8 µm, electro-chemical equivalent C=1,0947[g/Ah], cur-rent utilization η=95 [%], relative density of the deposited metal d=8,85 [g/cm^3];

a) cathode current density Dk=2 [A/dm^2], t=?

$$t = \frac{H*d}{Dk*C*\eta}, [h] \quad t = \frac{8*8,85}{2*1,0947*0,95} = \frac{70,8}{2,07993} \approx 34[h] \quad (13)$$

b) cathode current density Dk=4 [A/dm^2], t=?

$$t = \frac{8*8,85}{4*1,0947.0,95} = \frac{70,8}{4,15986} \approx 17[h] \quad (14)$$

b) cathode current density Dk=6 [A/dm^2], t=?

$$t = \frac{8*8,85}{6*1,0947.0,95} = \frac{70,8}{6,239796} \approx 11,34[h] \quad (15)$$

Task 10.

Calculate, using the values from the previous task, the magnitude of the currents for which electrochemical equivalent C=1.0947[g/Ah], current utilization η=95[%], relative density of deposited metal d=8.85 [µm]; I=?

$$I = \frac{S*d*H}{C*\eta*t} = \frac{S*d*V}{C*\eta} = \frac{100*10^{-4}*8,85*12}{1,0947*0,95} \approx 5,32[A] \quad (16)$$

Task 11.

Construction and encapsulation of a piezoresistive pressure sensor on a silicon substrate. A piezoresistive pressure sensor is to be designed. Figure 2. shows the cross-section of the sensor to be created. It must consist of a thin membrane on which the semiconductor resistances are located, which will convert mechanical quantities into electrical ones. With the selected projection, they are not visible, but should be on the upper side of the sensor. The sensor should be sized for a maximum pressure of 1*10^5 Pa. The membrane should have an area of 2x2 mm.

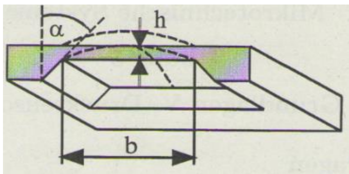

***Figure 2**. Section through the sensor from below*

Task 12.

At very high voltages in the membrane, linear errors occur in the transfer function of the converter. Therefore, the maximum voltage T appearing in the membrane should not be greater than 1/10 of the breakdown voltage. Calculate the resulting membrane thickness h and the maximum deflection x.

T=Tв/10; Tв≈500 [MPa]; p=10^5 [Pa]; b=2 [mm]; h=? x=?

T = Tв/10 = 500/10 = 50*10^6 [Pa]

$$T = \frac{1,18*b^2*p}{4h^2}$$

$$h = \frac{\sqrt{1,18*b^2*p}}{4T} = \frac{\sqrt{1,18*2^2*10^5}}{4*50*10^6} = 0,236[mm] = 236[\mu m] \quad (17)$$

$$x = \frac{b^4*(1-\nu)^2*p}{32h^3*E} = \frac{2^4*(1-0,26)^2*10^5}{32*0,236^3*170*10^{-9}} = 12,25[\mu m] \quad (18)$$

Importantly, when applying bright nickel coatings, higher current densities and elevated temperatures are used, which contribute to faster deposition of the coatings. S=100 [cm^2] – surface to be coated, deposition rate – V=12 [µm/h], the corresponding current densities must be set for the area of the substrate material A=100 [cm²]?

Task 13.

How are the planes of the crystal oriented, and what surface layer deposition method can be used to create a membrane in the shape shown? Indicate the directions of the crystal in Fig. 2. How big is angle α? How is membrane thickness fine-tuned? The crystal planes are oriented according to Fig. 3.

The membrane, with the shape shown in figure 3, is obtained by anisotropic etching. The angle between directions (100) and (111) is equal to 54.74°. Angle α is the difference from this angle to a right angle.

$$\alpha = 90 - 54{,}74 = 35{,}26° \qquad (19)$$

The thickness of the membrane is inversely proportional to the etching time h=1/t, and the speed reaches 3 μm/h. By precisely determining the etching time, the required thickness is achieved.

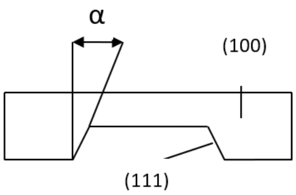

***Figure 3**. Planes of the crystal*

Task 14.

The resistances must be realized in a material doped with n-type conductivity. At creation the electron density should be set to n=1016/cm³. A resistance of 1000 Ω should be read over a 200 μm length without the influence of the piezoelectric effect. How large should the resistance cross-section be chosen? Arrange the resistors in the form of a bridge circuit for maximum sensitivity. Sketch the arrangement of the resistors and the supply wires to be fabricated from aluminum. There are 3 possible arrangements which are shown in figure 4:

a) mixed arrangement - small linear error; R1/R2 – resistance in the longitudinal direction to the current circuit; R3/R4 – esistance across the current circuit;

b) longitudinal arrangement – large linear error;

c) transverse arrangement - small linear error, large voltage at the zero point (fig. 4).

E=1,6*10^{-19}[As]; μn=1250 [cm^3/Vs]; n=10^{16} [cm^3]; l=200 μm = 0,2 [mm]; R=1000 [Ω]

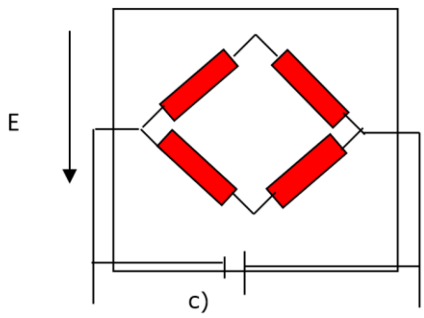

***Figure 4**. Bridge schemes of inclusion of resistances*

$$\rho = 1/e*n*\mu_n = 1/1{,}6*10^{-19}*10^{16}*1250 \approx 0{,}5 \qquad (20)$$

$$R = \frac{\rho * l}{A} \Rightarrow A = \frac{\rho * l}{R} = \frac{0{,}5*200}{1000} = 0{,}1\left[\mu m^2\right]$$

This concludes the sensor design considerations. Naturally, it is convenient here to mention the necessary conclusions to move forward. The indicated formulas are approximations that we can use without making a serious mistake. For those with a deeper interest in sensor development, formulas and constants are given in [1]. The following tasks are aimed at actual production.

Task 15.

Explain the manufacturing process of creating a membrane pressure sensor and transducers. Describe the technological scheme of basing, how and with what technology the individual work operations should be performed.

Figure 5 shows a piezoresistive pressure sensor with a silicon membrane fabricated by anisotropic etching on the reverse side of the silicon substrate. In the place of the maximum deformation of the membrane, the strongest piezo-resistive effect is manifested. Stoppers prepared by diffusion or ion implantation are used to form the active structure of the sensor. Silicon p-layer doped with high boron content (concentration of boron impurity 5*10^{19} cm^{-3}) is etched much more slowly in KOH than lightly doped. This possibility was implemented in the production of the membrane.

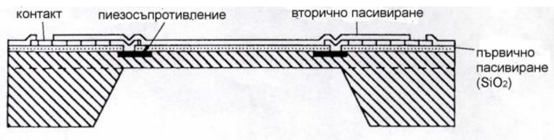

***Figure 5**. Piezoresistive silicon pressure sensor*

Task 16.

Is there another technological possibility for production with a similar result? Describe it briefly. The technological process for an acceleration sensor is shown in Figure 6. In the fabrication of this microstructure, a layer of silicon nitride (insulator) and silicon dioxide are successively deposited on the surface of a silicon substrate. In the next operation, the places where there should be holes are marked by photolithography. Next, a dense layer of polycrystalline silicon is applied and the desired structure is obtained by etching it. Finally, the unnecessary silicon dioxide is removed and a free structure is obtained.

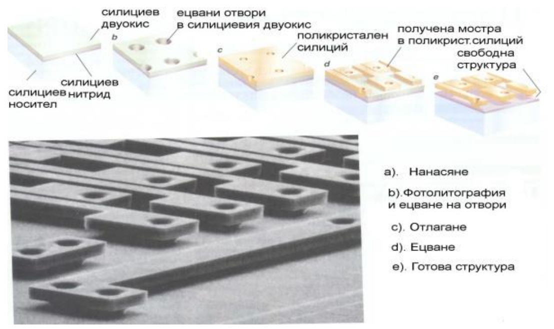

***Figure 6**. Technological process of acceleration sensor*

***Legend:** a) deposition, b) photolithography and hole etching, c) deposition, d) etching, e) finished structure; obtained sample in polycrystalline silicon, above free structure*

Task 17.

There is a possibility of production using the LIGA-method [1]. Describe the process flow of the LIGA-method and list its advantages and disadvantages.

The method is a combination of lithography and electroplating, shown in Figure 7. In the first stage, a three-dimensional structure is obtained in thick resistive layers by a lithographic process. Through electroplating, a metal negative of this structure is obtained, which in some cases represents the final product, but can also serve as a tool, for example, an injection mold, a press mold, and others. The latter allows the preparation of microstructures in serial production at high economic efficiency.

According to the type of structuring, the LIGA-method is divided into:

• depth lithography - the characteristic features of the method are:

- lithographic process for thick resist structures with high etching ratio up to 100:1;

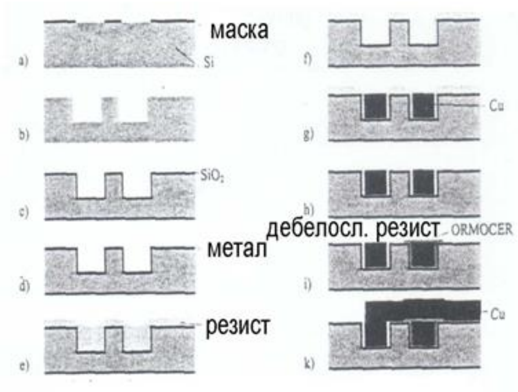

***Figure 7**. Technological process in photolithography*

Legend: a*) fabrication of SiO_2-mask on a silicon substrate, b) liquid etching of silicon, c) oxidation, d) metallization, e)-applying a special resist to stop the process, f) lithography, h) copper-based electroplating of the first conductive layers, i) structuring with thick film resist, k) electroplating.*

- additive method for the production of heterogeneous metal microstructures;
- formability, allowing the application of metal microstructures as tools for injection molding and hot stamping;
- a wide palette of workable materials - metals, alloys and ceramics;
- constructive diversity.

High precision and economic efficiency.

• lithography of the surface layer - the features of this process are:

- the possibility of depositing metals in small capillaries over large areas and gold electroplating in structures for X-ray masks with dimensions of the order of nm. Figure 8 shows a technological process sequence for the production of a capacitive acceleration sensor.

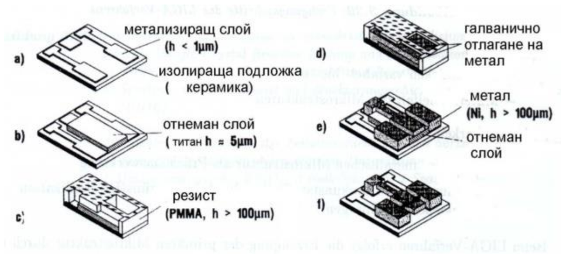

***Figure 8**. Sequence of a technological process for the production of a sensor*

In the case considered, many simplifications were made. In order to create an idea of a similar product that is available in commercial form, in fig. 9. two photographs of a photocell element that is proposed for use in medical technology can be seen.

***Figure 9.** Schematic diagram and photo of a pressure element of the company "Nova-sensor", with application in medical technology*

Electrostatic Actuators and Sensors: Actuators and sensors based on the principle of electrostatics are of great importance in micro-engineering.

Task 18. Electrostatic systems.

Electrostatic systems are based on the principle of a capacitor with flat plates moving relative to each other. Actuators and sensors can be built this way. Specify input and output parameters for electrostatic actuators and sensors! Electrostatic systems:

♣ Electrostatic actuators;
  - ✓ Input parameters: electric field controlling input voltage;
  - ✓ Output parameters: displacement, rotary motion;

♣ Electrostatic sensors;
  - ✓ Input parameters: mechanical impact (deformation, pressure, pressure, acceleration), acoustic emission;
  - ✓ Output parameters: charge, current, voltage, impedance, capacitance.

Task 19. Calculation of the power of electrostatic actuators.

In this task, a capaci-tive actuator must be considered. This type of actuators have a suspension that allows the movement of the armature only in a vertical direction to the electric lines of the field shown in Fig.10. In this case, the distance between the electrodes y_0 remains constant, regardless of the deviation. By means of the cam structure, the negligible electrostatic forces can be multiplied. Calculate the force F_{kap} in an electrostatic capacitive actuator with n zones of action of the electrostatic field, accumulating electrical energy in the capa-citor!

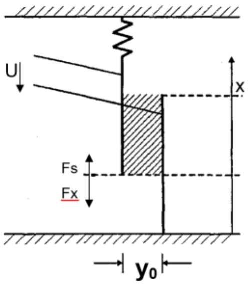

Figure 10. *Schematic diagram of an electrostatic capacitive actuator*

The capacity of the arms in the middle position is

$$C = \frac{\varepsilon * a * x}{d},$$

where x is the transverse size of the electrodes. For the off-center position, the capacities will be respectively:

$$C_1 = C_0 + \frac{\varepsilon * a * x_1}{d} \text{ and } C_2 = C_0 + \frac{\varepsilon_0 * a * x_2}{d}, \qquad (21)$$

where $x_1 = x - \Delta x$ and $x_2 = x + \Delta x$

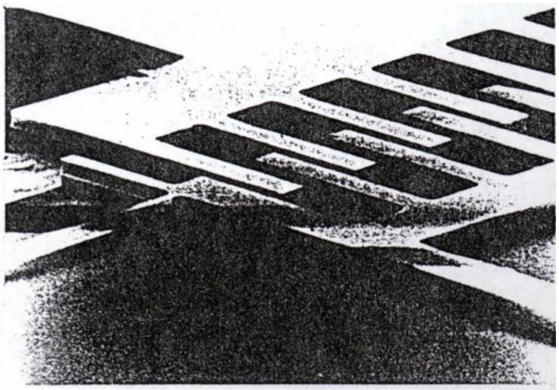

Figure 11. *Electrostatic actuator with variable area*

The displacement $\frac{\Delta x}{x}$ will be a linear function of the input voltage:

$$U = \frac{E}{2} * \frac{\Delta x}{x} \left(\frac{1}{1 + \frac{C_0}{C}} \right) \qquad (22)$$

With n-tooth comb actuators, n number of field zones is also obtained, and the total capacity will have the value:

$$C = \varepsilon_0 \varepsilon_r * \frac{a * n * x}{d} \left(\frac{1}{1 - \frac{\Delta x}{x}} \right) \qquad (23)$$

The force between the plates will have the value:

$$F_{кап.} = \frac{U^2}{2} * \frac{\delta C}{\delta x} = \frac{U^2}{2} * \frac{\varepsilon_0 * \varepsilon_r * a * n * x}{d} \left(\frac{1}{1 - \frac{\Delta x}{x}} \right) \qquad (24)$$

Task 20. Calculation of the field strength

The actuators described above need a return spring to bring them to a certain rest state. It can be realized as shown in fig.12.

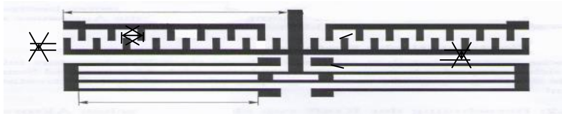

Figure 12. *Schematic diagram of an electrostatic comb actuator*

$$F_{np} = c * x_o \qquad (25)$$

with $c = b * E * \left(\frac{h}{l} \right)^3$ - spring constant of a simple s - shaped beam subjected to bending and guided by a parallel guide, $x_0 = \frac{U^2 * C}{2F_{kap}}$ - displacement caused by the control voltage and the attraction force between the capacitor plates.

1. Label the fixed and movable parts and describe the function of the arrangement!
2. Calculate the counteracting force of the spring. Consider also the arrangement as parallel and series inclusion of a simple beam subjected to bending, taking into account the acting external forces and moments!

Calculating the field strength:

By applying voltage, the overlap length of the actuator plates is increased, and the spring is stretched, which causes the occurrence of an opposing spring force of Fpr.

$$F_{np} = bE \left(\frac{h}{l} \right)^3 * \frac{U^2 C}{2F_{kap}} \qquad (26)$$

You have a dry etching facility available. It is able to etch (chemically etch) silicon with a depth of h=100 μm. Here it is possible to obtain large depths with a high etching ratio AR=50:1.

1: The actuator you need to create should be 20.5 μm wide. The spring elements must be a maximum of 0.5 μm long. What is the maximum deflection that can be achieved with this arrangement if the voltage is 100 V?

2: Describe the individual process operations in creating this actuator! List the possibilities for building the mobile structures!

Fabrication of a comb-shaped actuator using dry etching (Fig. 13).

The operating voltage of a capacitor U_{Cmax} depends on the electrical strength of the insulating layer E_i and its thickness d_i.

$$U_{C\max} \leq E_i * d_i$$

For silicon dioxide (SiO_2) the dielectric strength is: $E=1{,}7*10^4$[V/cm], and the dielectric constant $\varepsilon_{SiO2}=4$. For voltage U=100 V, the layer thickness will be:

$$di \le \frac{U_{C\max}}{Ei} = \frac{100}{1{,}7*10^4} = 58{,}824\mu m, \quad a=b=500[\mu m]$$

$$x = \frac{b}{2*n-1} = \frac{500}{249} = 2, \quad \varepsilon_0=8{,}854*10^{-12}[F/m]$$

n=500/4=125 the tooth $\varepsilon_r=1{,}00059$ (27)

$$E = \frac{C*U^2}{2} \Rightarrow C = \frac{2E}{U^2}$$ from the capacity

$$C = \varepsilon_0 * \varepsilon_r \frac{a*n*x}{d}\left(\frac{1}{1-\frac{\Delta x}{x}}\right)$$ the deviation is output:

$$\Delta x = 1 - \frac{\varepsilon_0*\varepsilon_r*a*n*x^2}{C*d} = 1 - \frac{\varepsilon_0*\varepsilon_r*a*n*x^{2.}*U^2}{2*E*d} =$$

$$= 1 - 1{,}107 = \pm 0{,}107\mu m \quad (28)$$

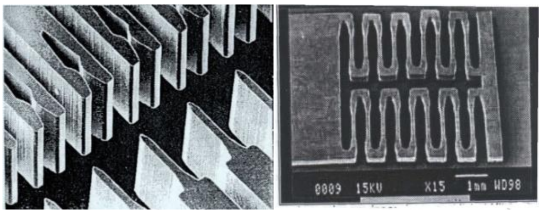

Figure 13. *a) Electrostatic Actuator Parts; b) Actuator spring*

Task 21. Creation of a silicon comb-shaped actuator by micromechanical processing of the surfaces.

With the parameters from the previous task, to fabricate the same comb-shaped actuator, but now through silicon micromachining of the surfaces.

A possible option for preparing such an actuator is by using the LIGA-method with depth lithography (Fig. 14.)

Describe the individual process operations in creating this actuator by micromachining the surfaces!

Creation of a silicon comb actuator by micromachining the surface layer:

1. With the development of the microtechnical production methods based on structuring by photolithography, the methods of mechanical micro-processing in the direction of ultra-precise technique also developed. This development of "conventional" machining methods from tool manufacturing has led to the precious production of volumetric microstructures, as

What height of the structure can be achieved with this technological method stones, hard metals and titanium. During micromechanical processing of the surfaces, shapes with a structure height of 20 to 500μm are obtained. The great flexibility of mechanical micro-machining makes it possible to obtain a variety of stepped structures, walls with an inclination as desired, structuring of a large area and height. The category of basic structures in the micromechanics of the surface layer includes membranes, bridge structures, beams loaded in bending and torsion, fixed or rotating structures.

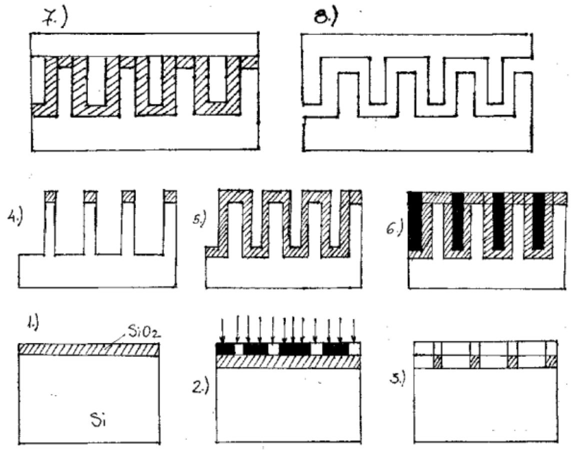

Figure 14. *Making an electrostatic actuator using the LIGA method*

Legend: *deposition of insulating coating, deposition of resist and photolithography to mark the etch locations, etching to obtain a free space for the mobile structure, stripping, metallization, epitaxial growth of the stationary structure, reactive bonding of the stationary plate, dry etching to release space for movement of structures*

2. Spring length = 0,5 mm

   Height of the spring = height of the structure = 0,2 mm

   Structure width = 200/100=2 μm

   Dielectric strength- $E=1{,}7*10^4$ [V/cm]

   Dielectric constant of the material - $\varepsilon_0=8{,}854*10^{-12}$ [F/m]

   Dielectric constant for air- $\varepsilon_r=1{,}00059$

$$C_{об} = \frac{1}{1/4C+1/4C} = 2C, \quad F_{кап} = 2*U*E\left(\frac{b}{l}\right)^3 * x, \quad F_{пр} = c*x \quad (29)$$

$$d = n*\left(b_{из}+b_{кап}\right) \Rightarrow n = \frac{1000}{4} = 250 \quad (30)$$

SIMOX – application of dielectric coatings in an oxygen environment.

$$F_{пр} = F_{кап} \Rightarrow \frac{U^2}{2}*\varepsilon_0*\varepsilon_r*\frac{a}{y_0}*n = 2*h*E*\left(\frac{b}{l}\right)^3*x$$

$$\Rightarrow x = \frac{U^2*\varepsilon_0*\varepsilon_r*a*n}{4*h*E*y_0*\left(\frac{b}{l}\right)^3} \quad (31)$$

Laser-induced processes in micromechanics are: recrystallization, laser lithography, exposure using an ultraviolet laser beam, etching or deposition from a gas phase without a mask layer. By locally depositing or vaporizing gas-phase absorbing material with a laser beam from a Nd: YAG laser, clear mask defects are removed, quartz resonators, silicon bridges and beams are A bidirectional capacitor may have a shape such as that shown in Figure 15.

