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TECHNICAL FACULTY
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ZRENJANIN**



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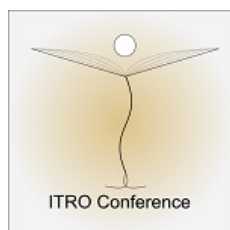
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INTRODUCTION

This Proceedings present the articles delivered at the international conference Information Technology and Education Development (ITRO 2024), held for the jubilee fifteenth time on November 29, 2024. This international event was conducted in a hybrid format, combining in-person and online participation. The conference continues its tradition of bridging science, professional practice, and educational experiences, with this year's focus on the conditions and perspectives of teachers' digital competencies.

The thematic fields of the conference reflect contemporary trends in education, addressing topics such as: the digitalization of education, education in crisis situations, educational challenges, theoretical and methodological issues in contemporary pedagogy, digital didactics and media, modern communication strategies in teaching, curriculum development for contemporary education, advancements in e-learning, education management practices, methodological approaches in teaching natural and technical sciences, and the integration of information and communication technologies in education.

The conference featured three plenary lectures that explored various aspects of the main topic, with the corresponding articles included at the beginning of this volume.

In total, this edition comprises 57 peer-reviewed articles, evaluated through a double-blind review process. These contributions represent the latest research and advancements in the field.

The conference received financial support from the Provincial Secretariat for Higher Education and Scientific Research, Novi Sad. Hosting and technical support were generously provided by the Technical Faculty "Mihajlo Pupin." We extend our sincere gratitude for this invaluable assistance.

The Organizing Committee expresses its heartfelt thanks to the authors, reviewers, and participants for their contributions, which ensure the success and continued tradition of this event.

We look forward to welcoming you to the next ITRO Conference!

On behalf of the ITRO Organizing Committee

Jelena Stojanov

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PLENARY PAPERS

Formation of Technological Competence in Students

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Abstract. The article examines the current problem related to the modernization of higher education through the formation of technological competence in students who are future teachers of technology and entrepreneurship. The importance of the competence approach in forming the technological competence of future teachers has been revealed. A theoretical framework of technological competence is examined, and the structure of technological competence is presented, which includes several key components: technological knowledge, technological skills, and attitude towards technology. The article presents a model for the formation of technological competence among students through the discipline "Technical modelling," which consists of several structural components: the goal as a system-forming component, the content, the mechanism for the interaction of subjects in the pedagogical process, as well as the forms, methods, and means of training. Special attention is paid to the content, which is reviewed within the discipline, as well as the learning outcome: knowledge, skills, and competences for designing and building 3D models of technical objects and the construction and programming of educational robots.

Keywords and phrases: technological literacy, technological education, engineering thinking, engineering literacy, competence, technology, model.

1 INTRODUCTION

The technological revolution of the 21st century is associated with the intensive development and use of nanotechnology, robotics, biotechnology, and others that are changing modern education. Artificial intelligence, STEM learning, virtual reality, educational robotics, and 3D modelling are rapidly entering education. The development of technology has a strong impact on the education system, and the technological culture and technological competence of future teachers of technology and entrepreneurship are becoming an important element of their training.

The technological competence of technology and entrepreneurship students is a key factor for their successful implementation in the modern world. It includes a combination of knowledge, skills, attitude, and ethical use of technology that help them adapt and develop in the rapidly changing technological environment.

2 METODOLOGY

2.1. Objective of the review

Creating a model for developing technological competence of students, future teachers of technology and entrepreneurship.

2.2. Research questions

This investigation is focused on a deep understanding of the technological competence concept.

To solve the research task:

- What is technological competence?
- What is the place in the structure of the professional competence of the technology and entrepreneurship teacher?
- How is the technological competence of students formed (theoretical framework, model)?

- How to apply the created model for the formation of technological competence in training in the discipline of technical modelling?

The methodological and theoretical basis of the research are the conceptual positions of the methodologies and theories of pedagogical research, competence-based approach in education and technological culture, and competence of Bulgarian and foreign authors.

In solving the research problems, a number of complementary general scientific and pedagogical methods were used: theoretical-comparative analysis; concretization; generalization; forecasting; modeling.