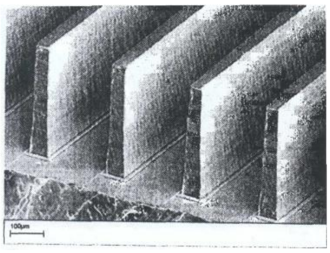

Figure 15. Comb-shaped actuator obtained by micromechanical treatment of the surfaces

The tooth tuned, layer resistors and capacitors are set to nominal value, resistances are equalized of the different layers in single-layer and multi-layer boards.

Task 22. Actuator oscillation:

The actuator shown in Fig. 16. can be deflected by applying tension in one direction only, and the counteracting force of the springs returns it to rest. For high-dynamic actuators, the counterforce is produced electrostatically. Describe what such a bidirectional actuator might look like?

Actuator oscillation:

For visible structures with a layer thickness of up to 1.5 μm, various options for micromechanical processing of the surface layer of silicon material with a depth of more than 200 μm are used well as the application of materials such as

- ✓ SCREAM – photolithographic method;
- ✓ SIMPLE - micromechanical treatment of silicone by plasma etching;

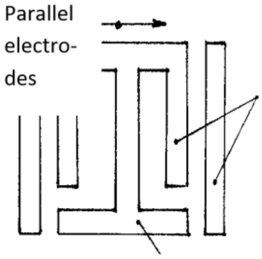

Figure 16. Two-way electrostatic actuator

3. CONCLUSION

Tasks are presented for the study of micro and nanosystems technology in the specialty Mechatronics at TU Gabrovo, Bulgaria. The aim is to use them, as well as the indicated sources, as teaching and methodical material by teachers and specialists. There are also self-study tasks in the test [1, 4, 5]. Information on the subject can also be found in [8,9,10]. The author is open for assistance.

CONSTANTS AND FORMULAS

- Electron mobility in silicon at room temperature: μ=1250 cm^2/Vs
- Charge of the electron: e=1,6*10^{-19} As
- Breakdown voltage of silicon: Тв≈500 MPa
- Modulus of elastic deformation of silicon: E=170 Gpa
- Poisson's ratio: ν≈0,26
- Stresses in a rectangular membrane:

$$T = 1{,}18 * \left(\frac{b}{2h}\right)^2 * p$$

- Average Bending of the Rectangular Membrane:

$$x = \frac{b^4 (1-\nu)^2 * p}{32 * h^3 * E}$$

- Resistivity for n-doped silicon: $\rho = \dfrac{1}{e * n * \mu_n}$ [11]

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Analysis of a Simple Algorithm for Phase Shift Measurement Between Sinusoidal Voltage Signals

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Abstract: *This paper presents the analysis of the problem of phase shift measurement error that arises in Simple Algorithm (SAL) when signals are not sampled synchronously. Data acquisition systems allow simultaneous multiple channel measurements by utilising one AD converter with multiplexer. Multiplexer introduces time latency between sampling of different channels, which makes sampling of signals non-simultaneous. By experimental measurements with NI 6009 data acquisition card and LabVIEW, as well as C++ simulations, two components of the measurement error will be identified: time dependant component which causes phase shift estimations to oscillate and constant component which introduces the offset in performed estimations.*

Keywords: *phase shift measurement; LabVIEW; Data acquisition system; measurement error*

1. INTRODUCTION

One of the problems when calculating electric power and energy in alternating current circuits is determining the phase difference between voltage and current signals [1, 2]. The current signal is easily transformed into a voltage signal by applying the shunt, so the task turns into estimating the phase difference between the two voltage signals. It is assumed that the harmonic distortions of these sinusoidal voltages are negligible, but realistic distortions and noise in the signals can also be considered.

High-accuracy measurements of phase are needed in the low-level RF systems [3]. Accurate and fast estimation of phase difference between the voltage and current of the electrical power system is required for calculation of its power factor [4]. It is also important in measurements of complex ratio of AC voltages [5]. The improvement of the precision of phase difference estimation method could be done by data extension and Hilbert transform [6].

This paper presents the application of the Simple Algorithm (SAL) for calculation of the phase shift between two signals [1, 2]. The analysis is performed both for measured and simulated signals. A focus is further given to the analysis of the measurement error identified during the measurements and simulations, caused by the imperfections in the signals or their sampling. Two independent components of this error are analysed in the paper.

The paper presents a short theoretical description of SAL, the obtained results and corresponding analysis, as well as the accompanying comments and conclusions.

2. THEORETICAL BACKGROUND

The problem of determining a phase shift between two signals can be mathematically described as follows: let two voltage signals be given in a form

$$u_1(t) = U_1 \sin(\omega_o \cdot t + \varphi_1), \tag{1}$$

$$u_2(t) = U_2 \sin(\omega_o \cdot t + \varphi_2), \tag{2}$$

where U_1 and U_2 are amplitudes, φ_1 and φ_2 are initial phases and ω_0 is the angular frequency which is known. The problem is finding the value of phase shift between two signals φ, given by:

$$\varphi = \varphi_1 - \varphi_2. \tag{3}$$

2.1. Mathematical base of Simple Algorithm

SAL is a fast algorithm for phase shift estimation between sinusoidal signals. It requires only two pairs synchronously and coherently obtained samples of signals to estimate their phase shift.

For solving a problem given by (3) two auxiliary signals should be introduced:

$$u_1'(t) = U_1 \sin(\omega_o \cdot t + \varphi_1 - \psi_1), \tag{4}$$

$$u_2'(t) = U_2 \sin(\omega_o \cdot t + \varphi_2 - \psi_2). \tag{5}$$

These auxiliary signals are phase-delayed for ψ_1 and ψ_2 compared to signals u_1 and u_2, respectively. Now, phase-delays can be set to:

$$\psi = \psi_1 = \psi_2 = \frac{\pi}{2}. \tag{6}$$

Finally, two parameters can be introduced:

$$m_a(t) = u_1(t)u_2(t) + u_1'(t)u_2'(t), \tag{7}$$

$$m_r(t) = u_1'(t)u_2(t) - u_1(t)u_2'(t). \tag{8}$$

It is easy to show that, when condition (6) is satisfied, solution of (3) is given by [1, 2]:

$$\varphi = \tan^{-1}\left(\frac{m_a(t)}{m_r(t)}\right). \tag{9}$$

Fig. 1 presents the signals and the corresponding samples needed for calculation of phase shift.

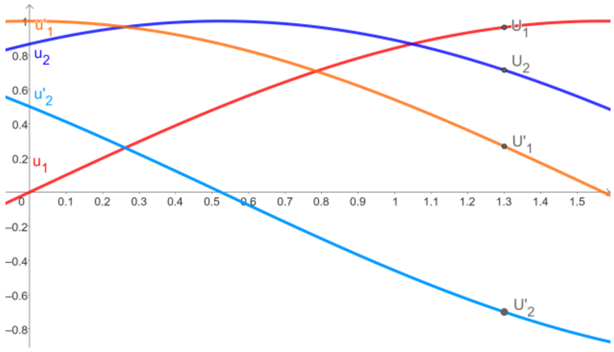

Figure 1. *An example of values necessary to estimate phase shift with SAL*

2.2. Sampling of original and auxiliary signals

By using any type of data acquisition system, a set of ordered pairs of time-discrete values of signals u_1 and u_2 can be obtained in the form of:

$$\{(u_1[nT_s], u_2[nT_s]) \mid n = 0, 1, 2, \dots\}, \tag{10}$$

where T_s is a sampling period. From this set of time-discrete values of the original signals, values of auxiliary signals can be obtained by assigning them the values of the original signals shifted for appropriate time interval:

$$u_1'[nT_s] = u_1[(n-r)T_s], \tag{11}$$

$$u_2'[nT_s] = u_2[(n-r)T_s]. \tag{12}$$

This is illustrated in Fig. 2.

Integer r should be chosen to satisfy the equation:

$$r = \frac{f_s}{4f_0}, \tag{13}$$

where $f_s = 1/T_s$ is the sampling frequency and f_0 is the signal frequency, so that sampling is coherent. It is important to note that since r is an integer, sampling frequency cannot be chosen arbitrarily.

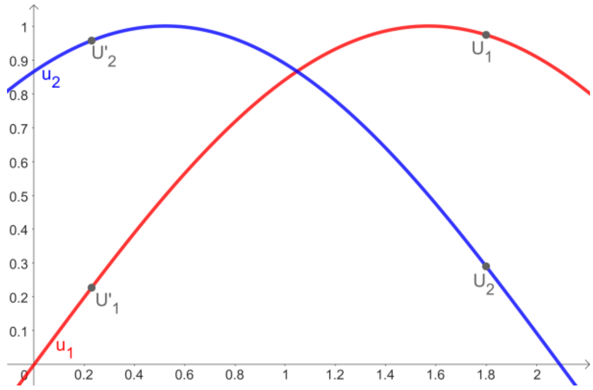

Figure 2. *Obtaining values of auxiliary signals from original signals*

After assigning values to auxiliary signals as described, equations (7) and (8) can be calculated, and therefore phase shift can be estimated using equation (9).

3. PHASE SHIFT MEASUREMENT ERROR ANALYSIS

From equations (7), (8) and (9) can be noticed that measurement error is dependent on the precision of measurement of signals u_1 and u_2 in terms of the current value and in terms of the time of sampling.

Measurement precision of current value of signals is directly determined by the resolution of AD converter used in data acquisition system.

If any pair of signal values is not sampled synchronously or if auxiliary signals are not determined from properly time-shifted original signals, the error will occur. In other words, if for samples of original signals $(u_1[t_1], u_2[t_2])$ and auxiliary signals $(u_1[t_3], u_2[t_4])$ equations:

$$t_1 = t_2, \tag{14}$$

$$t_3 = t_4, \tag{15}$$

$$t_3 = t_1 - r \cdot T_s, \tag{16}$$

do not hold true, algorithm produces the error in estimation.

It can be shown that errors of parameters m_a and m_r, denoted with δm_a and δm_r, respectively, are dependent of time and phase-delay ψ defined in equation (6), as [1, 2]:

$$\delta m_a = -\frac{\cos(\psi)}{\cos(\varphi)}\cos(2\omega_0 nT_s + \varphi_1 + \varphi_2 - \psi), \tag{17}$$

$$\delta m_r = \sin(\psi) - 1. \tag{18}$$

4. DATA ACQUISTION SYSTEM AND SIMULATIONS

Data acquisition system with NI 6009 data acquisition card based on LabVIEW software was created for utilisation of SAL in phase shift measurements [7]. C++ simulations of such measurements were then created for examining the measurement errors.

4.1. LabVIEW simulation

Before measurements with data acquisition card, LabVIEW simulation was created to verify the virtual instrument itself. A block diagram of the simulating application is presented in Fig. 3.

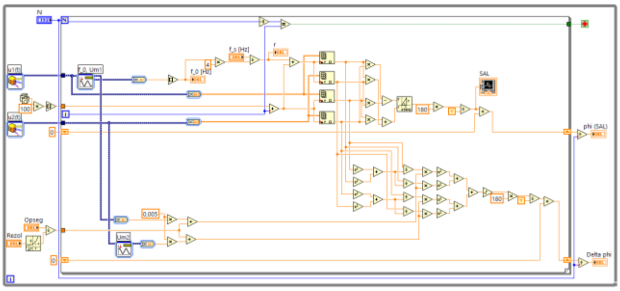

Figure 3. *Block diagram of simulated virtual instrument*

Existing functions (Express VI) of LabVIEW, "Simulate Signal", were used to create arrays of sampled values of signals u_1 and u_2. Using functions for array manipulation appropriate, the values for original and auxiliary signals were chosen, and then the phase shift was estimated. Obtained results, both with ideal and signals with white Gaussian noise, were satisfactory.

A front panel of the simulating application is presented in Fig. 4.

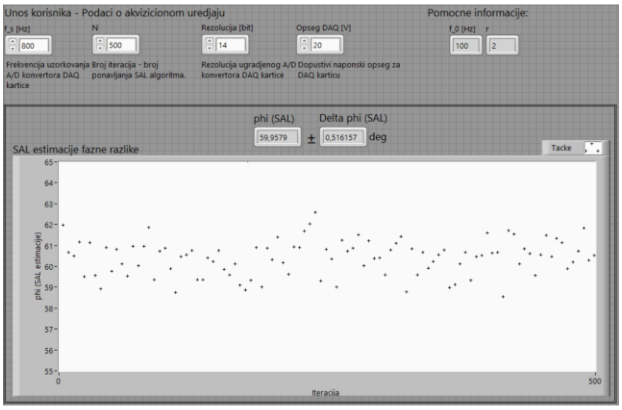

Figure 4. *Front panel of virtual instrument with simulated voltage signals with Gaussian white noise*

4.2. Data acquisition system

Signal generator (Siglent SDG 2082X), that can produce two voltage signals with predefined phase shift between them, was used as a signal source. NI 6009 data acquisition card connected to the laptop via USB was used as a measurement device. A photograph of the equipment is given in Fig.5.

Simulating LabVIEW application (Fig. 3) was modified to a virtual instrument to conduct measurement and analyse the results. Block diagram and front panel of this virtual instrument are presented in Figs. 6 and 7, respectively.

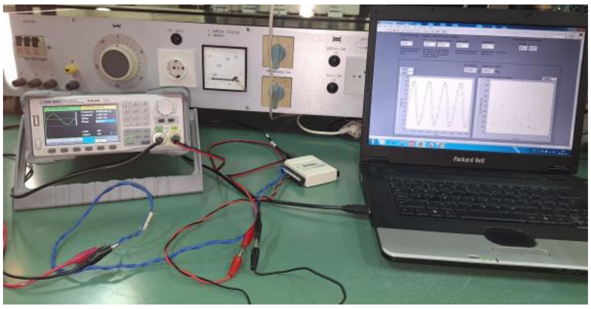

Figure 5. *Experimental equipment*

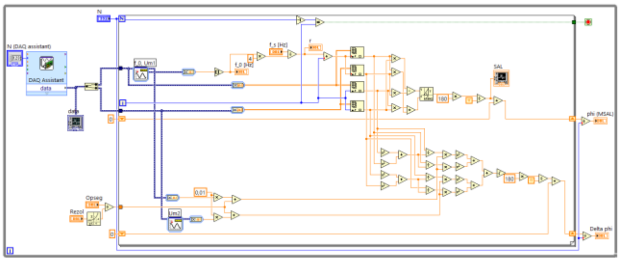

Figure 6. *Block diagram of virtual instrument for application of SAL algorithm*

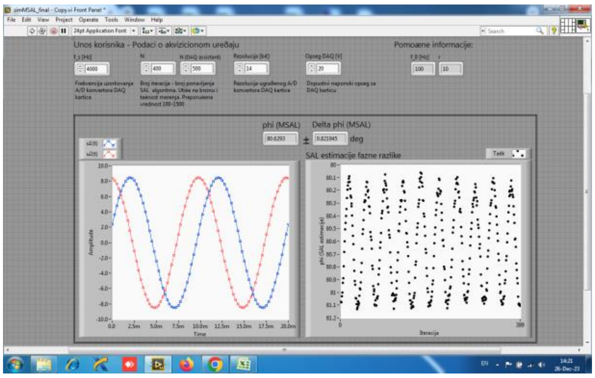

Figure 7. *Front panel of virtual instrument*

Shown virtual instrument utilises data acquisition card with "DAQ Assistant" function to collect time-discreet measurements of signals u_1 and u_2 into arrays. Further, using functions for array manipulation, appropriate values from arrays are used to calculate estimations of phase shift, as described in section 2.2. All estimations are then averaged, and average value is given as a measurement result. Bottom part of the diagram calculates an error of estimation, using a simplified approach which is acceptable for selected equipment and frequency range of signals.

Front panel of the virtual instrument shows an average value of estimations and two graphs. One graph shows measured signals, and the other shows estimated phase shift with respect to ordinal number of estimations.

Measurements were made for signals with frequencies of 50, 100 and 200 Hz, using the NI 6009 data acquisition card with one AD converter and multiplexer (multiplexed sampling). When current values of signals are obtained in this way, time latency occurs when multiplexer is switching between input channels, which means that equations (14)-(16) are not satisfied. It was observed, and is visible in Fig. 7, that values of phase shift estimations oscillate with time and have an offset from expected value.

For signals with the frequency of 100 Hz or less, error of average value of phase shift estimations was ±1°. For signals with frequency greater or equal to 200 Hz, error becomes equal or greater than ±3°.

4.3 C++ simulations

For purposes of additional error analysis, C++ simulations of acquisition of ideal signals for three cases were made:

<u>First case</u>: simulation of real measurements; when equations (14), (15) and (16) are not satisfied;

<u>Second case</u>: simulation when equations (14) and (15) are satisfied but (16) is not;

<u>Third case</u>: simulation when equations (14) and (15) are not satisfied but (16) is satisfied.

In all simulations values of sampled signals are obtained by calling a simple subfunction "double u" which is evaluated for input parameters: frequency (f), time (t) and phase (fi), as shown in Fig. 8.

```
//signal function
double u(float f, double t, double fi) {
    return sin(2*3.1415926535*f*t+fi);//sine signal
}
```

Figure 8. *Subfunction for calculating a value of sampled signal*

All relevant values: u_1, u_2, u'_1, u'_2, and ψ are initiated as double vector variables named "u1", "u2", "u1prim", "u2prim" and "fi", respectively, as shown in Fig. 9.

Simulation in the first case requires that none of the equations (14), (15) and (16) are satisfied. That calculation is realised by simple for loop, as shown in Fig. 9.

```
vector<double> u1, u2, u1prim, u2prim, fi; // signal values, parameters
int n=0;
for (int i=0; i<=N; i++) {
    u1.push_back(u(f_0, (i+n*k)*dt, fi1));
    u1prim.push_back(u(f_0, (r+i+(n+2)*k)*dt, fi1));
    u2.push_back(u(f_0, (i+(n+1)*k)*dt, fi2));
    u2prim.push_back(u(f_0, (r+i+(n+3)*k)*dt, fi2));
    fi.push_back(atan((u1prim.at(i)*u2.at(i)-u1.at(i)*u2prim.at(i))/
    (u1.at(i)*u2.at(i)+u1prim.at(i)*u2prim.at(i)))*57.2957795);
    n+=4;
}
```

Figure 9. *For loop for first case of phase shift measurement simulation*

Variable "f_0" corresponds with signal frequency f_0, "fi1" and "fi2" correspond with φ_1 and φ_2 respectively, "dt" corresponds with sampling period T_s, "k" is a value between 0 and 1 which represents time-latency due to multiplexing as a percent of sampling time T_s and "r" is the parameter defined by equation (13).

After calculations, C++ program creates a textual raw data file, formatted for further use in data analysis software.

Simulation for second case requires that equation (16) is not satisfied while equations (14) and (15) are satisfied. That can be easily accomplished by changing calculations in for loop as shown in Fig.10.

```
for (int i=0; i<=N; i++) {
    u1.push_back(u(f_0, i*dt, fi1));
    u1prim.push_back(u(f_0, (r+i)*dt, fi1));
    u2.push_back(u(f_0, (i+k)*dt, fi2));
    u2prim.push_back(u(f_0, (r+i+k)*dt, fi2));
    fi.push_back(atan((u1prim.at(i)*u2.at(i)-u1.at(i)*u2prim.at(i))/
    (u1.at(i)*u2.at(i)+u1prim.at(i)*u2prim.at(i)))*57.2957795);
    n+=4;
}
```

Figure 10. *For loop for second simulation of phase shift measurement*

Finally, for simulation of third case equations (14) and (15) are satisfied and (16) is not. For loop calculations for this case is given in Fig. 11.

```
for (int i=0; i<=N; i++) {
    u1.push_back(u(f_0, i*dt, fi1));
    u1prim.push_back(u(f_0, (r+i+k)*dt, fi1));
    u2.push_back(u(f_0, i*dt, fi2));
    u2prim.push_back(u(f_0, (r+i+k)*dt, fi2));
    fi.push_back(atan((u1prim.at(i)*u2.at(i)-u1.at(i)*u2prim.at(i))/
    (u1.at(i)*u2.at(i)+u1prim.at(i)*u2prim.at(i)))*57.2957795);
    n+=4;
}
```

Figure 11. *For loop for third simulation of phase shift measurement*

The results of simulations in all three cases were obtained with the following input data:

$\varphi = \varphi_1 - \varphi_2 = 40 - 0 = 40;\ f_0 = 50\ Hz;\ f_s = 800\ Hz;\ k = 0.01; N = 100$ iterations.

In the first case, graph of phase shift estimations is shown in Fig. 12. Signal samples are taken asynchronously (in the manner of multiplexed sampling) and time delay between original and auxiliary signals is different from condition (6).

Figure 12. *Results of the simulation for the first case*

It can be observed that estimations in this case behave in the same way as a physical measurement: they oscillate periodically with time around the average value and their average value has an offset from the true value of phase shift. This is consistent with equations (17) and (18). Error of parameter m_a is dependent from time (nT_s) of sampling and phase-delay ψ according to the cosine function, and error of parameter m_r is constant and dependent only from ψ.

For second case, ordered pairs of signal samples are taken synchronously, but time delay between original and auxiliary signal values is inaccurate. In other words, condition (6) is not satisfied. Graph of phase shift estimations with respect to ordinal number of estimations is given in Fig. 13.

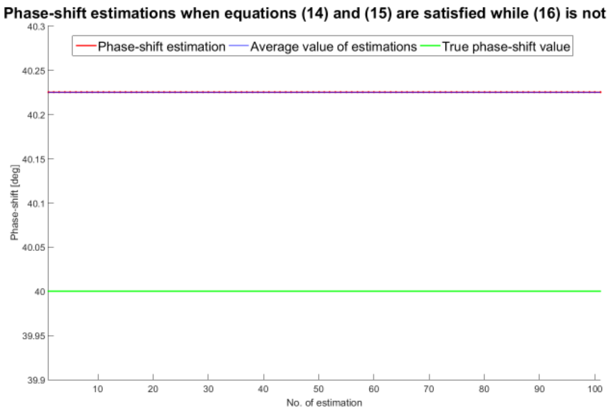

Figure 13. *Results of the simulation for the second case*

In this case δm_a is equal to zero, while δm_r is not, and its value is constant. This error component cannot be reduced by averaging estimations.

For the third case, ordered pairs of signals u_1 and u_2 are sampled asynchronously, but condition (6) is satisfied. Then δm_r is equal to zero, and only non-zero error component is δm_a. Graph of phase shift estimations with respect to ordinal number of estimations is given in Fig. 14.

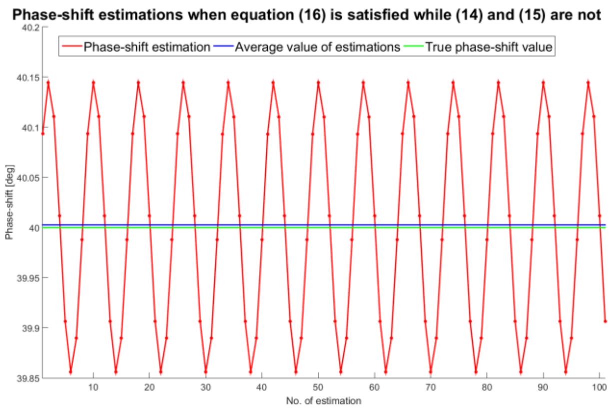

Figure 14. *Results of the simulation for the third case*

It is noticeable that the estimations oscillate around average value, which is consistent with equation (17). It is also observable that the average value of estimations tends to true phase shift value as number of estimations *N* tends to infinity. That means that this error component can be reduced by increasing the number of estimations.

In second case, where samples are taken synchronously and condition (6) is not satisfied, errors of parameters m_a and m_r can be described as: $\delta m_a = 0$, $\delta m_r \neq 0$. In third case, condition (6) was satisfied and samples were taken asynchronously, $\delta m_r = 0$ and $\delta m_a \neq 0$. Therefore, the first case can be interpreted a "superposition" of the other two.

5. CONCLUSION

The estimation of the phase shift between two sinusoidal voltage signals is performed using SAL, and the analysis of the error introduced by this algorithm is performed in this paper.

Calculated error was divided into two components and their separate analysis was performed using C++ simulations. It was shown by the experiment that the overall error increases with the frequency of the signals, with the satisfying level of the error (below 1%) at frequencies below 100 Hz. The main cause of the error was non-simultaneous sampling of the signals, which produces offset and oscillations in the phase shift estimation.

Further research would be focused on the analysis of the measurement error during the simultaneous sampling of the signals, especially at the increased signal frequencies, up to several kHz.

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Mechanical Properties of Hybrid Materials Based on Aliphatic Polyurethanes and Al_2O_3 Nanoparticles

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Abstract: *In this research, hybrid materials based on aliphatic polyurethanes and hydrophilic aluminum(III) oxide nanoparticles were synthesized. From an environmental point of view, synthesized hybrid materials represent significant engineering materials because the products of their thermal degradation are significantly less toxic compared to the products of thermal decomposition of polyurethane, for which production aromatic isocyanates are used. The presence of uniformly distributed Al_2O_3 nanoparticles in the sample containing 0.5 wt. % of inorganic filler influenced the additional formation of hydrogen bonds, as well as the improvement of the mechanical properties of the obtained polyurethane hybrid materials. Good mechanical properties, together with appropriate properties of thermal stability, allow the obtained hybrid materials based on aliphatic polyurethanes and Al_2O_3 inorganic filler to be used in the automotive industry (hydraulic seals, protective films), furniture and in the production of sports equipment.*

Keywords: *hybrid materials, aliphatic polyurethanes, Al_2O_3 nanoparticles, mechanical properties.*

1. INTRODUCTION

Hybrid polymer materials are attracting the attention of scientists worldwide due to many advanced properties compared to traditional composites. One of the most successful examples of this materials are composites obtained by incorporating the structural material into another substance, which represents a matrix, most often in the form of particles, fibers, lamellae or networks. Most of the resulting materials show improved mechanical properties. Today, this concept is intensively applied to obtain materials with exceptional mechanical properties that are used for various applications in numerous industrial branches.

Segmented polyurethanes and their nanocomposites, due to their exceptional application properties such as breaking strength, flexibility, chemical and abrasive resistance, are widely used in the automotive industry (hydraulic seals, protective films), furniture and in the production of sports equipment [1, 2].

From the environmental protection and sustainable development point of view, the appropriate choice of initial components is very important for the structuring of segmented polyurethanes and their nanocomposites. Thanks to their biostability and biocompatibility, they are used as "green" materials in the function of environmental protection [3, 4, 5].

Considering that thermoplastic polyurethane elastomers are multiphase and multicomponent materials (composed of heterogeneous blocks at the micro level), their thermal and mechanical properties are highly dependent on the degree of their phase separation. The presence of physical knots, instead of chemical ones, enables easier processing of polyurethane materials at high temperatures. The structure of the thermally reversible network of segmented polyurethanes provides them with elastomeric or apparently cross-linked properties. Thanks to the separation of phases, linear polyurethane elastomers have some properties of cross-linked elastomers, but unlike them, they can be processed by thermoplastic polymer processing procedures, so they are called thermoplastic elastomers [6, 7]. The modification of thermoplastic segmented polyurethanes based on polycarbonate diol with various nanoparticles and organic clays of a layered structure is the subject of numerous studies, with the aim of investigating the influence of the nanofillers addition on the structure and morphology of the obtained polyurethane nanocomposites, as well as improving their thermal and mechanical properties, thermal stability, and gas permeability [8]. The obtained polyurethane hybrid materials, due to the realized synergistic effect of nanofillers and a complex multi-component polyurethane system, showed improved thermal stability, dynamic-mechanical, as well as thermal and mechanical properties. It was determined that the addition of aluminum (III) oxide nanoparticles affects the increase in the degree of phase separation of soft and hard segments, as well as the improvement of mechanical properties [8 ,9, 10, 11]. The aim of this paper was to investigate the influence of the addition of different mass fractions of hydrophilic Al_2O_3 nanoparticles on the mechanical properties of thermoplastic polyurethane elastomers based on aliphatic non-toxic starting components, as well as the possibility of their application.

2. MATERIALS AND METHODS

All aliphatic components were used for the synthesis of multicomponent polyurethane systems. Hexamethylene diisocyanate (HMDI) (diisocyanate component) and 1,4-butane diol (chain extender) from the manufacturer Fluka were used as the building blocks of the hard segments, while the soft segments came from polycarbonate diol with a molar mass of about 100 g/mol (Asahi Kasei Corporation). The reaction to obtain polyurethane elastomers was catalyzed by a solution of dibutyl-tin-dilaurate, manufactured by Fluka. To obtain polyurethane hybrid materials, hydrophilic nanofillers of aluminum (III) oxide, produced by Evonik Industries, under the commercial name Alu C, were used. The particle size was 13 nm, and the specific surface area 100 m^2/g (data provided by the manufacturer).

Polyurethane nanocomposite elastomers (Table 1) with different content of hydrophilic Al_2O_3 nanoparticles (0.5, 1.0, 2.0 and 3.0 wt. %) were obtained in a one-step synthesis procedure (Figure 1). During the synthesis of segmented elastomers, the number of hydroxyl groups from the aliphatic polycarbonate diol and from the chain extender was equal ($R = [OH]_{diol}/[OH]_{BD} = 1$), and HMDI was added in excess $[NCO]/[OH] = 1.05$) [2]. Based on the mass of the initial components, the calculated share of hard segments of all samples was about 28 mass. %. In the first step, aluminum (III) oxide nanoparticles were added to a reaction flask with an aliphatic polycarbonate part, and after that, for the homogenization, mixing was carried out for 2 days. The chain extender, 1,4-butanediol, was added in a second step, after which stirring was applied for 2 h to achieve homogeneity of the mixture. The DBTDL catalyst solution (25%) was added to the reaction flask. After that, in the last step of the synthesis, the diisocyanate component was added. After 30 minutes of mixing (reaction between -NH and OH groups), the balloon with the reaction mixture was placed on the degassing system to remove any residual CO_2 bubbles. The prepared multicomponent mixture was poured using a microknife with a thickness of 350 μm onto polyethylene plates, in order to obtain polyurethane nanocomposites in the form of a film. Crosslinking of the reaction mixture lasted 26 h in a vacuum oven at 90 °C.

Table 1. *Sample name and composition of polyurethane thermoplastic materials based on polycarbonate diol, modified by the addition of different content of Al_2O_3 nanoparticles*

Sample name	Poly-carbonate diol	Al_2O_3 content [wt. %]	Hydrogen bonding index [%]
PU0	T5651	0	80.5
PU-0,5% AluC	T5651	0.5	83.5
PU-1,0% AluC	T5651	1	75.4
PU-2,0% AluC	T5651	2	65.6
PU-3,0% AluC	T5651	3	60.2

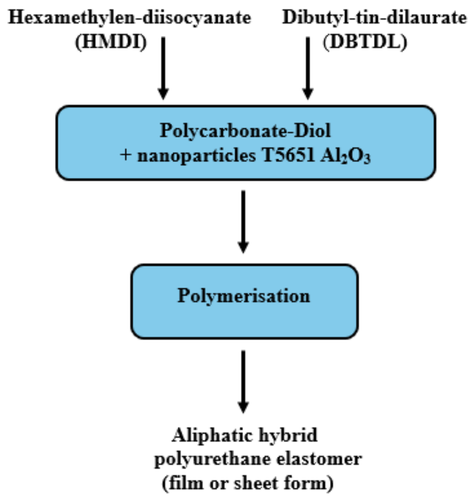

Figure 1. *Schematic representation of the one-step synthesis procedure of aliphatic hybrid polyurethane elastomer.*

A Nicolet Nexus 670 FTIR spectrometer was used to examine the chemical structure of nanocomposites based on aliphatic polyurethanes, the formation of new hydrogen bonds and the effect of the addition of nanoparticles on the separation of soft and hard domains. Absorptions were measured with a resolution of 2 cm^{-1}, in the infrared region in the range of wave numbers from 4000 to 500 cm^{-1}.

Stress-strain diagram was determined on an Instron model 6025 instrument, producer Instron Limited, England (constant speed, 10 mm/min, at room temperature). For testing the mechanical properties of aliphatic hybrid polyurethane elastomers, tubes size 25x4x1 mm, were used. As output data, the values of tensile strength σ, breaking elongation ε and Young's modulus of elasticity E were obtained.

3. RESULTS AND DISCUSSION

Data obtained after testing the mechanical properties of unmodified aliphatic polyurethane, as well as nanocomposite samples with 0.5; 1.0; 2.0 and 3.0 wt. %, of hydrophilic Al_2O_3 particles (values of tensile strength, maximum elongation and Young's modulus of elasticity) are shown in Table 2 and in Figure 2.

Table 2. *Mechanical properties of nanocomposites based on polyurethane and different content of hydrophilic nanoparticles Al_2O_3 (Alu C).*

Sample name	Tensile strength *σ* [MPa]	Modulus of elasticity *E* [MPa]	Maximum elongation A_{maks} [%]
PU-T5651-0,0	41.58	53.38	450
PU-T5651-0,5%AluC	50.11	54.28	462
PU-T5651-1,0%AluC	28.5	70.25	325
PU-T5651-2,0%AluC	12.94	19.28	275
PU-T5651-3,0%AluC	7.97	10.39	175

Based on the data shown in Table 2, it can be seen that the presence of a small amount of hydrophilic nanoparticles of aluminum(III) oxide (0.5 wt. %) affects the improvement of the values of mechanical properties, tensile strength (from 41.58 to 50.11 MPa), modulus of elasticity (from 53.38 to 54.28MPa) and maximum elongation (from 450 to 462%) of synthesized hybrid materials based on aliphatic polyurethanes and hydrophilic Al_2O_3 nanoparticles, compared to the pure sample, without the addition of filler nanoparticles.

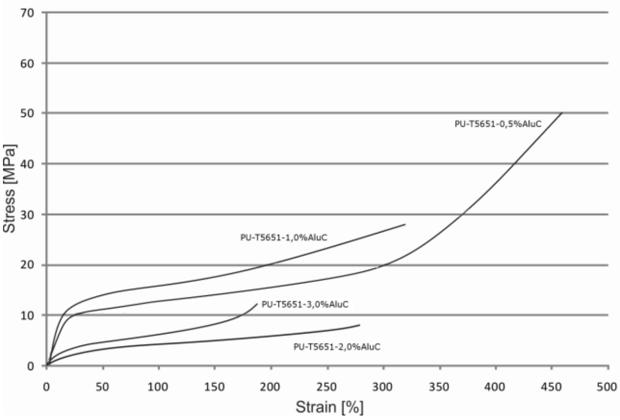

Figure 2. Stress/strain diagram for hybrid samples based on polyurethane and different content of hydrophilic *Al_2O_3* particles*.*

In all other samples (with a content of 1.0, 2.0 and 3.0 wt. % of hydrophilic Al_2O_3 nanoparticles) there was a drastic decrease in the value of the mechanical properties, which is in accordance with the results obtained for the hydrogen bonding index (Figure 3, Figure 4 and Table 1).

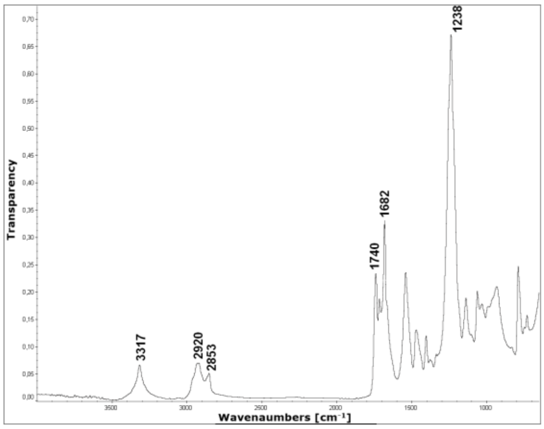

Figure 3. FTIR spectrum of polyurethane nanocomposite, obtained by using polycarbonate diol (T5651), with 0.5 wt. % of Al_2O_3 nanoparticles (Alu C).

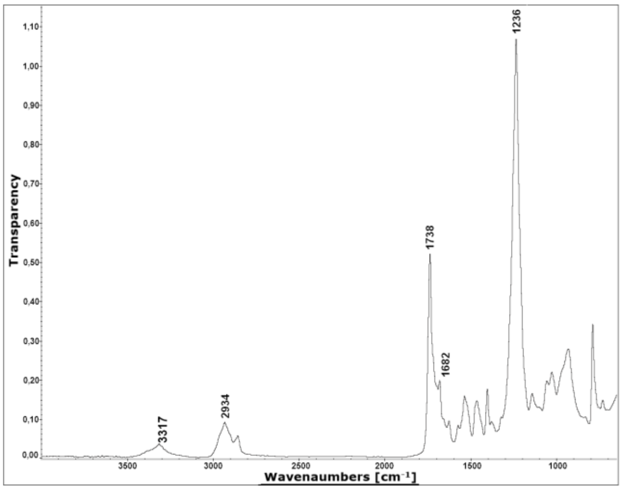

Figure 4. FT-IR spectrum of the polyurethane nanocomposite, obtained by using polycarbonate diol (T5651), with 3.0 wt. % of AluC nanoparticles.

4. CONCLUSION

In this research, hybrid materials based on aliphatic polyurethanes and small amounts of hydrophilic aluminum (III) oxide nanoparticles (0.5, 1.0, 2.0 and 3.0 wt.%) were synthesized. The best mechanical properties were determined for the hybrid material based on polyurethane with 0.5 wt. % Al_2O_3 (value of tensile strength - 50.11 MPa, Young's modulus of elasticity - 50.28 % and maximum elongation of 462%). The greatest decrease in breaking strength was observed in the polyurethane film with the highest proportion of Al_2O_3 nanoparticles (3.0 wt. %). A sample with 1.0 wt. % Al_2O_3 has the highest value of Young's modulus of elasticity - 70.25%, but significantly lower values of tensile strength (28.5 MPa) and elongation (325%) The obtained results of testing the mechanical properties of hybrid materials based on aliphatic polyurethanes and different proportions of Al_2O_3 nanoparticles are in accordance with the index values of hydrogen bonds. Good mechanical properties, together with appropriate properties of thermal stability, enable the application of these hybrid materials in the automotive industry (hydraulic seals, protective films), furniture and in the production of sports equipment.

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Change in Magnetization of the Fe/Pb/Zr/BaTiO₃ System Driven by Time of Mechanochemical Activation and Thermal Treatment

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Abstract: *Mixtures of high purity powders of 50 mass % Fe, 4 mass % Pb, 3 mass % Zr and 43 mass % $BaTiO_3$ were activated in a rotary ball mill for durations ranging from 30 min to 300 min. Samples were then pressed and sintered in the air atmosphere for 2 hours at 1200 °C. It was observed that the pressing alone, i.e. without sintering, led to a decrease of magnetization in all of the samples, with the process of sintering decreasing it further, with the most dramatic drop of 90.11 % belonging to the sample activated for 150 min. Samples activated for 90 min, 180 min and 300 min were subjected to subsequent cycles of heating to Curie temperature of 345.26 °C, then cooling to 25 °C, in the applied magnetic field of 20 kA m^{-1}, where an increase of magnetization in all of the samples was observed, with the biggest increase in magnetization of 198.56 % observed for the sample activated for 300 min.*

Keywords: *doped barium titanate; thermomagnetic properties; mechanochemical activation; sintering*

1. INTRODUCTION

For many decades, in solid-state science a class of materials known as perovskites has been occupying a central place in manifold research endeavours [1]. By virtue of their structure generalized as ABX_3 (Figure 1) where the large A cation occupies the body center, 12-coordinate position [2], perovskites doped with various elements continue to raise scientific interest demonstrating functional properties such as multiferroicity, ferroelectricity, piezoelectricity and superconductivity, among others.

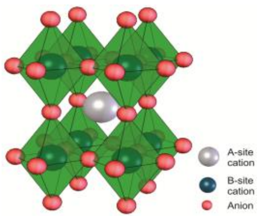

Figure 1. *The cubic ABO_3 perovskite structure [3]*

Of all the perovskites, barium titanate ($BaTiO_3$) has been one of the most investigated, due to the innate ability to accommodate into its structure a large number of dopants that yield interesting and, albeit in principle, *a priori* tailored properties. Novel development of practical applications of such systems range from high-power energy storage systems [4, 5] to sophisticated multifunctional sensors [6], highly stable WORM (Write-Once-Read-Many times) resistive memories [7] and so forth.

In this paper main focus is on the influence of mechanochemical activation time and the thermal treatment on magnetization of the Fe/Pb/Zr/$BaTiO_3$ system with preordained mass % composition of its constituents, hoping to contribute to the fundamental understanding of the processes that could benefit aforementioned applications.

2. EXPERIMENTAL

High purity powders of iron, lead, zirconium and barium titanate (Aldrich, St. Louis, MO, p.a. 99.99 %, 99.999 %, 99.99 % and 99 %, respectively) of 50 mass % Fe, 4 mass % Pb, 3 mass % Zr and 43 mass % $BaTiO_3$ were mixed and activated in a rotary ZrO_2 ball mill (Retsch PM 400) with rotation speed of 400 rpm for durations ranging from 30 min to 300 min. Samples were then pressed using the pressure of 500 MPa and sintered in the air atmosphere for 2 hours at 1200 °C. Modified Faraday method [8, 9] was used to realize thermomagnetic measurements with laboratory balance sensitivity of 10^{-7} kg and 20 kA m^{-1} of externally applied magnetic field at the location point of the sample. Experimental results were analyzed utilizing suitable software tools [10, 11].

3. RESULTS AND DISCUSSION

Since the investigated $Fe/Pb/Zr/BaTiO_3$ system is of fixed composition, time of mechanochemical activation predominantly affects the behavior of magnetization, prior to pressing and sintering. This was monitored using the equation

$$M = \Delta m \cdot g / m_s \qquad (1)$$

where magnetization M is expressed as a function of the sample weight change, Δm·g, caused by the external magnetic field. Here Δm is the apparent change in mass of the sample, m_s is the mass of a measured sample without the applied field and g is the standard acceleration due to gravity (~9.80665 m s^{-2}).

Figure 2 shows the change in magnetization due to pressing and subsequent sintering of initial powdery samples in regard to the time of mechanochemical activation, with the applied magnetic field of 20 kA m-1 and at the room temperature (before the thermal treatment).

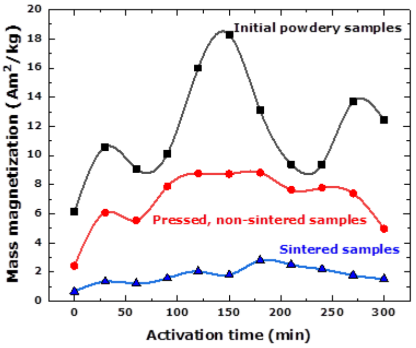

Figure 2. *Influence of pressing and the following sintering on the magnetization of initial powdery samples*

A noticeable decrease can be seen in the value of magnetization of pressed non-sintered samples from Figure 2, as well as sintered ones compared to the initial powders, for all activation times, with the most dramatic decrease in magnetization of 90.11 % shown by the sample activated for 150 min (Table 1). Iron dominantly contributes to the magnetization of the system both because of the starting amount of 50 mass %, as well as of its largest nuclear magnetic dipole moment of 1.22 μ_N [12] at the room temperature compared to the ones of lead and zirconium.

Table 1. *Decrease in magnetization of the initial powdery samples after the pressing and sintering processes.*

Activation time (min)	Magnetization (A m² kg⁻¹)		
	Initial	After pressing	After sintering
0	6.13	2.43	0.67
30	10.60	6.09	1.35
60	9.10	5.56	1.22
90	10.10	7.88	1.58
120	16.00	8.78	2.05
150	**18.30**	**8.74**	**1.81**
180	13.10	8.83	2.80
210	9.40	7.65	2.51
240	9.40	7.78	2.20
270	13.68	7.41	1.78
300	12.43	4.97	1.53

During the sintering (in an air atmosphere), iron enters the structure of the barium titanate lattice in the form of Fe^{2+} and Fe^{3+} ions, most likely replacing Ti^{4+} ions, but also Ti^{3+} and Ti^{2+} ions on the surface of crystallites. The potential of Fe-Ti substitution becomes even more apparent by comparing their intrinsic properties such as the same atomic radius of 156 pm, complementary oxidation states of +2 and +3, as well as comparable electronegativity of 1.83 for Fe and 1.62 for Ti. Sintering of samples involves pressing and thermal treatment during which the applied pressure and temperature in an oxygen (air) atmosphere affect the system not only in the sense of incorporation of Fe into the $BaTiO_3$ structure, but also of removal, i.e. evaporation of certain newly formed species such as lead and iron oxides, PbO and Fe_3O_4, in that order [13]. According to the defective dipole model [14], the incorporated iron effectively immobilizes its immediate chemical environment by reducing the mobility of neighboring dipoles, whereby new, more magnetically inert domains are formed.

Therefore, the observed decrease in magnetization can be explained by the superposition of all the above-mentioned processes, whereby the question of saturating the system with iron naturally arises, since the initial composition was 50 mass % Fe, 4 mass % Pb, 3 mass % Zr and 43 mass % $BaTiO_3$. Sintered samples that were activated for durations of 90 min, 180 min and 300 min were subjected to three successive cycles of heating to 420 °C and then cooling to room temperature of 25 °C (Fig. 3).