3 LITERATURE REVIEW AND DISCUSSION

According to the European Qualifications Framework for Lifelong Learning, "competence" is defined as a proven ability to use knowledge, skills and personality/social endowments in work or study situations, in professional and personal development. Examining the formation of technological competence of future teachers, we must dwell on the meaning of the concepts "technological" and "competence". In the pedagogical dictionary, "competence" is the level of education of an individual, which is determined by the degree of understanding and use of theoretical tools for cognitive or practical activity (Kosimov, Rafiqova, and Murodova, 2021).

The teacher's technological competence integrates sociocultural, design and creative, managerial and pedagogical, professional and pedagogical functions (Vaganova, 2019). Problems related to the formation of technological culture, technological competence, and literacy of technology and entrepreneurship students in Bulgaria have been examined by (Plachkov, 2011), (Plachkov, 2014), (Mitova, 2017), (Tsanev, 2017), (Tosheva 2022), (Vitanov 2021), (Ivanova 2009), (Zoneva 2021), and (V. Pavlova 2024). Technological competence is part of professional pedagogical competence and can be defined as an integrative professional quality, which is characterized by knowledge of technologies and knowledge of technologies, methods, means, forms of activity and the conditions for their application, organization, shows creative skills, design skills, analytical skills, and reflective positioning regarding the results of their activity (Gorbunov, 2019).

The technological competence of the technology teacher, as one of the components of his professional competence, is characterized by appropriate knowledge (technologies, methods, means, forms of activity (pedagogical, technological, entrepreneurial) and conditions of their application, organizations) and corresponding demonstrated skills to creatively apply this knowledge, to design a school activity, analyse the effectiveness and results of your activity, skills to construct your own technology and develop a methodology for organizing the educational process (Peycheva, 2020). The formation of technological competence is based on systematic, person-oriented and activity-based approaches. The systematic approach allows students to master the competence gradually, within the framework of a clear framework structure, built system. The person-oriented approach allows you to organize a learning process aimed at revealing the potential of the individual every student, allows you to individualize the learning process (Liza L. Mariscal and all (2023).

The competence approach in technological education implies the development of students' technical thinking, elements of construction and technological knowledge and skills, their practical application, and technical creativity. The creation of models of technical objects allows to isolate, describe, and study the most important characteristics and functions of technical objects or systems.

At the present stage, despite the need for such specialists for the education system, the professional training of the future teacher of technology and entrepreneurship does not adequately meet the requirements of the formation of technological competence, which characterizes the possession of a sufficient level of technological literacy, mastery of the skills of independent solution to the problems of everyday life, successful and painless adaptations to changes in the social environment (Gadzhiev & Bilalov, 2014).

3.1 Framework for Technological competence

According to the General Technology Competence and Use (GTCU) Framework, key components of technology competence are:

- Technological Knowledge: Understanding the principles and concepts behind various technologies.
- Technological Skills: Practical abilities to use and manipulate technology effectively.
- Problem-Solving Abilities: Capacity to troubleshoot and resolve technical issues.
- Adaptability: Ability to learn and adapt to new technologies quickly.

- **Communication Skills:** Explaining technical concepts to non-technical stakeholders and collaborating effectively.
- **Cybersecurity Awareness:** Protecting information and systems from cyber threats.
- **Ethical and Legal Awareness:** Understanding the ethical and legal implications of technology use.

These components are fundamental for the successful functioning of specialists in the modern technological society.

3.2 Structure of Technological Competence

The literature analysis shows that we can determine the place of technological competence in the structure of technological culture (Figure 1). The concepts of "technological competence" and "technological literacy" are very close, in fact they are structural elements of technological culture. Technological literacy is a set of information, methods and tools, which, with their accumulation, qualitatively transform technological literacy into technological competence. The latter, in turn, integrating with value, activity, quality and other components, forms a technological culture (Figure 1).