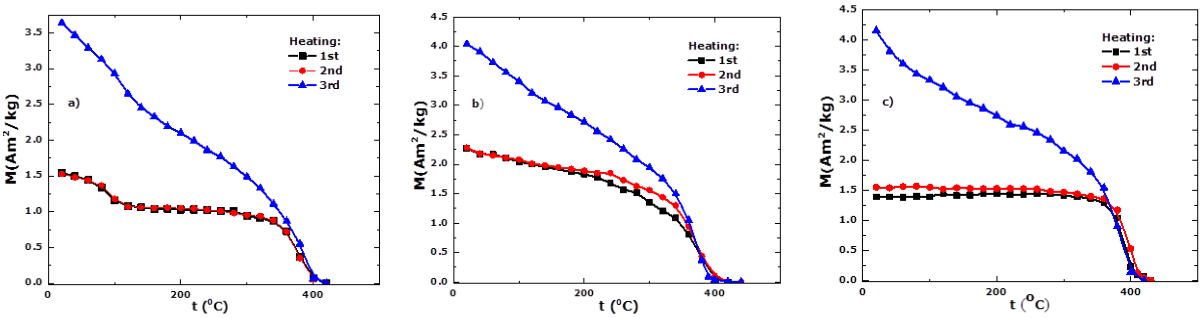

Figure 3. *Magnetization in an applied field of 20 kA m⁻¹ as a function of successive heating and cooling for the sintered sample activated for: a) 90 min; b) 180 min and c) 300 min*

It is noticeable that under the thermal treatment, magnetization follows comparable paths in all of the three samples.

Magnetization of the sample activated for 90 min begins to drop almost from the beginning of the first heating and the initial value of 1.54 A m^2 kg^{-1}, reaching plateau at approximately 160 °C and retaining the value of about 1.03 A m^2 kg^{-1} until the Curie temperature of 345.26 °C is reached, when it steeply decreases to zero. The said drop at the beginning could be attributed to the phase transition the system undergoes thus changing its crystallinity. At the Curie temperature, thermal energy absorbed by the system becomes dominant and the system shifts from being ferromagnetic to paramagnetic [15]. During the second heating, magnetization follows almost identical path, starting with the value of 1.54 A m^2 kg^{-1}. The second cooling however leads to an increased magnetization of 3.64 A m^2 kg^{-1} (Table 2). During the third heating, magnetization constantly decreases, with the aforementioned drop still visible albeit less pronounced.

Table 2. *Change in magnetization of the sintered samples activated for 90 min, 180 min and 300 min, caused by the thermal treatment.*

Activation time (min)	Magnetization (A m^2 kg^{-1})	
	Before the 1st heating (initial)	Before the 3rd heating (after the 2nd cooling)
90	1.54	3.64
180	2.27	4.04
300	**1.39**	**4.15**

In comparison to the sample activated for 90 min, magnetization of the sample activated for 180 min exhibits similar trend, the main difference being the diminishing of the initial drop. Starting from a value of 2.27 A m^2 kg^{-1}, the magnetization gradually decreases, manifesting sharp decline once the same Curie temperature is reached. The second heating then cooling leads to an overall increase and the value of 4.04 A m^2 kg^{-1}.

Magnetization of the sample activated for 300 min shows complete disappearance of the drop, nigh on maintaining its initial plateau value of 1.39 A m^2 kg^{-1} until the Curie temperature shared with the previous two samples activated for 90 min and 180 min is reached. The second cooling elevates the magnetization up to 4.15 A m^2 kg^{-1}, the highest net increase of 198.56 % amongst the selected samples.

4. CONCLUSION

Ongoing development of practical applications of perovskites, namely barium titanate doped with various elements, continues to attract attention of researchers worldwide. Fe/Pb/Zr/$BaTiO_3$ samples with 50 mass % Fe, 4 mass % Pb, 3 mass % Zr and 43 mass % BaTiO3 were mechanochemically activated for time intervals ranging from 30 min to 300 min, then pressed and sintered at 1200 °C. Pressing, as well as sintering that followed, decreases magnetization of all of the initial powdery samples, with the most pronounced decrease of 90.11 % belonging to the sample activated for 150 min. Magnetization of the sintered samples activated for 90 min, 180 min and 300 min, subjected to three successive cycles of heating to 420 °C and then cooling to room temperature, displayed comparable behavior and transition from ferromagnetic to paramagnetic phase at the Curie temperature of 345.26 °C. After the second heating then cooling, the biggest increase in magnetization of 198.56 % showed the sample activated for 300 min.

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Appendix A:

Symposium “Technics, Informatics, and Education: School Teachers for Teachers”

Notes:

10th International Scientific Conference
Technics, Informatics, and Education – TIE 2024
20-22 September 2024

Simpozijum: *Nastavnici za nastavnike*
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Ekološki menadžment u osnovnoj školi

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Rezime: *Rad istražuje implementaciju sadržaja iz oblasti ekološkog menadžmenta u okviru predmeta Geografija, Biologija, Čuvari prirode i Moja životna sredina u osnovnoj školi, kao strategiju za održivo upravljanje resursima i podizanje ekološke svesti među učenicima. Fokus je na identifikaciji ključnih područja za unapređenje ekološke efikasnosti, uključujući upravljanje otpadom, energetsku efikasnost, promociju održive mobilnosti i edukaciju o ekološkim temama. Kroz sveobuhvatan pristup, rad istražuje koristi ekološkog menadžmenta u kontekstu osnovne škole, ističući njegovu ulogu u oblikovanju odgovornih građana i čuvara okoline za budućnost.*

Ključne reči: *ekologija, održivi razvoj, ekološki menadžment*

Ecological Management in Elementary School

Abstract: *The paper explores the implementation of topics from the field of environmental management within the subjects of Geography, Biology, Nature Conservation, and My Environment in elementary school, as a strategy for sustainable resource management and raising environmental awareness among students. The focus is on identifying key areas for improving environmental efficiency, including waste management, energy efficiency, promoting sustainable mobility, and education on environmental issues. Through a comprehensive approach, the paper explores the benefits of environmental management in the context of elementary school, highlighting its role in shaping responsible citizens and environmental stewards for the future.*

Keywords: *ecology, sustainable development, environmental management*

1. UVOD

U današnjem svetu, suočeni smo sa sve većim izazovima u očuvanju životne sredine i odgovornom korišćenju resursa. Ova pitanja posebno su relevantna u obrazovnim ustanovama, gde se formira budućnost i gde se oblikuje svest narednih generacija. Osnovne škole, kao ključne institucije u razvoju dece, imaju važnu ulogu u podsticanju ekološke svesti i promovisanju održivih praksi.

Upravo iz tog razloga, istraživanje i primena ekološkog menadžmenta postaju sve značajniji aspekti obrazovnog procesa. Kroz primenu principa održivosti i upravljanja resursima na lokalnom nivou, osnovne škole mogu postati centri pozitivnih promena u zajednici i izgrađivači trajnih vrednosti očuvanja prirode.

Ovaj rad ima za cilj istražiti važnost i mogućnosti implementacije ekološkog menadžmenta u osnovnoj školi. Kroz analizu postojećih praksi, identifikaciju izazova i predlaganje konkretnih rešenja, pružiće se uvid u potencijalne koristi koje bi ovakav pristup mogao doneti, kako u obrazovnom procesu tako i u širem društvenom kontekstu.

Kroz ovo istraživanje, osnažiće se svest o važnosti ekološkog obrazovanja i podstaknuti dalje akcije ka održivijoj budućnosti za sve nas.

2. EKOLOGIJA PREDMET IZUČAVANJA

Ekologija je nauka koja proučava životnu sredinu, odnos između živih bića i nežive prirode, kao i načine na koje su se živa bića prilagodila uslovima spoljašnje sredine. Vodi poreklo od grčkih reči ***oikos*** – dom, stanište i ***logos*** – učenje, nauka. Prvi put ju je upotrebio nemački zoolog *Ernest Hekel 1866.* u knjizi Prirodna istorija stvaranja (*Natural History of Creation*). Originalna Hekelova definicija ekologije glasi:

„Pod ekologijom podrazumevamo korpus znanja u vezi ekonomije prirode – odnosno nauku koja se bavi proučavanjem svih odnosa životinja prema njihovoj okolnoj organskoj i neorganskoj sredini, njihove prijateljske i neprijateljske odnose sa životinjama i biljkama sa kojima dolaze u direktan ili indirektan kontakt, odnosno drugim rečima ekologija je studija svih složnih međuodnosa prepoznatih od strane Darvina kao uslov borbe za opstanak" [1].

U početku je nastala kao grana zoologije, a kroz istraživanje odnosa između životinja i njihove žive i nežive prirode.

Smatra se da je njen stvarni utemeljivač *Čarls Darvin* (1809 – 1882.). On smatra da pojam borbe za opstanak obuhvata međusobne odnose živih bića, jednih prema drugima i prema neživoj prirodi. Ti odnosi omogućavaju prilagođavanje organizama na promenljivost životne sredine.

Siniša Stanković se smatra osnivačem moderne ekologije kod nas, a njegova knjižica „Okvir života – načela ekologije" [2] sadrži gotovo sve osnovne stavove i principe savremene ekologije.

3. ŠKOLA KAO FAKTOR EKOLOŠKOG OBRAZOVANJA

Škola je osnovni faktor vaspitanja i ekološkog obrazovanja. U osnovi, naš obrazovni sistem podrazumeva kontinuirani vaspitno-obrazovni proces u svim ustanovama namenjenim za tu vrstu delatnosti. Kolika će se važnost dati ekološkim sadržajima i da li će se vršiti korelacija između nastavnih predmeta u nastavnom procesu, u velikoj meri zavisi i od afiniteta i obučenosti nastavnika. Zato se kod nas velika pažnja posvećuje stalnom stručnom osposobljavanju nastavnika kroz seminare i dodatne obuke, kao i uključivanje u aktivnosti koje se organizuju na nivou lokalne sredine.

Postavlja se pitanje: „Koji faktori, koliko i kada doprinose cilju izgradnje ekološki odgovorne ličnosti?" Porodica je bitan faktor vaspitanja mladih, koja deluje pozitivno i na ostvarivanje brige o neposrednoj okolini i razvoju ekoloških vrednosti svojih članova. Značajan faktor društvene svesti mladih je vršnjačka grupa, gde treba uzeti u obzir njihovo sagledavanje ekoloških problema, kako bi se oni angažovali na zaštiti i unapređenju životne sredine. Postoje različiti izvori znanja ekološkog obrazovanja, a koji će biti favorizovani zavisiće od nastavnika koji rukovodi vaspitno – obrazovnim procesom. Koriste se sledeći izvori znanja:

- Nastavnik – je realizator ciljeva i zadataka ekološkog obrazovanja; vrši izbor nastavnih sadržaja; organizuje i vodi proces usvajanja znanja; formira stavove i navike učenika; organizuje i izvodi vannastavne aktivnosti; neposredno svojim postupcima deluje na ličnost učenika.
- Školski udžbenici – su osnovni izvor, ali ekološki sadržaji su nedovoljno i nefunkcionalno zastupljeni.
- Nastavna sredstva – e – udžbenici, modeli, slike, grafikoni, fotografije, tabele, crteži.
- Ekološki bilteni, ekološki projekti, medijska informisanost o aktivnostima građana u zaštiti životne sredine – omogućavaju neformalno ekološko vaspitanje i obrazovanje.

4. ODRŽIVI RAZVOJ I ODRŽIVOST U OBRAZOVANJU

„Održivi razvoj je razvoj koji zadovoljava potrebe sadašnjice, ne dovodeći u pitanje sposobnost budućih generacija da zadovolje vlastite potrebe" jedna je od najpoznatijih definicija održivog razvoja, koju je 1987. godine dala Svetska komisija za udruženje i razvoj pri Ujedinjenim nacijama (tzv. Bruntland komisija) u svom izveštaju pod nazivom „Naša zajednička budućnost".

Održivost u obrazovanju odnosi se na integraciju održivog razvoja u procese učenja i upravljanja obrazovnim institucijama kroz edukaciju i praktične aktivnosti, a u cilju promocije ekološke, društvene i ekonomske odgovornosti kod učenika.

- Ekološki aspekt ima za cilj podizanje svesti kod učenika o zaštiti životne sredine, očuvanju biodiverziteta, racionalnoj upotrebi resursa i smanjenju emisije štetnih gasova. Učenici treba da razviju razumevanje ekosistema, klimatskih promena i njihovog uticaja na životnu sredinu.
- Ekonomski aspekt veže se uz ekonomsku stabilnost, kao i važnost ravnoteže između ekonomskog razvoja i očuvanja resursa. Učenici treba da shvate koncepte kao što su pravedna raspodela resursa, odgovorno potrošačko ponašanje i unapređenje lokalne ekonomije.
- Društveni aspekt podrazumeva poštovanje kulturološke raznolikosti i očuvanje kulturne baštine. Učenici treba da budu svesni društvenih problema, sposobni za saradnju i angažovanje u zajednici, poštuju različitosti među ljudima.

Održivi razvoj kao međupredmetna tema pruža učeniku saznanja o izazovima modernog vremena na lokalnom i globalnom nivou, kao i saznanja o održivosti resursa, granici opterećenja, ljudskim potencijalima, sopstvenim i zajedničkim pravima i odgovornostima. Takođe podržava razvoj generičkih veština kao što su inovativnost, praktičnost, preduzetništvo, kritičko mišljenje i sposobnost prilagođavanja i rešavanja problema. Veoma je važno da se primenom praktičnog rada kod učenika podstiče odgovorno korišćenje prirodnih resursa i energije, pravilno postupanje sa otpadom, aktivan rad i saradnja u zajednici. Učenje i podučavanje ove međupredmetne teme nastoji podići svest o svim pitanjima koja se odnose na održivost, omogućava učenicima da biraju održivo ponašanje u svakodnevnom životu, osposobljava ih za samostalno i odgovorno odlučivanje o pitanjima koja su važna kako za njih same, tako i za društvo u celini.

Održivi razvoj postaje sve važniji u obrazovanju, a škole igraju ključnu ulogu u podizanju svesti i osposobljavanju budućih generacija za održivije prakse. Evo nekoliko primera dobre prakse održivog razvoja u školama:

1. Programi obrazovanja o održivosti – Škole mogu implementirati programe obrazovanja koji podučavaju učenike o važnosti očuvanja prirodnih resursa, recikliranju, obnovljivim izvorima energije. Ovo može biti integrisano u nastavni plan.
2. Energetska efikasnost – Sprovođenje mera za povećanje energetske efikasnosti, kao što su zamena tradicionalnih sijalica LED sijalicama, upotreba solarnih panela za proizvodnju električne energije, poboljšanje izolacije zgrada ili zamena dotrajale stolarije.
3. Programi recikliranja -Organizovanje prikupljanja papira, plastike, stakla i drugih materijala za reciklažu, kao i podučavanje učenika o važnosti recikliranja.
4. Ekološki osvećeni događaji – Organizacija događaja povodom Dana planete Zemlje može podići svest o održivom razvoju među učenicima. Ovi događaji mogu uključivati aktivnosti poput čišćenja školskog dvorišta i okoline, sadnje drveća, predavanja o zaštiti životne sredine i slično.
5. Partnerstva sa lokalnom zajednicom – Škole mogu uspostaviti partnerstva sa lokalnim organizacijama koje se bave održivim razvojem kako bi dobile podršku, resurse i stručnost za implementaciju održivih praksi.

Ovi primeri ilustruju različite načine na koje škole mogu doprineti održivom razvoju i podučiti učenike o važnosti brige o životnoj sredini. Implementacija ovih praksi može stvoriti pozitivan uticaj ne samo na školsku zajednicu, već i na širu zajednicu i okolinu.

5. EKOLOŠKI MENADŽMENT

Menadžment je proces planiranja, organizovanja, vođenja i kontrole resursa kako bi se postigli određeni ciljevi organizacije ili institucije. To uključuje upravljanje ljudskim resursima, informacijama, finansijama, vremenom kako bi se postigla uspešnost u postizanju ciljeva.

Ekološki menadžment je nova naučna disciplina čiji je cilj da na bazi saznanja i činjenica o ekološkim uslovima promeni postojeća zagađenja i degradacije čovekove okoline koristeći metode ekološkog inžinjeringa i pravno ekonomske instrumente u skladu sa postojećim zakonima, propisima i međunarodnim standardima.

Važnost ekološkog menadžmenta u osnovnoj školi predstavlja sistematski pristup upravljanju resursima i aktivnostima koje se sprovode u okviru školskog okruženja , s ciljem smanjenja negativnog uticaja na životnu sredinu i očuvanja održivog razvoja. Evo nekoliko ključnih razloga zašto je ekološki menadžment važan u osnovnim školama:

- Obrazovanje o održivosti – Implementacija ekološkog menadžmenta pruža priliku za učenje o važnosti održivog razvoja i ekološke svesti. Kroz aktivnosti poput recikliranja, potrošnje energije i vode, očuvanja prirodnih resursa, učenici mogu sticati znanja i veštine za održavanje zdrave životne sredine.
- Primer odgovornog ponašanja – Osnovne škole imaju ulogu formiranja odgovornog ponašanja prema životnoj sredini. Implementacija ekološkog menadžmenta šalje snažnu poruku učenicima, roditeljima i lokalnoj zajednici o važnosti brige za sredinu i preuzimanje odgovornosti za očuvanje prirode.
- Smanjenje troškova i resursa – Efikasan ekološki menadžment ima za rezultat smanjenje troškova školskog poslovanja kroz uštede u potrošnji energije, vode i materijala. Ovo može osloboditi dodatna sredstva koja se mogu reinvestirati u poboljšanje obrazovnih resursa i programa.
- Povezanost sa nastavnim planom i programom – Ekološki menadžment se može integrisati u nastavni plan i program kako bi se učenici dodatno edukovali o ekološkim temama. Aktivnosti poput školskih bašti, recikliranja i ekoloških projekata mogu se koristiti kao praktični primeri učenja.

U celini, ekološki menadžment u osnovnoj školi pruža sveobuhvatni pristup održivosti koji ne samo da doprinosi zaštiti životne sredine, već i oblikuje buduće generacije kao odgovorne građane sveta.

Implementacija ekološkog menadžmenta se može realizovati kroz sledeće korake:

- Formiranje ekološkog tima od nastavnika, učenika, roditelja i predstavnika lokalne zajednice. Tim je odgovoran za planiranje, implementaciju i praćenje ekoloških aktivnosti u školi.
- Procena stanja životne sredine u školi kako bi se identifikovali glavni ekološki izazovi sa kojima se škola suočava.
- Na temelju procene stanja ekološki tim razvija ekološki plan koji sadrži konkretne ciljeve, strategije i aktivnosti za unapređenje ekološke održivosti škole.
- U skladu sa ekološkim planom škola implementira niz mera održivosti, uključujući smanjenje potrošnje energije, recikliranje

otpada, promovisanje ekološke svesti među učenicima.

Očekivani rezultati implementacije ekološkog menadžmenta u školama:

- Smanjenje potrošnje energije kroz sprovođenje mera energetske efikasnosti, edukaciju o razvrstavanju i recikliranju otpada.
- Učenici postaju svesniji važnosti očuvanja životne sredine kroz učešće u ekološkim projektima, aktivnostima i edukativnim radionicama u školi.
- Implementacija ekološkog menadžmenta u školi podstiče veće angažovanje lokalne zajednice u promovisanju održivog razvoja i zaštite životne sredine.

6. ZAKLJUČAK

Implementacija ekološkog menadžmenta u osnovne škole pokazala se kao ključan korak u postizanju održivosti u obrazovnom sistemu. Kroz sistematski pristup upravljanju životnom sredinom, škola postiže značajne rezultate u smanjenju negativnog uticaja na životnu sredinu i razvijanju ekološke svesti među učenicima, osobljem i lokalnom zajednicom.

Jedan od glavnih postignuća implementacije ekološkog menadžmenta je smanjenje potrošnje resursa, uključujući energiju, vodu i materijale, što ima za rezultat smanjenje ekološkog otiska škole. Škola postaje centar za razmenu znanja i iskustva o održivosti i na taj način dobija podršku lokalnih organizacija, institucija i medija. Integracija ekološkog menadžmenta u obrazovni sistem je jako važno sredstvo za promovisanje održivog razvoja i stvaranje ekološki osvešćenih građana.

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Značaj upotrebe edukativih softvera u nastavi tehnike i tehnologije za osnaživanje veština rešavanja problema

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Abstrakt: *Zadatak obrazovanja je da pripremi učenike za realne životne izazove sa kojima se će se suočavati u poslovnom okruženju, predmet tehnika i tehnologija nije izuzetak. Uzimajući u obzir promene u poslovom okruženju koje se ubrzano dešavaju, veština rešavanja problema je od velike važnosti za akademski i poslovni uspeh. U nastavu je stoga potrebno uvesti novine koje će doprineti osposobljavanju učenika za zadatke koji ih čekaju u daljem obrazovanju i poslovnom okruženju. Ovaj rad bavi se istraživanjem na koji način edukativni softveri mogu da doprinesu da učenici tokom nastave tehnike i tehnologije steknu veštine rešavanje problema.*

Ključne reči: *edukativni softver, tehnika i tehnologija u vaspitanju i obrazovanju, rešavanje problema, veštine 21.veka.*

The Importance of Using Educational Software in Teaching Technology and Engineering to Empower Problem-Solving Skills

Abstract: The task of education is to prepare students for the real-life challenges they will face in the business environment, and the subject of technology and engineering is no exception. Considering the rapid changes in the business environment, problem-solving skills are of great importance for both academic and business success. Therefore, it is necessary to introduce innovations in teaching that will equip students for the tasks awaiting them in further education and business settings. This paper explores how educational software can contribute to students acquiring problem-solving skills during technology and engineering classes.

Keywords: *educational software, technology and engineering in education, problem-solving, 21st-century skills.*

1. UVOD

Učenici 21. veka imaju visok stepen naviknutosti na nove tehnologije. Čak i pre uključivanja u formalno obrazovanje učenici stiču prva znanja u pogledu korišćenja tehnologija.

Uključivanje tehnologija u nastavu predstavlja logičan sled za poboljšavanje procesa učenja i za korišćenje veština koje učenici imaju za proširivanje novih znanja. Ističe se da se na ovaj način može doprineti povećanoj motivisanosti učenika i njihovoj zainteresovanosti za učenje. Kroz uključivanje igara i programa koji su kreirani za učenje, postižu se različiti ciljevi. Najpre može se staviti fokus na podršku da se određena lekcija lakše savlada ili da se radi na poboljšanju određenih veština učenika [1]. U današnjem digitalnom dobu, jedna od ključnih svrha obrazovanja je da razvije pojedince sposobne da razmišljaju kreativno, rešavaju probleme i budu inovativni i produktivni. *Računarsko razmišljanje* je analitički proces koji uključuje definisanje problema i njihovo rešavanje na nove načine [2]. Ističe se da sposobnosti računarskog razmišljanja olakšavaju razumevanje suštinskih uzroka problema, pronalaženje najboljeg rešenja, pa čak i razvoj kreativnih ideja.

Mnoge zemlje su prepoznale važnost uključivanja veština 21. veka kao što su rešavanje problema, kompjutersko razmišljanje i kreativnost u obrazovni sistem kako bi se uticalo na razvoj pojedinca sposobnih da prevaziđu izazove koje im nameće savremeno društvo i njegov razvoj [3]. Dakle, jedan od najznačajnijih zadataka obrazovanja poslednjih godina je stvaranje kreativnih i produktivnih pojedinaca koji mogu da generišu kreativne odgovore na pitanja u svakodnevnom životu. Zbog toga se posebna pažnja posvećuje načinima na koje se može uticati na osnaživanje ovih veština i koju ulogu u tome imaju edukativnih softveri i tehnologije koje se mogu koristiti u nastavnom procesu.

Cilj ovog rada je da ukaže na načine na koje uključivanje edukativnih softvera u nastavu tehnike i tehnologije može da doprinese da se osnaže veštine rešavanja problema na osnovu pregleda postojećih radova koji daju uvid u bolje razumevanje načina na koji edukativni softveri utiču na razvoj i osnaživanje veštine rešavanja problema kod učenika. Fokus se najpre stavlja na razloge zbog kojih je potrebno da se steknu veštine rešavanja problema i na koje načine su te veštine potrebne učenicima u kontekstu savremenog obrazovanja. Time se daje osnova za posvećivanje ovoj temi i traganje za načinima na koje se mogu osnažiti veštine rešavanja problema kroz upotrebu edukativnih softvera.

Kao jedno od mogućih rešenja, u dosadašnjoj literaturi je prepoznato i uključivanje edukativnih softvera u nastavu te se pregled ovih radova navodi kao osnova za ukazivanje na potencijal koji edukativni softveri mogu imati ukoliko se uvedu u nastavu na osnaživanje veština rešavanja problema učenika.

2. OSNAŽIVANJE VEŠTINE REŠAVANJA PROBLEMA

2.1. Značaj veštine rešavanja problema

Rešavanje problema je ključna veština 21. veka koja je neophodna za učenje, rad i svakodnevni život u našem društvu koje se brzo menja. Zbog toga se pažnja usmerava sve više ka načinima na koje se mogu poboljšati ove veštine. Kako rešavanje problema uključuje kognitivne procese i strategije kao što su analiza podataka, identifikacija uzroka, osmišljavanje planova i pronalaženje rešenja, to je osnovni pristup postizanju efektivnog i smislenog učenja. Stoga se rešavanje problema smatra suštinskim u mnogim predmetnim domenima u formalnom obrazovnom okruženju od osnovnog do tercijarnog obrazovanja [4].

Da bi učenici razvili veštine rešavanja problema, učenicima se mora pružiti mogućnost da vežbaju pristup rešavanja problemima i da razvijaju mehanizme koji im mogu biti od pomoći. Brzi razvoj informacione i komunikacione tehnologije pretvorio je učenike u „digitalne građane" sa efikasnim kompjuterskim i internet veštinama [5]. Da bi se odgovorilo na promenjene zahteve koji se postavljaju pred učenike, može se zaključiti da je potrebno da se razviju novi načini na koje se nastava odvija a koji bi pomogli da učenici osnaže svoje veštine rešavanja problema.

Veštine rešavanja problema su veoma važne u podršci društvenom razvoju. Učenici sa veštinama rešavanja problema mogu da izgrade zdrave odnose sa svojim prijateljima, razumeju emocije onih oko sebe i vide događaje iz perspektive drugih ljudi. Početne veštine rešavanja problema se povećavaju jer učenici imaju tendenciju da budu entuzijastični i uzbuđeni u vezi sa raznim aktivnostima igre koje priprema nastavnik. Stimulacija i motivacija nastavnika omogućava deci da pronađu rešenja za probleme sa kojima se susreću u toku igranja. Dakle, može se zaključiti da je učenje programiranja aktivnost koja može privući interesovanje dece i postati rešenje za podizanje početnih sposobnosti dece za rešavanje problema [6]. Ovo usmerava ka traženju alatki za podršku razvoja veštine rešavanja problema učenika u tehnološkim rešenjima.

Ove studije jasno ukazuju na rezultate do kojih može dovesti uključivanje edukativnih softvera u nastavu tehnike i tehnologije. Ti pozitivni rezultati su prepoznati u ovim studijama kao značajni za učenike. Prednosti i pozitivni efekti uvođenja tehnoloških rešenja u nastavu, nisu prepoznati sa same učenike već i za nastavnike.

Zajedno sa ovim tehnološkim napretkom, obrazovna tehnologija je školama i nastavnicima pružila više mogućnosti da sprovode smislene nastavne aktivnosti u okruženjima unapređenim tehnologijom. Kako bi postigli postavljene ciljeve u pogledu veština koje učenici moraju da postignu, nastavnici moraju tragati za rešenjima koja mogu da podrže promenu u organizaciji nastave.

Sve veći broj istraživanja se fokusirao na integraciju obrazovne tehnologije sa razvojem veština rešavanja problema. Stoga, metodičko ispitivanje studija u ovoj oblasti može dati neprocenjive uvide i reference i za naučnike i za praktičare [4]. Ovo je od velikog značaja za razumevanje značaja koji ima dalje analiziranje ove teme.

Dugoročni pozitivni efekti se takođe prepoznaju kao verovatan ishod u pregledanim studijama. Predviđa se da ljudi koji su razvili veštine rešavanja problema neće biti neodgovorni na probleme sa kojima će se suočiti u budućnosti, ispitivaće, razmišljati višedimenzionalno, donositi odluke bez poteškoća i proizvoditi rešenja. Sposobnost rešavanja problema je urođena osobina. Međutim, zrelost, motivacija, obrazovanje, socijalno i kulturno okruženje pojedinca utiču na sposobnost rešavanja problema. Iz tog razloga, lekcije koje će unaprediti veštine rešavanja problema treba pripremiti obraćajući pažnju na individualne razlike

[7]. Upravo zbog toga se ističe da značaj u prilagođavanju nastave jeste u osnaživanju ovih veština i davanju prostora učenicima za lični napredak. Brojni izazovi i prepreke koji se javljaju u savremenoj organizaciji nastave se ističu ka značajan deo traženja najboljeg mogućeg načina da se odgovori na potrebe reforme školstva.

Potreba da se nastava prilagodi savremenim potrebama učenika je jasno navedena od strane autora koji su navedeni u ovom delu rada. Prepoznato je da je osnaživanje ovih veštna od velikog značaja za sve učenike i da postoji potreba da se nađu načini da se razvijanje ovih vešina uključi u nastavu. Navedena istraživanja u delu rada koji sledi pokazuju da postoji značajan potencijal edukativnih softvera za postizanje ovog cilja.

2.2. Uloga edukativnih softvera

Kao jedno od rešenja koje se može koristiti za osnaživanje veština rešavanja problema kod učenika izdvajaju se edukativni softveri.

Eduktivni softveri uključuju veliki stepen interaktivnosti koja daje slobodu učenicima da odluče na koji način žele da odgovore na postavljeni zadatak. To daje mogućnost da se problem reši na više od jednog načina, kao i da se do rešenja dođe drugim putem odnosno da se na različite ačn postignu isti rezultati. Ova odlika edukativnih softvera dovodi do toga da se menja odnos prema učenju, i da se pasivni pristup zamenjuje aktivnijim [8]. Ujedno je upravo ova odlika edukativnih softvera značajna jer je u skladu sa prethodno pomenutom potrebom da se akivnosti prilagode individualnim karakteristikama učenika.

Značajan je primer kada je 21 učenik učestvovao u studiji u desetodnevnom letnjem programu za dizajniranje igara i učenje. Opšte veštine učenika u rešavanju problema su se poboljšale kako su naučili osnove programiranja u Microsoft Kodu Labu i kreiranje igara. To je dobar pokazatelj na koji način se upotrebom tehnologije mogu postići željeni rezultati na ovom polju [9]. Sudije su do sada prepoznale da postoji napredak u razvoju veština kada se edukativni softveri uključe u razvijanje veština rešavanja problema. Nedostaje pak jasno razvijanje ideje kako se ovi softveri mogu uključiti u samu nastavu dugoročno a ne kao izdvojeni program ili u ovo slučaju letnja škola.

Kada je reč o veštini rešavanja matematičkih problema sa kojima se učenici osnovne škole susreću, ukazano je da postoji značajan uticaj edukativnih medija, a posebno edukativnih softvera za poboljšanje ovih veština [10]. Takođe, ukazano je da upotreba programa Scratch doprinosi boljem rešavanju problema i da dovodi do efikasnije upotrebe tehnologija [11].

Istraženo je i koji od postojećih softvera najbolje odgovaraju potrebama dece. Alati kao što su Scratch, Code.org, Arduino, App Inventor, Codemonkey, koji sadrže različite medijske alate, imaju strukturu koja može da privuče pažnju dece svojim jednostavnim interfejsom i logikom kodiranja [7]. Izbor edukativnog softvera koji bi na najbolji mogući način odgovorio potrebama dece samo je još jedan od aspekata koje je potrebno uključiti kada se razmatra uvođenje ovih alatki u nastavu i proceni njihovog doprinosa.

Učenici mogu da obavljaju aktivnosti programiranja koje odgovaraju njihovom uzrastu prevlačenjem i ispuštanjem blokova koda. Istraženo je 40 različitih platformi za programiranje. Zaključeno je da su platforme za programiranje Code.org, Scratch i App Inventor kvalifikovanije od drugih alata za programiranje. Iako svaki programski jezik sadrži svoje posebne kodove, logika rada kodova je slična [7].

Pored edukativnih softvera, pažnju treba posvetiti i ulozi robotičkih aktivnosti u nastavi. Danas se koriste različiti robotski kompleti kao što su Lego Wedo 2.0, Lego Mindstorms EV3, Lego Education Spike Prime, Arduino, Makeblock mBot, VEKS Robotics [7].

Roboti kreirani Lego Mindstorms EV3 i Lego Vedo 2.0. setovima mogu da komuniciraju sa okolinom preko senzora. Sve osnovne operacije kodiranja mogu se izvesti kombinovanjem vizuelnih blokova koda umesto programiranja zasnovanog na tekstu. Smatra se da obrazovanje iz robotike pruža podršku u oblastima kreativnosti, samopouzdanja, komunikacije, liderstva i primene teorijskog znanja u praksi [7]. Dakle, pored edukativnih softvera shvaćenih u najužem smislu a koji i sami nude veliki broj alternativa, robotički programi mogu biti od velikog značaja za osnaživanje veština rešavanja problema.

Važno je istaći da konstruisanje i programiranje robota da bi se postigao cilj, zahteva mnoge sposobnosti vezane za kompjutersko razmišljanje, kao što su logičko i proceduralno razmišljanje, prepoznavanje obrazaca, dizajn algoritama i otklanjanje grešaka. Stoga se, na metodološkom nivou, pokazuje kao moćno sredstvo za promovisanje procesa rešavanja problema i postavljanja problema [12]. Ideja je da se kroz razvijanje praktičnih rešenja utiče na sposobnost davanja pratično značajnih rešenja. Kao rezultat koji se očekuje navodi se povećanje digitalne pismenosti učenika [12]. Uzimajući u obzir sve navedeno, treba istaći da je uključivanje više digitalnih alatki sa istim ciljem osnaživanja veštine rešavanja problema takođe značajno. Zajedničkim delovanjem različitih alatki može se raditi na tome da se postigne osnaživanje veština rešavanja problema uzimajući u obzir individualne razlike i potrebe da se nastava prilagodi i različitim potrebama učenika. Kombinovanje edukativnih softvera i robotičkih aktivnosti po svojoj prirodi se mogu lako kombinovati i usmeravati da zajedno doprinose poboljšanju ovih veština učenika.

Razvoj veštine rešavanja problema je u velikoj meri potpomognut iskustvenim obrazovnim metodologijama, odnosno korišćenjem obrazovnog softvera zasnovanog na ovim strategijama. Za početnike u programiranju manje je potrebno poznavanje specifičnih algoritama. Nasuprot tome, sposobnost razumevanja algoritamskih koncepata i osmišljavanja originalnih rešenja za nova pitanja je veoma poželjna. Dečji programski jezici se široko koriste u nastavi informatike u osnovnoj školi. Elementarne kontrolne strukture su izgrađene na jednostavnim principima programiranja lakim za korisnika (npr. zagonetke i blokovi). Na ovaj način se može pomoći programerima početnicima da unaprede svoj posao upotrebom jasno definisanih procesa i pružanjem brzih povratnih informacija. Takođe je moguće vizualizovati redosled koraka u programu [13].

Digitalne tehnologije poboljšavaju mentalne sposobnosti učenika i njihov način razmišljanja. Važno je istaći da kada se uključuju ove aktivnosti, nije reč o savršenom usvajanju programskih jezika i programiranja već se radi u velikoj meri upravo o razvoju veština, što uključuje i veštine rešavanja problema. Isitče se i velika uloga koju imaju roditelji i nastavnici za uvođenje ovih aktivnosti u nastavu i prepoznavanje njihovog značaja kao i adekvatnog načina korišćenja [14].

Pregled radova pokazuje da edukativni softveri mogu u velikoj meri da doprinesu da se utiče na razvijanje veština rešavanja problema i da se nastava prilagodi novim zahtevima tržišta. S toga, sledeći zaključci se mogu izvesti.

3. ZAKLJUČAK

Kada se sagledaju rezultati svih pregledanih istraživanja, ističe se da postoji veliki broj očekivanih prednosti do kojih dovodi primena tehnolgija i edukativnih softvera u nastavi. Posebno se isitče značaj koji imaju ove aktivnosti u nastavi kada se govori o razvoju veština rešavanja problema i razmišljanja koje vodi proceni alternativa i njihove učinkovitosti.

Navodi se da zbog interaktivnosi koja je potreba za učenje kroz ove aktivnosti dolazi neretko do veće uključenosti učenika u proces učenja i preuzimanja aktivne uloge. To povećava njihovu motivisanost i zainteresovanost za učenje i dovodi do poboljšanja njihovih akademskih veština.

Ujedno robotičke aktivnosti doprinose povezivanju prakse i teorije i razmišljanju koje je usmereno pronalaženju rešenja koje može da doprinese proceni alternativa i pronalasku rešenja koje najbolje odgovara postavljenom problemu. Ukazuje se da se kombinacijom ovih digitlanih alata mogu postići željeni rezultati u nastavi i doći do osnaživanja veštine rešavanja problema. Digitalne igre u nastavi takođe pokazuju postojeća istraživanja imaju značajan doprinos za razvoj veštine rešavanja problema i za unapređivanje digitalne kompetencije.

Buduća istraživanja trebala bi da se usmere na brojne načine na koje se može upotrebti tehnologija da se u najvećoj mogućoj meri unaprede veštine rešavanja problema i da se istakne koji su to načini koji mogu da maksimiziraju prednosti tehnološki podržanih aktivnosti u nastavi.

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Turistički tehničar u eri digitalizacije: međupredmetna implementacija veb baziranih servisa

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Ključne reči: *WordPress; CMS; Google Translate; YouTube; Web 2.0*

Tourism Technician in the Digitalization Era: Interdisciplinary Implementation of Web-Based Services

Abstract: *In this paper, we present web-based services and tools used in school practice to empower students and teachers to develop cross-curricular competencies. These competencies include lifelong learning, communication, work with data and information, digital competence, cooperation, responsible attitude towards the environment, aesthetic competence, entrepreneurship and entrepreneurial competence. In particular, we focus on the educational profile of tourism technician and the subjects Business Informatics, Geography, Tourism Geography, Marketing in Tourism and Hospitality, Agency and Hotel Business. Our goal is to instruct teachers of all professions in the existence of web 2.0 tools and popularize their use. These tools allow students to connect the acquired knowledge in computer science in the creation of websites and apply them in tasks in other subjects. The possibility of creating public websites free of charge, simultaneous teamwork with administrator access from different locations, as well as integrating Google surveys, translators, calendars, site search, YouTube content and links to social networks (Instagram, Facebook, etc.) are particularly emphasized. With this, students develop key digital competences and entrepreneurial competences for competitive employment in the labor market.*

Keywords: *WordPress; CMS; Google Translate; YouTube; Web 2.0*

1. UVOD

Nastavni sadržaji iz oblasti kreiranja internet sadržaja su u srednjim stručnim školama prošli dug put, počev od modula u okviru izbornog predmeta Poslovna informatika u turizmu i ugostiteljstvu do nastavne teme u okviru obaveznog predmeta Poslovna informatika, koja po svom obimu zauzima 13% svih godišnjih časova, predviđenih za realizaciju nastave u odeljenju. Ova tema je značajna za učenike sa tačke gledišta budućeg zaposlenja nakon završavanja srednje škole i studija, jer se svi sektori obrazovanja i privrede neprestano razvijaju ka digitalizaciji. Ovim su zahtevi i standardi tržišta za stručnošću u vezi digitalnih komeptencija zaposlenih primetno viši iz godine u godinu. Poslednje promene u statusu predmeta Poslovna informatika za obrazovni profil turistički tehničar su nastupile školske 2022/2023. godine. Pravilnikom o izmenama i dopunama Pravilnika o planu i programu nastave i učenja stručnih predmeta srednjeg stručnog obrazovanja i vaspitanja u području rada Trgovina, ugostiteljstvo i turizam [1], predviđeno je da se predmet Poslovna informatika izvodi u obimu od 64 časa godišnje u drugom razredu. Pri ovom, nastavne jedinice grupisane se u 6 nastavnih tema, odnosno oblasti: tabelarni proračuni, obrada crteža na računaru, obrada video i audio zapisa, obrada digitalne fotografije na računaru, prezentacije i internet prezentacije.

Program se nadovezuje tako da se sadržaji iz prethodnog razreda predmeta Računarstvo i informatika ponavljaju i proširuju u drugom razredu u okviru predmeta Poslovna informatika. Takođe je preporuka da se radi na primerima iz prakse, sa posebnim akcentom na rad u turističkim agencijama ili hotelima („kreirati primere koji se koriste za potrebe agencija i hotela"). Predloženi oblici rada su: frontalni, rad u grupi, rad u paru, individualni rad. Takođe, preporuka je i primena projektne nastave.

Oblast predmeta Poslovna informatika je dinamična i podložna promenama tj. unapređenjima, što se vidi i kroz promene programa nastave i učenja za ovaj obrazovni profil, koji se u proteklih 6 godina više puta menjao i prilagođavao [1-6].

Sadržaji i ishodi iz programa nastave i učenja predmeta Poslovna informatika u velikom delu zasnivaju se na korelaciji sa programom nastave i učenja predmeta: Geografija, Turistička geografija, Marketing u turizmu i ugostiteljstvu, Agencijsko i hotelijersko poslovanje [1, 2].

Predmet Poslovna informatika oslanja se na multidisciplinarnosti znanja učenika, kao i razvoju kompetencija za celoživotno učenje, komunikaciju, rad s podacima i informacijama, digitalne kompetencije, kompentencije za saradnju, odgovoran odnos prema okolini, estetičke kompetencije, preduzimljivost i preduzetničke kompetencije.

Stručne kompetencije obuhvataju primenu stečenih znanja iz predmeta: Geografija u drugom razredu, Turistička geografija, Marketing u turizmu i ugostiteljstvu i Agencijsko i hotelijersko poslovanje u trećem razredu.

Na osnovu navedenog, može se zaključiti koliko je oblast nastave u eri digitalizacije dinamična i podložna promenama i unapređenjima.

Cilj rada je upućivanje nastavnika u novije metode rada sa učenicima, načine povezivanja znanja iz više nastavnih predmeta, orijentacija nastave ka ishodima učenja i upotreba besplatnih verzija web 2.0 online alata. Ovi alati su se u praksi pokazali kao dobra rešenja za zadatke koji su postavljeni programom nastave i učenja, posebno u predmetima za koje ne postoji odobreni udžbenik.

Predmet ovog rada je analiza prednosti projektne nastave, saradnje nastavnika, savremenog pristupa nastavi i upotrebe onlajn okruženja, kao alata za učenje i kreiranje. Takođe, razmatrane su prednosti, koje se manifestuju kroz primere unapređenja nastavne prakse u slučaju upotrebe web 2.0 okruženja u nastavi.

2. NASTAVNA TEMA INTERNET PREZENTACIJE - ODABRANA BESPLATNA VERZIJA ONLAJN WEB 2.0 PLATFORME

Trenutno ne postoji odobreni udžbenik za predmet *Poslovna informatika* u okviru obrazovnog profila turistički tehničar. Iako je obaveza da udžbenici, kao osnovni didaktički oblikovani materijali [6], obuhvate sve ishode predviđene pravilnicima, trenutno se nastavnici ovog predmeta i učenici smera turistički tehničar suočavaju sa nedostatkom odgovarajućeg materijala za rad. Nastavnici su primorani da samostalno pronalaze izvore za učenje, prilagođavaju ih i u saradnji sa kolegama ostalih predmeta osnažuju teorijska i praktična znanja učenika, kako bi se ispunili zahtevi programa nastave i učenja. Ova situacija zahteva dodatne napore i kreativnost, kako bi se obezbedio adekvatan materijal za učenje i podrška učenicima u njihovom obrazovanju.

U okviru predmeta Agencijsko i hotelijersko poslovanje učenici stiču znanja i kompetencije o tome šta je to turistička agencija, koje sve modele i vidove turistitčkih proizvoda mogu ponuditi konkurentnom tržištu, kroz programe i ponude turističke agencije. Takođe, sticanjem znanja kroz predmet Geografija i Turistička geografija usvajaju znanja o prirodnim resursima i lepotama Srbije. Na predmetu Marketing u turizmu i ugostiteljstvu stiču znanja o instrumentima za ispitivanje turističkog tržišta. Time su se stekli svi potrebni uslovi za rad na projektu digitalizacije nastave odnosno pravljenja sajta virtuelene turističke agencije i kreiranja predloga programa putovanja učeničkih ekskurzija, izleta i studijskih putovanja, zasnovanih na potrebama učenika svih profila naše škole.

2.1. Google alati

Jedan od najpopularnijih i najkorišćenijih servisa trenutno je *Google*. Ova platforma omogućuje besplatno korišćenje servisa za slanje i prijem pošte, onlajn upotrebu Google dokumenata, tabela, prezentacija, anketa/formi. Obukom nad ovim alatima učenici su osnaženi za lako i samostalno rešavanje problema, sa bilo kog pametnog uređaja i računara u svetu. Takođe, otvaranje Google naloga je preduslov za uspostavljanje besplatnog naloga i na portalu *WordPress* [7].

2.2. WordPress

WordPress je popularna platforma za upravljanje sadržajem CMS (Content Managment System), koja omogućava korisnicima da lako kreiraju, uređuju i održavaju veb stranice i blogove.

WordPres se može instalirati na svoj server ili se može koristiti WordPress.com verzija platforme. Ovaj program pruža intuitivan korisnički interfejs koji olakšava kreiranje i uređivanje sadržaja. Jednostavno je dodavanje teksta, slike, video zapisa i drugih medijskih elementa na svoje veb stranice putem jednostavnih alata za uređivanje.

Izuzetno je fleksibilan i prilagodljiv. Korisnici mogu birati između hiljada tema (templates), kako bi promenili izgled svojih veb stranica, kao i dodataka (plugins), koji dodaju različite funkcionalnosti, poput kontaktnih formi, galerija slika, SEO alata i još mnogo toga.

Ovo je besplatan softver otvorenog koda, što znači da ga svako može koristiti, menjati i prilagoditi prema svojim potrebama. Posebno je koristan, jer ga mogu koristiti i osobe koje nemaju znanje iz programiranja.

Što se tiče bezbednosti, WordPress je posvećen zaštiti svojih korisnika i redovno ažurira svoj softver, kako bi se sprečile potencijalne ranjivosti.

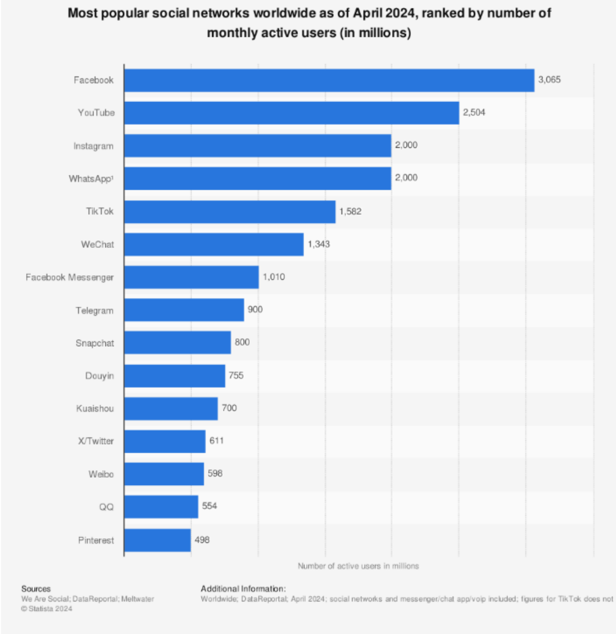
Učenici preko WordPress platforme mogu da naprave sajt svoje virtuelne agencije.

Google prevodilac i Google anketa mogu se ugraditi u okviru sajtova kao njihov sastavni deo. Time korisnici mogu obezbediti optimalne uslove za povećanje publike, istraživanje turističkog tržišta i van okvira jezičkog područja srpskog jezika.

2.3. Procena izbora društvenih mreža prema jednom od vodećih portala za statistiku *Statista*

Za procenu društvenih mreža, koje su bitne za održivost projekta sajta turističke agencije, rukovodili smo se pouzdanim izvorima. *Statista* [6] je vodeći portal za statistiku, tržišne podatke i istraživanja u vezi sa tržištem. Ovaj portal pruža insajderske informacije i činjenice iz više od 170 industrija u preko 150 zemalja. Evo nekoliko ključnih tačaka o *Statisti*:

1. *Statistika i istraživanje:* Na *Statisti* možete pronaći statističke podatke, rezultate potrošačkih anketa i istraživanja industrije iz više od 22.500 izvora na preko 60.000 tema. To uključuje informacije o društvenim mrežama, e-trgovini, veštačkoj inteligenciji, inflaciji, električnim vozilima, održivosti, gejmingu, brzoj modi i mnogim drugim oblastima.
2. *Društvene mreže: Statista* pruža podatke o broju korisnika društvenih mreža širom sveta. Na primer, Facebook je najpopularnija društvena mreža sa oko 2,9 milijardi aktivnih korisnika. Takođe, možete saznati koliko vremena ljudi prosečno provode na društvenim mrežama i koje su najpopularnije platforme.



Slika 1. *Najpopularnije društvene mreže u svetu u aprilu 2024, rangirano prema broju mesečno aktivnih korisnika [8]*

Prema slici 1 odabrane društvene mreže za izradu školskog projekta su: Facebook i instagram, a zatim i YouTube.

3. PRIKAZ IZRADE UČENIČKOG PROJEKTA

Učenici su podeljeni u timove od po tri-četiri učenika. Projektni zadaci se realizuju delom u školi, a delom ga učenci rade samostalno kod kuće, timski onlajn. Ukupno vreme trajanja rada na celokupnom projektu od ideje do realizacije je mesec dana.

Projektni zadatak svakog tima je da kreiraju virtuelnu turističku agenciju na WordPress platformi uz upotrebu besplatnih Google alata i ukljuučivanjem društvenih mreža.

Sa timovima učenika sarađivalo je nekoliko nastavnika iz različitih struka kako bi se interdisciplinarni pristup u potpunosti ispoštovao:

U pripremnoj fazi nastavnica turističke geografije i nastavnik agencijskog i hotelijerskog poslovanja radili su sa učenicima na ideji o nazivu turističke agenicje, pretraživanju sličnih sajtova na internetu. Učenici su imali potpunu slobodu u istraživanju, kreativnosti i timskom radu.

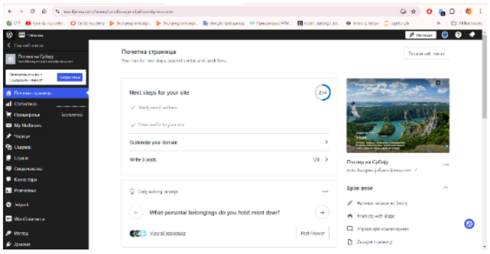
„Projektna nastava predstavlja pristup koji pripada novoj paradigmi i podrazumeva istraživačku orijentaciju učenika u nastavi i učenju, tokom koje se koriste već usvojena znanja, stiču nova i razvijaju stvaralaštvo, samoregulacija i timski rad kod učenika. Takav pristup bi, teoretski, trebalo da omogući, kako ostvarivanje ishoda i standarda predmeta, tako i razvoj predmetnih i međupredmetnih kompetencija." [9]

Potom se pristupilo izboru sadržaja tekstova, forme tekstova i formata turističkih aranžmana koji su planirani za prikaz.

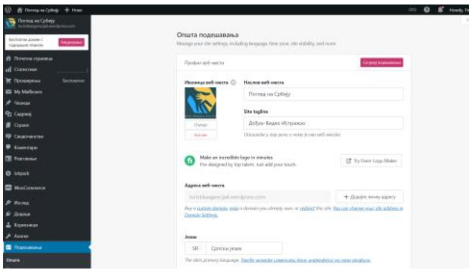
Za tehnički deo izrade sajta i upotrebe digitalnih alata sa učencima sarađivala je nastavnica poslovne informatike:

Prvi korak za sve timove je bio da kreiraju Google nalog.

Drugi korak: upotrebom Google naloga omogućeno je logovanje na WordPress. Ovaj portal je interaktivan sa korisnikom i daje da kroz nekoliko intuitivnih koraka se izvrši izbor naziva sajta, tipa bloga/sajta, njegove namene i osnovnih podešavanja. U ovom koraku birana je URL adresa sajta. U varijanti besplatnih verzija se u okviru adrese nalazi deo adrese koji izabere korisnik, a potom je obavezan **.wordpress.com** deo adrese. Takođe, kroz programom vođene korake bira se besplatna verzija sajta koja se kasnije može kupiti ukoliko je to potrebno. Tokom rada u svakom trenutku moguće su izmene naziva sajta i opštih podešavanja.



Slika 2. *WordPress administratorska strana*



Slika 3. *WordPress administratorska strana – opšta podešavanja – jezik sajta admin i korisnička strana*

Važno je napomenuti da korisniku nisu potrebna napredna znanja web dizajna i internet programiranja. To je odlično jer obrazovni profil turistički tehničar ne izučava web dizajn i internet programiranje tokom školovanja.

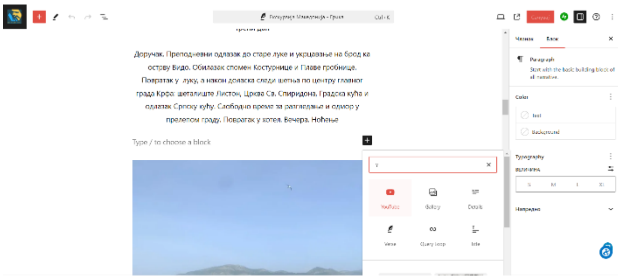
Treći korak: Izbor teme – dizajna bloga/sajta.

Slika 4. *WordPress izbor teme i dodatna podešavanja teme*

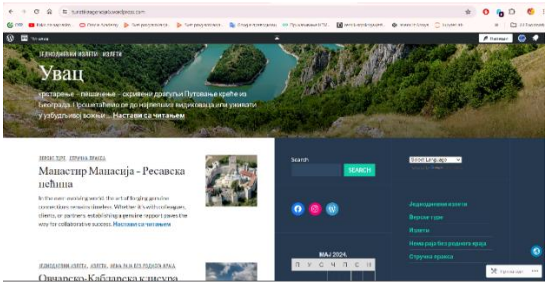
Četvrti korak: Nakon sređivanja teme, jezika administratorske i korisničke strane, pristupa se kreiranju postova-članaka i njihovom objavljivanju.

Slika 5. *WordPress –uređenje članka / posta sa administratorske strane*

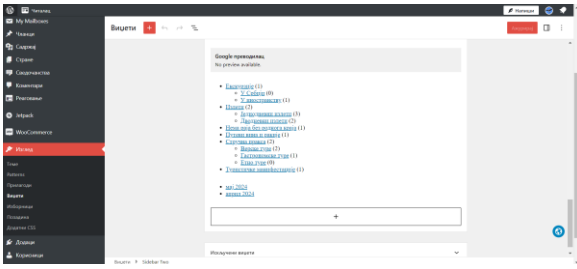
Dodatno se svaki članak može obogatiti spoljnjim linkovima i embedovanjem snimaka sa YouTuba



Slika 6. *WordPress –umetanje bloka YouTube u članak i sa administratorske strane*

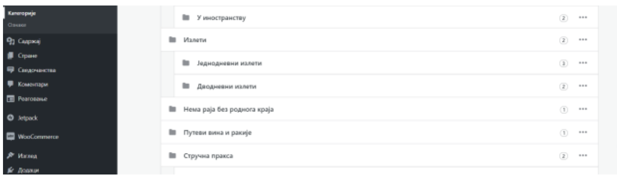


Slika 7. *WordPress korisnička strana – izgled članka koji vide zainteresovani posetioci*

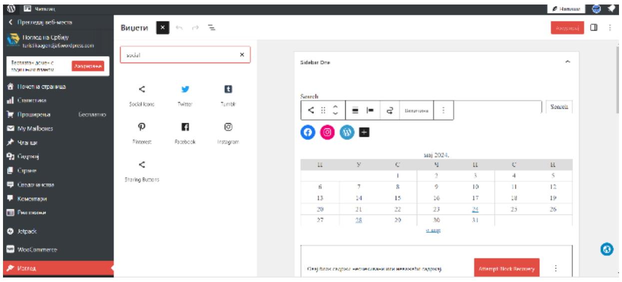


Slika 8. *WordPress – uređenje vidžeta Google prevodilac i vidžeta Kategorije sa administratorske strane*

Članci se svrstavaju u kategorije koje služe za razvrstavanje sadržaja i davanje smisla celokupnom sajtu/blogu.



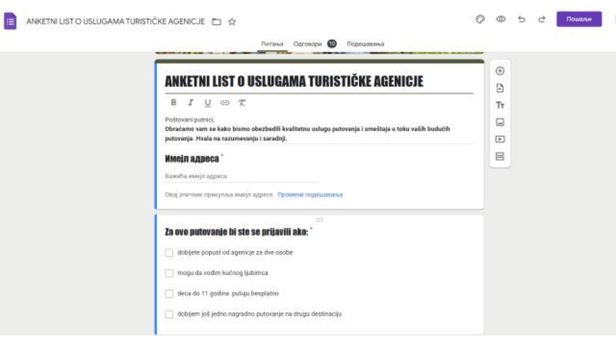
Slika 9. *WordPress –Kategorije*



Slika 10. *WordPress –umetanje vidžeta za povezivanje sa profilima na društvenim mrežama sa administratorske strane*

Peti korak: Vidžetima se postiže preglednost i uređenost sajta - odnosno mapa sajta tako da korisnik brzo i lako može doći do željenih informacija. Takođe uvođenjem Google prevodioca omogućen je prevod sajta na ogroman broj stranih jezika – čime je povećana ciljana publika.

Šesti korak: Izrada i ugradnja Google ankete – Google Forms [10] za potrebe istraživanja turističkog tržišta. Učenici su upotrebom alata Google Forms kreirali anketu.



Slika 11. *Google Forms –Anketa*

Anketa je ugrađena u članak sajta kroz opciju umetanja generisanog html koda kroz upotrebu html bloka koji je omogućen na WordPress-u.

Tokom izrade projektnih zadataka timovi učenika su se suočavali sa različitim tehničkim i sadržajnim problemima koji su se otvarali prilikom izrade sajtova i prilikom prikupljanja materijala. Do rešenja se dolazilo tako što su učenici radili po principu učenja putem pokušaja i pogrešaka. Greške su prirodni deo procesa učenja, a svaka greška predstavlja korak prema uspehu.

Blog jednog učeničkog projekta prikazan je na slikama 2, 3, 4, 5, 6 i 7 se nalazi na adresi: https://turistikaagencija6.wordpress.com/

4. ZAKLJUČAK

Nastava budućnosti je takva da se okruženje učenja, iz tradicionalne učionice premešta u online okruženje i digitalizuje. Web alati i servisi se neprestano inoviraju i unapređuju.

Nastavom nije moguće obraditi sve web 2.0 alate koji se nalaze na internetu.

Na kraju to nije ni cilj. Kroz nastavu Poslovne informatike učenike je potrebno naučiti digitalnom načinu razmišljanja.

Povezivanje znanja iz više nastavnih predmeta stimuliše nastavnike ka kvalitetnijoj nastavi sa jasno definisanim ishodima.

Ovim interdisciplinarnim pristupom učenici su pokazali uspešan transfer znanja, zaključak je da su se zaista razvile međupredmetne kompetencije. Učenici su stekli digitalna znanja koja ih čine konkurentnim na tržištu rada [11].

Nastavnici u srednjim stručnim školama, zbog povezanosti predmeta i širine u pristupu, potrebno je da timski rade i prate razvoj dostignuća svojih uže stručnih oblasti. Kroz saradnju sa kolegama stručnih predmeta, oslanjajući se na međupredmetne kompetencije u nastavi potrebno je koristiti određene prednosti inoviranih okruženja, ukoliko su korisna za učenike. Cilj ovog rada je da kod nastavnika probudi želju za daljim samostalnim usavršavanjem i praćenjem trendova u predmetnoj oblasti, što je u skladu sa savremenim tokovima celoživotnog učenja.

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Kapacitet znanja i problematika rada nastavnika tehnike i informatike 21. veka

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Rezime: *U radu se istražuju mogućnosti rada nastavnika tehnike i informatike i njegova konstantna spremnost za potrebnim usavršavanjem na poljima tehnološkog razvoja i informaciono – komunikacionih tehnologija, razvoja hardvera i softvera. Tehnika i tehnologija, informatika i računarstvo danas zauzimaju sa sigurnošću visoko mesto u predmetnoj nastavi odnosno obrazovanju učenika. Živimo u 21 veku, veku naučno – tehnoloških dostignuća, a nastavnik je ključan faktor u savremenom obrazovanju. U radu se ističe da današnji nastavnik tehnike i informatike sa učenicima pored redovne nastave, priprema i učestvuje sa učenicima na raznoraznim takmičenja iz oblasti tehnike i tehnologije, saobraćaja, robotike, interfejsa i veštačke inteligencije i programiranja. U radu se postavlja i trenutna realnost "živog časa", a to je da je danas situacija takva da u mnogim školama nastavnici tehnike i tehnologije, informatike i računarstva nemaju adekvatne uslove za rad. Kao rešenje u radu se ističe korišćenje obrnute učionice umesto tradicionalne učionice.*

Ključne reči: *nastavnik; tehnika; tehnologija; informatika; savremeno obrazovanje; obrnuta učionica*

Knowledge Capacity and Problems of Work of Technology and Informatics Teachers in the 21st Century

Abstract: *The work explores the possibilities of the technical and informatics teacher's work and his constant readiness for the necessary training in the fields of technological development and information and communication technologies, hardware and software development. Engineering and technology, informatics and computer science today occupy with certainty a high place in subject teaching, that is, in the education of students. We live in the 21st century, the century of scientific and technological achievements, and the teacher is a key factor in modern education. The paper points out that today's teacher of technology and informatics, in addition to regular classes, prepares and participates with students in various competitions in the fields of technology and technology, traffic, robotics, interfaces and artificial intelligence, and programming. The paper also presents the current reality of the "living class", namely that today the situation is such that in many schools teachers of technology, information technology and computer science do not have adequate working conditions. As a solution, the paper highlights the use of a flipped classroom instead of a traditional classroom.*

Keywords: *teacher; technique; technology; computer science; modern education; flipped classroom*

1. UVOD

Nastavnik tehnike i informatike u osnovnoj školi danas predaje dva veoma značajna predmeta 21. veka – tehniku i tehnologiju, računarstvo i informatiku. Zašto su danas itekako važna ova dva međusobno povezana predmeta?

Obrazovanje u 21. veku predstavlja sticanje znanja iz oblasti tehnike, tehnologije, informatike i računarstva, jer ovi predmeti omogućavaju učenicima da na pravi način izgrade odgovoran odnos prema sebi, životnom i radnom okruženju. Nastavnici tehnike i informatike na časovima od 5 do 8. razreda osposobljavaju učenike za život i rad u današnjem globalnom svetu koji se tehnički i tehnološki menja munjevitom brzinom, podstiće razvijanje kritičkog mišljenja i preduzimljivosti. Pored toga, nastavnik edukuje učenike kroz rad na računaru i učenju raznoraznih programskih paketa koji su propisani nastavnim planom i programom. On je taj koji učenike uči da efikasno i racionalno koriste IKT uređaje, i na način koji ne ugrožava njihovo zdravlje i sigurnost. Međutim, od 2020.

godine zbog epidemije Covid-19, u Srbiji se primenjivao hibridni model nastave odnosno model obrnuta učionica o kojoj će biti reči u nastavku rada. Od tog modela nastave nakon završetka epidemije se nije skroz odustalo i pominje se sve više pitanje budućnosti nastave u obrazovnim ustanovama i primeni ovakvog kombinovanog modela nastave (tradicionalna nastave/onlajn nastava).

2. KAPACITET ZNANJA NASTAVNIKA TEHNIKE I INFORMATIKE 21. VEKA

Usavršavanje nastavnika je proces koji uvek ima pozitivne ishode. Nova iskustva i informacije bude kreativnost nastavnika i stvaraju nove prilike. Nastavnici tehnike i informatike u obrazovnim ustanovama, iza sebe imaju formalno, fakultetsko obrazovanje. To je minimum potreban da bi neko mogao da se bavi prosvetnim radom. Ipak, da bi nastavnici napredovali u svojoj karijeri i postali lider u obrazovanju, potrebno je više. Za razliku od formalnog, neformalno obrazovanje je ono što pokazuje trud i želju pojedinca da se izdvoji od ostalih i postane natprosečan. Ono ne samo da nudi mogućnost da se nastavnik usavršava već i da usmerava i osavremenjuje svoje znanje. Nastavnici tehnike i informatike koji stalno rade na svom profesionalnom razvoju su oni koji imaju kapacitet da naprave promenu i zbog toga ih nazivamo liderima u obrazovanju. Za to je potrebno mnogo energije, rada, truda, dobre volje da bi on to postao [4].

Promene u oblasti tehnike i tehnologije, iziskuju modernizaciju obrazovno-vaspitnog sistema. Usvajanje informacionih tehnologija i specifičnost zahteva koje nameću u današnjem društvu, „društvu znanja", uslovili su potrebu za prilagođavanjem obrazovnog sistema inovacijama, a samim tim i nastavnika tehnike i informatike, koji preuzimaju nove i odgovorne uloge i zadatke. Profesionalni razvoj zaposlenih u obrazovanju, je proces koji se odnosi na stalno unapređivanje znanja, veština i sposobnosti nastavnika i na razvijanje nastavničkih kompetencija. Potreba za profesionalnim razvojem proizilazi i iz razvoja tehničko-tehnoloških i informatičkih dostignuća [5].

3. NASTAVNIK TEHNIKE I INFORMATIKE 21. VEKA

Društvo u kome živimo se konstantno menja, tehničko – tehnološke inovacije konstantno napreduju, informaciono – komunikacione tehnologije (u daljem tekstu IKT) se razvijaju velikom brzinom a ono što je do pre samo nekoliko godina bilo trend u obrazovanju, danas se smatra zastarelim. Zato nastavnik tehnike i informatike mora konstantno pratiti nove trendove savremenog obrazovanja. Svaka nova generacija učenika donosi svoje promene, a dobar nastavnik je onaj koji zna kako da ih isprati, koriguje i oblikuje.

Da bi postali nastavnik tehnike i informatike 21. veka koji svoje učenike razume, neophodno je da prate trendove razvoja pedagogije, ali i tehnologije, i da nikada ne pomisle da su završili sa svojim obrazovanjem. S tim u vezi i naredna izreka kaže "čovek se uči dok je živ", pa tako i nastavnik.

Integracija znanja i veština je rastući trend obrazovanja u svetu. Finska, čiji se edukativni sistem smatra najboljim, najnaprednijim i koji svakako daje najbolje rezultate (između ostalog, učenici u Finskoj su uvek među prvima na PISA testovima) uvela je upravo tu integraciju.

Znanje je nešto što nam nijedan sistem ne može osporiti, bez obzira koliko je rigidan i zastareo. Bez obzira na kom kontinentu živimo i u kom ćemo sistemu sutra raditi, kvalitet je uvek prepoznatljiv.

Nastavnici tehnike i informatike se ne plaše intenzivnih promena koje dolaze iz godinu u godinu, sopstvenim primerom izazivaju promene. Oni zapravo redefinišu ulogu nastavnika tehnike i informatike i koriste sve svoje potencijale.

Nastavnik po nastavnik, škola po škola i jednoga dana možemo očekivati drugačiji, bolji obrazovni sistem [6]. Počnimo sada od sebe samih i pokrenimo promenu.

Nastavnik tehnike i informatike u obrazovnom sistemu obavlja raznorazne poslove, od onih koji su mu propisani dokumentacijom od onih koji i nisu propisani, ali se podrazumeva da oni to rade. Navešćemo samo neke od aktivnosti:

- redovna nastava;
- dodatna nastava (priprema učenika za takmičenja);
- elektronski dnevnik (koordinatori);
- tehnička podrška za vreme prijemnog ispita za upis u srednje škole;
- administracija (sajta, svih računara u obrazovnoj ustanovi) i dr.

Sve gore navedeno govori da nastavnici tehnike i informatike su itekako zauzeti tokom jedne školske godine, raznoraznim aktivnostima, ali isto tako ima i nastavnika koji rade manje ili više od toga i to je realnost, ne samo u našem sistemu.

Tehnička i informatička pismenost su deo znanja, umeća i razumevanja koje učenik treba da dostigne na kraju obaveznog osnovnog obrazovanja, a koje treba da mu obezbede i valjanu profesionalnu orijentaciju i dalje obrazovanje i svakodnevno delovanje [1].

Nastavnik tehnike i informatike 21. veka mora da:

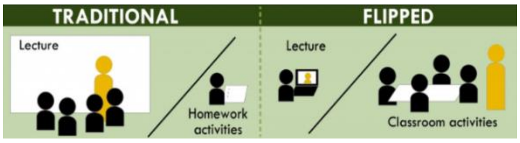
- ima velika očekivanja koja inspirišu, motivišu i koja su izazov učenicima;

- teži napredku i dobrim rezultatima učenika;
- pokazuje dobro poznavanje nastavnog predmeta i nastavnog plana i programa;
- planira i predaje dobro osmišljene lekcije;
- prilagođava nastavu tako da ona odgovara talentima i potrebama svih učenika;
- precizno i produktivno ocenjuje;
- vodi računa o ponašanju, kako bi se obezbedilo zdravo i sigurno okruženje za učenje;
- ispunjava veliki broj profesionalnih obaveza [6].

4. OBRNUTA UČIONICA/TRADICIONALNA UČIONICA U NASTAVI TEHNIKE I INFORMATIKE

Kod tradicionalne učionice odnosno tradicionalnog načina nastave imamo uglavnom jednosmernu komunikaciju, prenošenje činjenica, pasivno učenje i drugo. Svesni smo da nastava i učenje mogu biti drugačiji i nekako pristupačniji.

Obrnuta učionica je metoda koja predstavlja sasvim nov pristup nastavi. Njena glavna karakteristika je što se novo gradivo ne obrađuje u učionici, već kod kuće. Zapravo, ono što je ranije rađeno na času, sada se radi kod kuće i obrnuto.



Slika1. *Šematski prikaz – Tradicionalna i obrnuta učionica [2]*

Nastavnik tehnike i informatike nema u svakoj školi adekvatne uslove i sredstva za rad, pa s tim u vezi obrnuta učionica bi se ogledala u tome da nastavnici pripremaju nastavne sadržaje u vidu podkasta, tutorijala, prezentacije, video snimka, pdf ili nekog drugog fajla.

Učenicima se preporučuje odgovarajući tekstovi na internetu ili stranice za istraživanje/surfovanje. Nastavnik tehnike i informatike, dakle, koristi IKT za pripremu i deljenje materijala koji se mogu lično izrađivati ili preuzimati.

Uloga nastavnika i učenika se menja, jer se prelazi sa modela zasnovanog na predavaču, na model usmeren na učenika. To je zapravo personalizovani model učenja koji bi odgovarao - svakom učeniku ponaosob.

U takvoj situaciji, nastavnik tehnike i informatike nije samo osoba koja prenosi znanje, već postaje mentor/vodič u učenju, dok učenik postaje aktivan učesnik, koji istražuje, postavlja pitanja, komunicira, sarađuje sa drugima.

Obrnuta učionica je zapravo alat koji nastavnik može prilagođavati učenicima i ciljevima koje želi da ostvari [3].

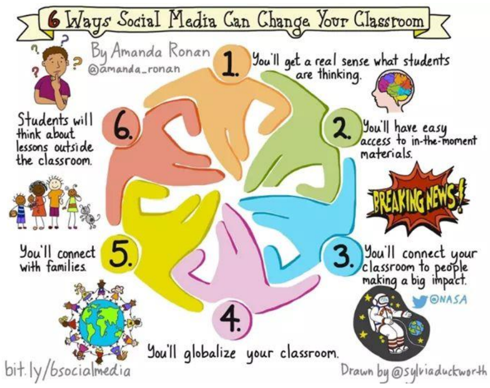
U globalnom svetu, pa i kod nas 2020. godine došlo je do epidemije Covid-19, koji je naterao obrazovne sistema širom sveta da primenjuju model obrnute učionice - flipped classroom. Koristili smo raznorazna IKT nastavna sredstva, prvo smo počinjali sa viber grupama, zatim prelazili polako na Google učionicu, Microsoft Teams, YouTube, Edmodo, WordPress, Padlet i mnoge druge aplikacije za komunikaciju nastavnika sa učenicima.

U narednom tabelarnom prikazu, navešćemo gore navedene socijalne medije i neke internet servise koje su nastavnici tehnike i informatike i njihovi učenici koristili u on-line nastavi za vreme Covid-19.

Tabela1. *Korišćenje socijalnih medija/internet servisa u nastavi za vreme Covid-19*

Socijalni mediji u nastavi/internet servisi	Korišćenje nastavnika u on-line nastavi	Korišćenje učenika u on-line nastavi
Google Classroom	DA	DA
Microsoft Teams	DA	DA
Youtube	DA	DA
Edmodo	NE	NE
WordPress	NE	NE
Padlet	NE	NE
Viber	DA	DA
E-mail	DA	DA

U nastavku rada prikazan je slikovito uticaj socijalnih medija u učionici, a pre svega mislimo na obrnutu učionicu i model on-line nastave, koji se koristio za vreme Covid-19 nastave, a koji i danas ima ulogu u normalnom načinu obavljanja nastave i komunikacije nastavnika i učenika.



Slika2. *Socijalni mediji u nastavi [2]*

U toj situaciji nastavnicima tehnike i informatike je bilo najlakše u smislu jer su tehnički odnosno informatički obrazovaniji od drugih nastavnika, ali da je bilo lako kod svakog nastavnika pa i kod njih nije bilo sasvim sigurno.

Glavna prednost obrnute učionice odnosno ovog tipa nastave je sloboda kako za učenike tako i za nastavnike. Otvorenija je i slobodnija komunikacija između nastavnika i učenika i to se zapravo videlo tokom onih godinu i više dana nastave. Nastavnik ne mora da ponavlja iste lekcije, već dobija na vremenu i priliku za neposredan kontakt sa učenikom, odnosno dostupan je svakom.

Ostale pozitivne strane su:

- veće angažovanje učenika na časovima i bolje usvajanje znanja;
- naučeno gradivo je postojanije i trajnije;
- bolja saradnja među vršnjacima;
- nastavni materijali su stalno dostupni;
- odsutnim učenicima je jednostavnije da nadoknade propušteno gradivo;
- slabiji učenici dobijaju neophodnu pomoć jer nastavnik odmah dobija povratnu informaciju, koje su najčešće nedoumice, nejasnoće, šta učenici teško savladavaju. Prema tome usmerava rad, zadaje zadatke, organizuje grupe itd.;
- bolji učenici brže i lakše usvajaju gradivo;
- mogućnost da se nove tehnologije uvedu u učionicu i podstaknu đake da uče.

Dešavalo se tokom onlajn nastave, da su učenici koji su pokazivali lošija znanja u školi i bila pa gotovo nemotivisana za bilo kakav oblik rada, tokom onlajn učenja bili veoma aktivni i saradljivi sa nastavnicima, dok su neki bolji učenici bili pasivniji.

Nedostaci obrnute učionice ogledaju se u sledećem:

- Inovativne nastavne medode uvek zahtevaju detaljnu i pažljivu pripremu nastavnika, od koga se zahtevaju i veštine za izradu i deljenje on-line sadržaja;
- Nemoguće je kontrolisati rad učenika kod kuće i vreme koje su proveli radeći na nastavnom materijalu;
- Ova metoda ne priprema učenike za standardizovane testove;
- Ako učenik nema IKT uređaje (iz raznoraznih razloga), on ne može pratiti ili pohađati onlajn nastavu, odnosno ovaj vid nastavne metode.

5. STATISTIČKI POKAZATELJI ŽIVOTA NASTAVNIKA TEHNIKE I INFORMATIKE 21. VEKA

Na osnovu sprovedene on-line ankete među nastavnicima koji predaju tehniku i tehnologiju, informatiku u računarstvo u osnovnim školama po Srbiji, dobili smo sledeće važne informacije:

1) „Da li u svojim školama imate kabinet za tehniku i tehnologiju?"

   Odgovor: 61,8 % nastavnika je odgovorilo da imaju, a 38,1 da nemaju.

2) „Da li u svojim školama imate kabinet za informatiku i računarstvo?"

   Odgovor: 100 % (svi imaju).

3) „Da li imate adekvatan alat i mašine za rad u učionici na časovima tehnike i tehnologije (ponuđeni odgovori)?"

   Odgovor: 9,5 % nastavnika je odgovorilo da imaju alat i mašine, 19 % nastavnika da nemaju ni alat ni adekvatne mašine, 38,1 % nastavnika da ima alat, ali da nema mašine, čak 42,9 % nastavnika se izjasnilo da se snalaze kako znaju i umeju, donose od kuće, dok se 14,3 % nastavnika izjasnilo da i učenici donose od kuće alat.

4) „Da li predmet informatika i računarstvo treba da ima blok nastavu (kao i tehnika i tehnologija), (ponuđeni odgovori)?"

   Odgovor: 76,2 % nastavnika je da je potrebno zbog preobimnog nastavnog plana i programa, dok je 23,8 % nastavnika odgovorilo da nije potrebno.

5) „Koji su najveći problemi današnjice u 21. veku nastavnika tehnike i informatike?"

   Odgovori su bili različiti (citiramo neke od njih):

   - "Nestručni kadar, predaju ili učitelji koji nemaju posao ili sa bilo kojom školom, posao dobijen preko stranačkog aktivizma";
   - "Nedostatak stručnog kadra. Veliki broj nekompetentnog kadra koji je poslednjih godina uveden u nastavu TiT, po sistemu "da ne trpi nastava" zbog nedostatka stručnog kadra. Neopremljenost kabineta TiT nastavnim sredstvima. Nedostatak stručnih seminara vezanih za metodiku nastave TiT pa nastavnici i da hoće nemaju gde da se usavršavaju. Iako je prošlo 4 godine od donošenja zakonske obaveze podele odeljenja na grupe i dan danas u mnogim školama to nije urađeno zbog opstrukcije direktora škola pa čak i nekih nastavnika TiT";
   - "Potreba za savremenim alatima i uređajima";
   - „Preobimno gradivo, u nekim školama nastava tehnike se ne izvodi po grupama, a veoma je teško raditi sa 30 učenika, naročito kada dođe praktičan rad. Na časovima informatike se previše pažnje posvećuje programiranju, veoma malo osnovnim stvarima (Office), to se "pretrči"";
   - "Nedostatak adekvatnog kabineta i nevrednovanje predmeta";

- "U poslednjih par godina uslovi za rad su bolji, mislim na mogucnost rada u grupama ali je malo praktične nastave u planu i programu";
- „Zastarelost alata i računarske opreme, nedovoljno časova na sedmičnom nivou";
- „Učenici na časovima informatike i računarstva žele da se igraju igrice";
- „Veliki broj učenika";
- „Plata";
- „Više pažnje i uvažavanja";
- "Učenici su sve manje motivisani za rad na času, pribor za crtanje im je "noćna mora"";
- "Ne bih nazvala problemom, ali nije lako ispratiti sve promene, biti u toku, naročito u nastavi informatike";
- „Preobiman nastavni program, roditelji i učenici ne shvataju važnost predmeta i njegov veliki značaj";
- „Kabinet za tehniku sa potrebnim mašinama i alatom i veći fond časova informatike";
- „Nemamo problema, mi se snalazimo mnogo brže i jednostavnije u poređenju sa drugima. Naučili smo da pratimo sve izazove današnjice, čak i brže od informatičara je samo sklop tehnike i informatike je prava celina";
- „Kao i kod svih nastavnika, isti problem - nezainteresovanost dece za učenje";
- "Praćenje novih tehnoloških inovacija".

6) „Da li u budućnosti treba primenjivati model hibridne nastave tehnike i tehnologije, informatike i računarstva (kombinovani model: redovan čas u školi i onlajn čas)?"

   Odgovor: 19 % nastavnika se izjasnilo da treba primenjivati model hibridne nastave, a 81 % ne treba.

7) „Koji su glavni razlozi po vašem mišljenju nedostatka profila nastavnika tehnike i informatike u školama u Srbiji?"

   Odgovorili su bili različiti (citiramo neke od njih):

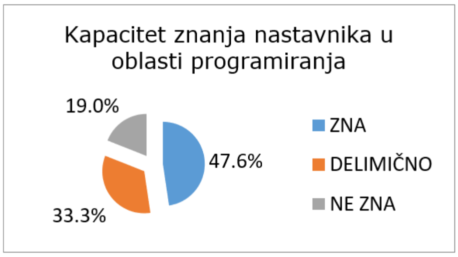
   - „Kao i u celoj prosveti, ne žele da rade za mizernu platu";
   - "Neodgovoran odnos nekih naših strukovnih fakulteta po tom pitanju. Odnos države uopšteno prema pitanju prosvete. Nezainteresovanost mladih za nastavničke fakultete. Loš marketing predmeta i mnogo toga";
   - "Stanje u društvu, odnos prema prosveti";
   - "Informatika – ljudi rade kao programeri za mnogo veći novac";
   - "Smerovi na fakultetima su ukinuti jer veliki broj studenata ne želi rad u prosveti zbog malih plata i loših uslova rada";
   - „Nedovoljno afirmisanje i motivisanje mladih ljudi da se bave ovim poslom, nema adekvatnih obrazovnih profila za školovanje istih";
   - „Uslovi rada, omalovažavanje profesije nastavnika";
   - „Kompleksnost";
   - „Isto kao i sa drugim profilima u prosveti, profesija nam je potcenjena i ponižena, negativna selekcija sve izraženija, zahtevi pred nastavnicima sve veći, nadoknada za rad mala, ispalo je da svako ko i šta drugo ume da radi - ne ostaje u prosveti";
   - „Jer ne postoji smer koji će školovati stručan kadar, a i gde ima posla (u većim gradovima) ljudi se teško odluče da odu iz finansijskih razloga";
   - „Nepoštovanje nastavnikovog lika od strane učenika i roditelja";
   - "Studije teške, preveliki broj ispita. Bolje je završiti IT smer, nego raditi u školi za malu platu".

8) „Da li posećujete kao nastavnik tehnike i informatike seminare stručnog usavršavanja?"

   Odgovor: 100 % nastavnika je odgovorilo potvrdno.

9) „Da li znate da programirate?"

   Odgovor: 47,6 % da, 19% ne i 33,3 % i da i ne.



Slika 3. Kapacitet znanja nastavnika tehnike i informatike u oblasti programiranja

10) „Da li po vašem mišljenju treba izbaciti neke sadržaje nastavnog plana i programa tehnike i tehnologije 5-8 razreda (ponuđeni odgovori)?"

    Odgovor: 38,1 % je odgovorilo da, 38,1 % ne i 23.8 % da određene nastavne jedinice treba izbaciti iz nastavnog plana i programa – da je zastareo.

11) „Koristite li IKT u nastavi tehnike i informatike?"

    Odgovor: 100 % da.

12) „Da li vaš kabinet za tehniku i informatiku poseduje projektor, računar (ponuđeni odgovori)?"

    Odgovor: 95,2 % da imaju, 4,8 % nemaju.

13) „Da li imate dovoljno računara u vašim kabinetima za računarstvo i informatiku?"

    Odgovor: 76,2 % da, 23,8 % ne.

14) „Da li u vašem kabinetu za informatiku i računarstvo imate adekvatan hardver i softver?"

    Odgovor: 71,4 % da, 28,6 % ne.

15) „Šta karakteriše savremenog nastavnika tehnike i informatike 21. veka?"

    Odgovorili su bili različiti (citiramo neke od njih):

    - „Slaba motivisanost";
    - "Posvećenost poslu kojim se bavi. Entuzijazam i kompetentnost. Želja za stalnim stručnim usavršavanjem i napredovanjem";
    - "Nastavnik koji ide u korak sa vremenom";
    - "Rad u adekvatnom prostoru sa adekvatnom opremom";
    - "Informisanost i upornost";
    - „Digitalne kompetencije, stalno učenje i usavršavanje, sposobnost razumevanja i prenošenja znanja na moderne generacije današnjice";
    - „Omiljenost i saradnički odnos sa učenicima";
    - „Lakoća u primeni novih tehnologija, mogućnost osmišljavanja kreativnih časova";
    - "Široko opšte i stručno obrazovanje, prilagodljivost, otvorenost ka novom, konstantan rad na sebi";
    - „Borba za predmet, bolji uslovi rada i veća plata, jer je manja od prosečne plate u Srbiji";
    - „Domišljatost";
    - „Kritičko mišljenje i rešavanje problema na putu od ideje do realizacije".

6. ZAKLJUČAK

Situacija je danas takva da možemo slobodno reći da ima određenih problema/prepreka/izazova sa kojima se nastavnik tehnike i informatike suočava, ali i da iste te problem/prepreke/izazove moramo rešavati u hodu, da nešto od nas ne zavisi, ali ima i stvari od kojih itekako zavisi, a to je da mi kao nastavnici tehnike i informatike školujemo buduće generacije za mnoga zanimanja i oblasti kojima se čovek bavi, a koje mi pokrivamo kroz naša dva predmeta međusobno i neraskidivo povezana tehnika i tehnologija, informatika i računarstvo.

Možemo zaključiti da tehnika i tehnologija, informatika i računarstvo u osnovnoj školi, prolaze kroz brojne izazove savremenog obrazovanja. Ono što trenutno nedostaje kako bi mogla da se ostvari potpuna implementacija novog Programa nastave i učenja iz tehnike i tehnologije, informatike i računarstva jeste opremanje kabineta savremenim nastavnim sredstvima. 2020. godine je objavljen novi Normativ opremanja osnovnih škola nastavnim sredstvima. Međutim, na tome se stalo, jer škole nemaju para, lokalne samouprave i MPNTR-a nisu se izjasnile u vezi ovog još uvek aktuelnog problema i tu za sada nema pomaka napred. Pored toga, veliki problem je nedostatak stručnog kadra za izvođenje nastave tehnike i tehnologije, a uskoro sigurno i za nastavnika informatike i računarstva, zato što budući student ne žele da upisuju pedagoške profile i uče da budu neki novi savremeni nastavnici. Naši strukovni fakulteti u Čačku i Zrenjaninu već nekoliko godina unazad, zbog male zainteresovanosti, upisuju veoma mali broj studenata ili ih uopšte ne upisuju na studijske programe za profesore tehnike i informatike. Da bi se rešili ti problem država mora napraviti jasnu strategiju i rešiti gorući problem nedostatka nastavnog kadra, ne samo za naše predmet već i sve ostale. Jedan od načina bi bio motivaciono sredstvo za buduće studente na studijskim pedagoškim programima, npr. dobijanje stipendija, odnosno zagarantovanog radnog mesta po završetku fakulteta i sl. Došlo se i do polovine 2024. godine i još uvek nisu objavljeni obrazovni standardi za predmet tehnika i tehnologija, što bi svakako unapredilo nastavni proces.

Nastavnik tehnike i informatike je multipraktik koji radi, inovira, bori se, ali ponekad deluje da svo to njegovo kompleksno angažovanje liči kao "prohujalo sa vihorom" ili "čekajući godoa". Na državi i ministarstvu prosvete je da oslušne nastavnike na terenu i krene sa jasnom strategijom obrazovanja i promenom sistema kako bi nastavnici u učenici bili zadovoljni jednim jednostavnim, ali praktičnim dualnim obrazovanjem. Vreme će pokazati, gde će se nastavnik tehnike i informatike i uopšte bilo koji drugi nastavnik nekog predmeta nalaziti, da li u sistemu obrazovanja ili na nekom drugom mestu tržišta rada.

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Windows MultiPoint Server 2016 у савременој настави информатике и рачунарства

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Резиме: *Овај рад ружа осврт на извођење наставе информатке и рачунарства у основној школи, користећи савремене методе рада уз помоћ оперативног система Windows MultiPoint Server 2016. У раду су представљене савремене методе комуникације са ученицима, као начин демостративне методе рада презентујући наставнички екран на радним станицама, као и праћење рада свих радних места са једног места.*

Кључне речи: *настава; методе наставе; МПС; радна станица; облик рада*

Windows MultiPoint Server 2016 in Modern Teaching of Computing and Informatics

Abstract: *This paper presents work in the teaching of computer science using modern methods of work with the help of the operating system Windows MultiPoint Server 2016. The paper presents modern methods of communication with students, as a way of demonstrating the method of work by presenting the teacher's screen at workstations, as well as monitoring the work of all workstations places from one place.*

Keywords: *teaching; teaching methods; MPS; work station; form of work*

1. УВОД

Информатика као наука има широк спектар примена: од теорије информација до метода рачунарске и примењене математике и њихове примене до фундаменталних и примењених истраживања у различитим областима знања (програмирање, мултимедија, мрежне технологије, развој рачунарских система и софтвера, друштвена информатика, вештачка интелигенција и др.). Свака од ових области има своју сложеност, свој приступ учењу, узимајући у обзир интелектуалне способности ученика.

Кроз наставни предмет Инфроматика и рачунарство ученици треба да стекну основну информатичку писменост, упознају се са принципима програмирања и пројектовања софтвера. Интегрисање нформационо-комуникационих технологија у образовање ученика неминован је процес условљен друштвеним и технолошким променама. Развијеност овога процеса показатељ је развијености целокупног друштва и прихваћен је као један од индикатора развијености информационог друштва, односно друштва базираног на знању.

Инфроматика и рачунарство је специјалистички предмет који комбинује основе теорије информатике и рачунарских наука са методама непосредног прикупљања, складиштења, дистрибуције и обраде података. То подразумева стицање основног нивоа програмерског знања као и коришћење апликативнних софтвера потребних за живот и рад у информационом друштву и даљи наставак школовања.

Предмет се изучава у V, VI, VII и VIII разреду основне школе са по једним часом седмично, тј. по тридесет шест часова годишње. У сваком разреду ученици раде пројекат, са акцентом на употребу апликација за обраду текста, табеларне прорачуне и израду презентација. Осим рада на пројекту, наставници могу распоредити годишње до десет часова за међупредметне области.

Број часова намењен настави предмета Инфроматика и рачунарство по разредима у односу на остале наставне предмете, неопходно је да се одељења деле у две групе до 16 ученика, с тим да свакој групи припада планирани фонд часова.

У табели 1 приказан је број часова намењен настави предмета Инфроматика и рачунарство по разредима.

Табела 1. *Број и расподела часова по разредима*

Разред	Седмични број	Број часова обавезни део (80-85%)	Број часова отворени део (15-20%)	Укупно часова	Теоријска настава	Вежбе и остали видови наставе
V	1	30	6	36	20% - 40%	60% - 80%
VI	1	30	6	36	20% - 40%	60% - 80%
VII	1	30	6	36	20% - 40%	60% - 80%
VIII	1	27	7	34	20% - 30%	70% - 80%

Однос времена теоријске наставе и времена предвиђеног за вежбе и остале видове наставе и учења, наставник сходно сопственој процени и избору дидактичко–методичке концепције остваривања исхода. Да би план и програм који је предвиђен програмима наставе и учење био у потпуности остварен и ученици савладали неопходно знање, а нарочито у другом полугодишту VI и VII разреда, када се ради програмски језик PYTHON неопходна су бар два часа недељно.

2. ОРГАНИЗАЦИЈА НАСТАВЕ ИЗ ПРЕДМЕТА ИНФРОМАТИКА И РАЧУНАРСТВО

У организацији наставе Информатике и рачунарства један од најважнијих момената јесте правилан одабир метода наставног рада, заједно са средствима. Методе слично циљевима требају у процесу планирања наставе експлицитно описати.

Уколико тај метод детерминишу спољашњи услови, онда тај опис може бити мање или више глобалан. Ако се иде на операционализовање делатности, онда опис метода треба бити што детаљнији, односно описивање пута до циља који је у овој фази већ постављен.

Потребно је извршити класификацију метода, односно поставити критеријуме за класификацију. Основни критеријум је да ли методе требају бити класификоване према циљевима садржаја или према циљевима ученика. Методе се бирају према циљевима учења, садржају, ситуацијама и условима учења. Детаљно се анализира сваки од критеријума. Методе се придружују циљевима учења и мери њихов учинак.

Планирање наставе мора бити заокружено планом контроле учења како би се утврдило да ли су ученици овом организацијом наставе постигли задати циљ. Коначне резултате свих концепцијских елемената можемо сагледати након примене у пракси.

Оваква концепција планирања наставе има следеће предности:

- планирање је транспарентно, што значи да су сви структурни елементи наставе отворено представљени;
- циљно усмерени приступ даје изванредне могућности за проверљивост, па се може утврдити колико су добро утврђени циљеви, одабране методе и остали елементи у планирању;
- у конципирању наставе учествују наставници, али велики утицај имају и сами ученици, па чак и родитељи, јер одабраним циљевима и методама наставног рада активирају се ученици и наставници.

Фронтални облик рада је погодан при изучавању теоријских основа самог предмета, у уводном или завршном делу часа и у ситуацијама када природа градива налаже демонстрацију одређених операција на рачунару које ученици касније самостално примењују. Примери из праксе указују на то да фронтални рад треба користити у настави, али у комбинацији са другим облицима рада.

Метода демонстрације подразумева очигледно показивање предмета, модела, цртежа, макета и слика. Циљ је научити ученике да уочавају и да ангажују што више чула. Ученици до сазнања стижу индуктивним путем.

Ученик уочава проблем и алгоритамски представља решење, анализира утиске, новозапажени садржај повезује са претходним, од опажаја и представа формира појмове.

Улога наставника је да разматра приступ за упознавање ученика са различитим алатима и методама наставе информатике у школи. Логотип језика се користи као универзални алат за:

1. Увођење неких основних појмова, принципа и метода информатике и низа средстава и специфичних приступа за њихово објашњење и појашњење;
2. Демонстрирање разних примена рачунара у различитим областима: математика, језик, цртање, музика, физика, биологија, историја итд.;
3. Развој софистицираног програмског окружења које одговара проблему који се решава и специфичним потребама корисника;
4. Демонстрирање неких основних принципа развоја образовног софтвера, пролазећи кроз све фазе животног циклуса софтвера;
5. Примена метода и алата вештачке интелигенције при развоју и коришћењу образовног софтвера.

Ученици стичу самопоуздање и као наставници информатике и као дизајнери образовног софтвера. Тако могу искорачити ка новој педагогији у богатом компјутеризованом окружењу за учење.

3. МЕТОДЕ РАДА У САВРЕМЕНОЈ НАСТАВИ ИНФОРМАТИКЕ

Иновација у настави подразумева новину која се спроводи у педагошкој стварности. Сврха сваке новина је да унапреди делатност у коју се уводи. Посебно се мора променити сама организација образовања садржаји и методе рада васпитача. Школа какву данас познајемо, мирна и релативно затворена оаза знања, мора прерасти у отворено истраживање

станица где ће млади стићи и стално иновирају своје знање.

Интензиван развој науке, технологије и инжењеринг захтева да сваки васпитач унапреди својевештине и будите у току са иновацијама у свету који су од значаја за њихову стручну област икоји директно утичу на квалитет наставе. Наставник треба да има за циљ да помогне ученицима да формирају одређена знања, вештине и способности. Циљ школе је развијање личности и индивидуалност сваког детета.

Пошто иновације треба да постану начин рада наставника у школама, сваког наставника

треба оспособити за извођење иновација и коришћење иновативних модели рада у настави. Данас је ученицима важније да уче како и где пронаћи потребне информације, како да га провери и користи, него како да задржи све информације у њиховим главама. „Учити како учити" је постало више важних од сувог памћења и репродукције знања.

3.1 Савремене наставне методе

Вероватно би се сви могли сложити да је, добра, успешна настава она која, пре свега, мотивише ученике за учење, која буди њихову активност и покреће их да напредују. У зависности од тога можемо применити неку од наведених наставних метода:

- Колаборативно учење помаже ученицима да развију своје друштвене вештине иако су у онлајн окружењу. Наставници бирају тему и формирају групу у којој дискутују, дебатују и решавају проблеме.
- Размакнуто учење је наставни метод који се користи да би се ученицима помогло да разумеју лекцију. Састоји се од понављања задатка онолико често колико је потребно док га сви у потпуности не разумеју.
- Преокренута учионица је прелеп начин подучавања. Састоји се од тога да ученици проучавају лекцију код куће, разумеју је, а затим су спремни да о њој разговарају. Ученици могу да гледају видео записе, траже тему на мрежи или читају материјал из учионице.
- Гамификација односно коришћење игара за узбуђивање ученика о часу и новим материјалима. То је одлична стратегија, посебно за курсеве засноване на пуно информација. Деца свих узраста и одрасли воле игрице – на терену или онлајн игре су забавне и пружају одличан начин да их задржите.

3.2 Алати информационо-комуникационих технологија који се користе у савременој настави

Пре неколико деценија могли смо да функционишемо ефикасно цео радни век, користећи знања стечена у средњој школи или на факултету. Данас, захваљујући убрзаном развоју технологије и интернета, такву „комфорност" ниједан професионалац себи не може да дозволи. Знање се повећава експоненцијално и још брже застарева. У области учења и образовања алате можемо поделити у следеће категорије:

- **Системи за управљање учењем** - Системи за управљање (eng. Learning Management Systems – LMS) омогућавају управљање, дистрибуцију и објављивање каталога, предмета, лекција или сегмената лекција, и обухватају, бележе и управљају информацијама о корисницима учења, ученицима и наставницима. Системи за управљање учењем са беслатном лиценцом за рад: MOODLE, ATUTOR, CLAROLINE, SITE@SCHOOL, DOKEOS, WORLD CIRCLE, OLAT, ILIAS, GOOGLE CLASSROOM. Комерцијални системи који обезбеђују управљање електронским учењем: WebCT, Blackboard, Knowledge Presenter Learner, Learn2Learn, Sakai, eCollege, JoomlaLMS, Microsoft Teams.
- **Алати за размену медија** - омогућавају претраживање, коментарисање и организовање фотографија (Flickr), али имају и могућност стварања, публикована, прегледа, организовања и коментарисања видео материјала (YouTube, Google videos и сл.), као и podcasting који се односи на стварање и објаву аудио садржаја на Webu (Odeo).
- **Алати за комуникацију и друштвено умрежавање** - служе за слање инстант порука, аудиовизуелну комуникацију, повезивање преко мреже, прављење група корисника са сличним интересовањима, размену ресурса, дописивање кратким порукама (Skype, Chat, Viber, WhatsApp, Instagram, Facebook, Twiter, Bebo, MySpace, Skyblog, Hi5 ...)
- **Алати за креативно учење** - су специјализовани web сервиси који на једноставан начин омогућавају прављење квизова (JotForm), израду стрипова (Bubblr) и уређивање видео записа кроз додавање

белешки (Bubbleply и Mojiti) . LetterPop је web апликација намењена ученицима који је могу користити при изражавању креативности кроз израду разних врста брошура. Bubb[leply и Mojiti су web сервиси који ученицима и професорима омогућавају креативно уређивање видеозаписа кроз додавање белешки путем балончића.

- **Алати за израду материјала за учење** - су алати које наставник може сам да направи за свој конкретан час и подели са другима. Ови алати омогућавају наставницима организацију наставних садржаја у мање целине при чему свака може да се састоји од аудио или видео записа (Nanolearning) или интеграцију сликовних записа и презентацију са аудио zapisom (Slidestory). Наставници их користе за израду филмова и видеа (GoAnimate), ukrštenica (Crossword Labs) и квизова (Quiz Revolution), презентација (Prezi) и стрипова (Bitstrips), што умногоме доприноси занимљивости самог часа и мотивацији ученика за рад.

4. WINDOWS MULTIPOINT SERVER

MPS је оперативни систем заснован на **Microsoft Windows Server (MPS)** који користи технологију **Remote Desktop Services (RDS)** за хостовање више истовремених независних рачунарских станица или терминала повезаних на један рачунар (multiseat computing). Windows MultiPoint Server 2012 био је последње издање као независна SKU и замењен је улогом MultiPoint Services role у Windows Server 2016.

Историја развоја MPS:

- **Windows MultiPoint Server 2010 -** Ова верзија је планирана у јануару 2010, али је објављена у фебруару 2010, месец дана касније и заснована је на Windows Server 2008 R2. Више станица се може додати на WMS 2010 хост рачунар повезивањем једног монитора, USB 2.0 чворишта, тастатуре и миша за сваку станицу.
- **Windows MultiPoint Server 2011 -** заснован на Windows Server 2008 R2 SP1, објављен је 10. марта 2011. године. За разлику од предходне верзије поседује апликацију MultiPoint Manager, која вам омогућава да надгледате и предузимате радње на станицама MultiPoint Services.
- **Windows MultiPoint Server 2012 -** је наследник Windows MultiPoint Server 2011 и треће издање Windows MultiPoint Server које је објављено 27. новембра 2012. и касније постало опште доступно 10. фебруара 2013. Поседује апликацију MultiPoint Dashboard која омогућава неадминистраторима да надгледају и комуницирају са корисничким радним површинама свих станица на серверу. Такође додаје могућност креирања станица на виртуелним машинама које користе Premium edition of WMS 2012. Додао је заштиту диска што је функција која се може применити на WMS серверима која одбацује све промене направљене на серверу током корисничких сесија и враћа сервер у првобитно стање. Такође је додао MultiPoint Server Connector који омогућава праћење клијентских рачунара који користе Windows 7 и Windows 8 оперативне системе.
- **Windows MultiPoint Server 2016** – Развијен је уз Windows 10 и постао је доступан 12. октобра 2016. године. Омогућава даљинско повезивање више корисника са Windows Server 2016 помоћу RDS апликације за удаљену радну површину са било ког уређаја.

Табела 2. *Хардверска структура MPS* (минималне спецификације)

CPU	• 1.4 GHz 64-bit processor • Compatible with x64 instruction set • Supports NX and DEP • Supports CMPXCHG16b, LAHF/SAHF, and PrefetchW • Supports Second Level Address Translation (EPT or NPT)
RAM	• 8 GB for Server with Desktop Experience • ECC (Error Correcting Code) type or similar technology for physical host deployments
Network	• An Ethernet adapter that can achieve a throughput of at least 1 gigabit per second • Compliant with the PCI Express architecture specification

5. WINDOWS MULTIPOINT SERVER 2016 У НАСТАВИ

WMS је једноставан, исплатив начин за више ученика и наставника да стекну приступ најновијој технологији, побољшавајући учење и помажући ученицима да се припреме за такмичење у глобалној економији. WMS се најбоље користи у школама за употребу у учионицама, лабораторијама и библиотекама. Омогућава више корисника да истовремено деле један рачунар. WMS омогућава школама да смање укупне трошкове за 66% уштедом на хардверу, енергији и одржавању. Школе могу ефикасно утростручити број Виндовс рачунара без повећања буџета.

WMS пружа наставницима и ученицима најновије и познато **Windows** искуство. Такође даје наставницима алате лаке за коришћење и управљање употребом рачунара од стране ученика и за помоћ ученицима да остану фокусирани на своје учење.

У системском окружењу WMS, станице су корисничке крајње тачке за повезивање са рачунаром на којем ради WMS. Свака станица пружа кориснику независно искуство са **Windows 10**. Подржани су следећи типови станица:

- Direct-video-connected stations
- USB-zero-client-connected stations
- RDP-over-LAN-connected stations (for rich client or thin client computers)

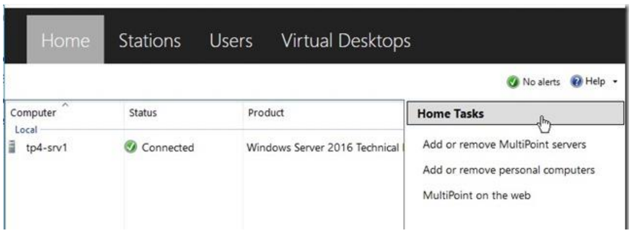
WMS подржава било коју комбинацију ових типова станица, али се препоручује да једна станица буде директно видео повезана станица, која може послужити као примарна станица.

Кофигурисање и логовање радних станица

Притисните дугме **Start** и отворите **MultiPoint Manager** (слика 1).

Слика 1. *Старт*

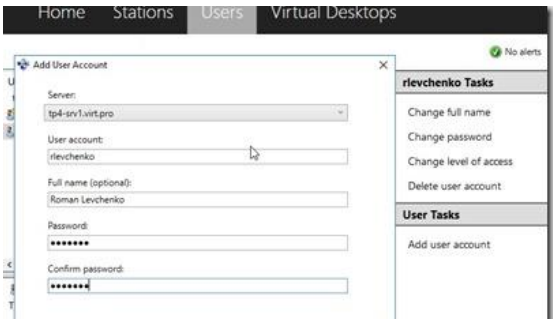
Add MultiPoint Servers или **personal computers (optional)** (слика 2).



Слика 2. *MultiPoint Manager*

Идите на картицу **Users** и кликните на "**Add user account**", кликните на Next и изаберите тип корисника, а потом унесите корисничко име и лозинку (слике 3 и 4).

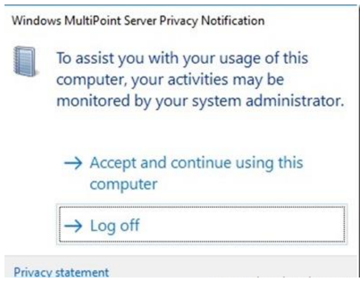
Слика 3. *User* account



Слика 4. *User name and password*

Повежите се на MultiPoint Server из корисничке везе користећи **RDP**. Када се корисник први пут пријави на MPS, добија обавештење о приватности.

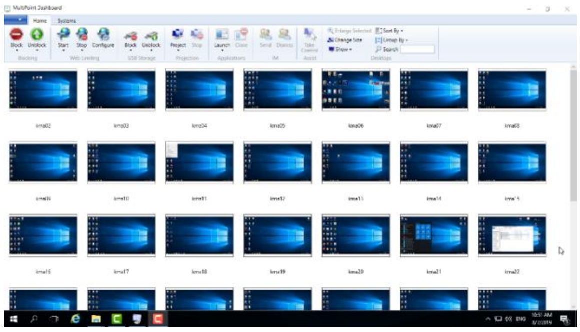
Кликните на „Accept and continue using this computer" и вратите се на MPS сервер (слика 5).



Слика 5. *MPS Privacy Notification*

5.1. Начин праћења и комуникације са ученицима ученика

На MPS серверу покрените **MultiPoint Dashboard** (слика 6). Сви екрани са корисничких станица се додају и ажурирају на контролној табли. Можете видети шта се дешава на корисничкој станици, блокирати ову радну површину, поставити поруку за блокиране кориснике, преузети контролу, писати ИМ кориснику, блокирати USB меморију или ограничити приступ вебу на одабраним радним површинама.



Слика 6. *MultiPoint Dashboard*

Blocking - закључава клијентске екране у мрежи. Ради и појединачно и као целина (слика 7).

Слика 7. *Blocking*

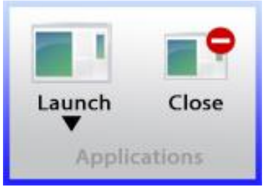
Web Limiting - ограничава одређени приступ одређеним веб локацијама (слика 8).

Слика 8. *Web Limiting*

Projection - пресликава екран наставника на све клијентске екране (слика 9).

Слика 9. *Projection*

Applications - покреће одабране програме на клијентским машинама (слика 10).



Слика 10. *Applications*

IM - започиње разговор са радним станицама (слика 11).

Слика 11. *IM*

Take Control Assist - приступа радним станицама са даљине ради решавања било каквих проблема без потребе да физички буде на на њима (слика 12).

Слика 12. *Take Control Assist*

6. ЗАКЉУЧАК

Предност овог решење је и то да ИТ сада брине о једном рачунару, на једном месту се врши *update*, на једном месту и једном се врши инсталација софтвера, могуће је и даљинско одржавање итд. Професор лакше контролише и надгледа шта ученик ради на рачунару уз помоћ *MultiPoint Dashboard*-а где одмах може да види сваки ученички десктоп. Професор може и преузети ученичке радне површине и на њих послати оно што он тренутно ради, тако да сви виде, као и блокирати све активности на ученичким мониторима, како би скренуо пажњу на оно што прича. Професор такође може блокирати приступ одређеним WEB сајтовима, као и стартовати или затворити одређену апликацију на ученичким "рачунарима".

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Appendix B:

Framework for network support for psychological and digital resilience – Concept and Results of ERASMUS+ DigiPsyRes Project

Notes:

Enhancing digital and psychological resilience through peer networking in the online environment in times of crises: project results

DigiPsyRes Research Team
University of Kragujevac, Serbia

Within the TIE 2024 conference, a special thematic segment is dedicated to the current ERASMUS+ cooperation partnerships in higher education project "Enhancing digital and psychological resilience through peer networking in the online environment in times of crises – DigiPsyRes" (2021-1-RS01- KA220-HED000032204). This multidisciplinary project deals with the problem of the growing need for psycho-social support in times of crises by enhancing digital and psychological resilience through peer networking in the online environment. The main goal of the project is to build capacities, readiness and procedures to empower students to enhance their digital and psychological resilience. The project is coordinated by the University of Kragujevac (2021-2024), and partner institutions are The University of Foggia, Italy, and The Kazimierz Wielki University in Bydgoszcz, Poland.

The TIE2024 Conference is hosting the following project dissemination activities: a round table and a special thematic session.

In its efforts to create more resilient student population in digital environment during the crises, project team members have collaborated efficiently and with continuous dedication over the past three years. The project is set to finish in December this year (2024) with most of the main project results being already achieved and, hopefully, put to use for students and educators across different educational contexts. The three results discussed and presented at TIE 2024 Round table are: The Guide for DigiPsyRes Support Networking, The “Step by Step” Manual and E-Magazine.

The Guide for DigiPsyRes Support Networking is one of the key project results, created as an overarching document that defines instructions for higher education institutions (HEIs) on how to establish a network for peer support and enhance psychological and digital resilience. It was developed by members of an international team of university teachers and associates involved in the *DigiPsyRes* project, experts in the fields of psychological and digital resilience. The concept of a peer support network was refined throughout the project, and this guide serves as an operationalized framework for establishing that network. Being a valuable resource for higher education institutions, this Guide is supposed to provide the educators with the tools necessary to establish robust peer support networks and enhance both psychological and digital resilience among their students.

The training program “Step by Step from Trainees to Trainers and Peer-Supporters in the Student Peer-Support Network” aims to equip students with necessary skills to provide peer support. This training program seeks to enhance both psychological and digital resilience among peers, cultivating a peer support network to enhance resilience in educational settings. The Manual for this training is an instructional document that provides general information about the DigiPsyRes Network and it includes the following: goals and descriptions of the training programs A, B and C; content and outcomes of the training programs A, B and C; detailed scenarios for programs delivery; general and overall instructions and recommendations; plans and time-frames for program realization; general instructions on how to establish and sustain the support network; detailed teaching/training methodology; rules for training selection, participation and delivery; communication procedures and rules; examples of best practices, suggested resources and literature; appendix with protocols, the instruments for (assessment/evaluation procedures), and resources (learning-teaching materials). It is a comprehensive document collaboratively designed by the experts and practitioners from the 3 partner universities to guide users through the functions and objectives of the DigiPsyRes Network. It serves as a reference guide for students involved in digital and psychological resilience training and networking.

Finally, the E-Magazine emerges as the third and likely the most diverse publication of the series. The E-Magazine features a rich collection of articles and essays contributed by students and staff from the three universities, each shedding light on various aspects of psychological and digital well-being and resilience. It also includes practical advice on thriving during crises, insights from trainers, a pop culture perspective on well-being, book recommendations, and more, making it a diverse and engaging resource for readers.

A special thematic parallel session *Psychological and digital resilience* is organized and completed with seven selected papers, all addressing different aspects of the psychological and digital resilience of university students, teachers and institutions themselves. In comparison to the previous edition from 2022, the papers now are less focused on the pandemic as a crisis context, but investigate certain specific aspects of the DigiPsyRes project training, while also dealing with some more generic aspects of resilience and networking and peer support in different contexts. The first three papers provide a closer look at the training program "Step by Step from Trainees to Trainers and Peer-Supporters in the Student Peer-Support Network" and its evaluation, offering a systematic overview of this process, from its international pilot phase to final implementation in Serbia. A special contribution to this session are two papers that are diving into the field of biology and IT; A literature review paper on the biological framework of psychological resilience opens a discussion and provides insights to this important topic, while the other paper deals with factorial structure of knowledge and risky behavior of information system users among adolescents. The final two papers examine resilience from the perspective of educational psychology, in two very different yet informative way: the first perspective explores the challenges of the interdisciplinarity in combining digital technologies and educational psychology, while the other paper investigates the role of school psychologists in the USA in empowering digital and psychological resilience.

In the long term, this project aimed to create the path for students to become a more resilient population in digital environments, and ready to learn to be safe but open at the same time. By developing the related e-sources for the network of students' support and relevant toolkit (portals, guides, etc.) and instigating these kind of exchanges we hope to raise awareness of the critical importance of digital resilience and psycho-social well being of students.

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DigiPsyRes

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