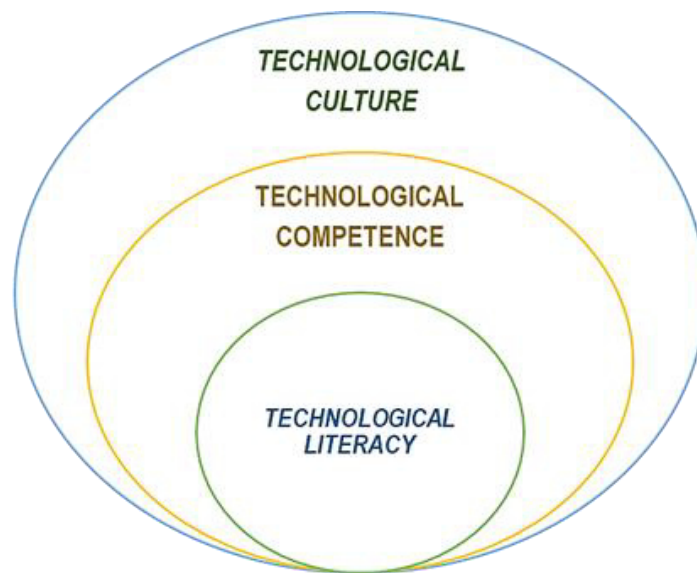


Figure 1. Hierarchical structure of technological culture

Technological competence is multifaceted, encompassing technological knowledge, skills, and attitudes. Technological competence refers to the skills and knowledge needed to effectively use and manage technology. For student to be teachers of technology and entrepreneurship, technological competence includes the formation of specific skills for working with specific tools and software, skills for creating models of technical objects, and training robots.

4 MODEL FOR THE FORMATION OF TECHNOLOGICAL COMPETENCE OF STUDENTS THROUGH THE DISCIPLINE "TECHNICAL MODELING."

The use of modelling as a research method provides a targeted, consistent, and in-depth study of the object or process being studied and facilitates the analysis of options for effective functioning with a better result.

For the formation of technological competence of students through the discipline "Technical Modelling," we can apply the model for the formation of technological competence of future technology teachers (Figure 2).

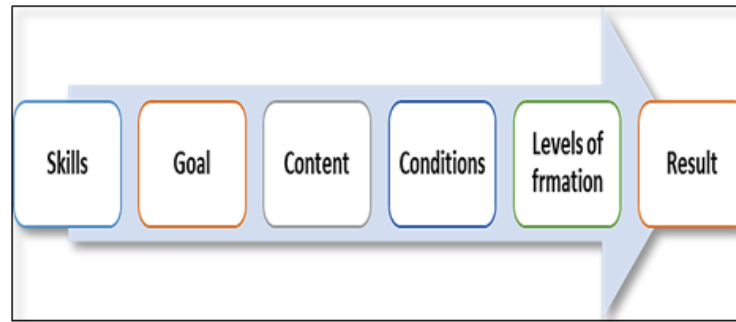


Figure 2. Model of formation of technological competence of future technology teachers

The model consists of several structural components: teaching skills, the goal as a system-forming component, and the content and mechanism of interaction of the subjects of the pedagogical process, which are the forms, methods, and means of training, conditions, levels, and results.

Skills are:

- motivational skills: interesting content; problem situation; setting a technical and technological task; the importance of knowledge in future activities; clarity of competitions; encouragement, punishment; personal example of the teacher; self-evaluation;
- organizational skills: presentation of a learning task; organization of learning activities; organization of individual, group, and frontal forms of learning activity; organization of interaction between students; transfer of knowledge in different ways;
- control skills: assessment of students' knowledge and skills; periodic, current, and final control; analysis of own pedagogical activity.

Purpose: Formation of technological competence of the future teacher.

Content:

- The mandatory discipline "technical modelling" is included in the curriculum of future teachers of "technology and entrepreneurship." The discipline is related to courses in engineering and computer graphics, mathematics, applied mechanics, electrical engineering, and technological practicums. Discipline "Technical modelling", which includes two modules: MODULE I: Technical modelling and MODULE II: Educational Robotics ([link](#))

Table 1 displays the content of the technical modelling curriculum as well as the goals and objectives of each topic.

Table 1. Content of the Technical Modelling curriculum and the aims and objectives of each topic

Module I	
Topic	Objectives and tasks of the topic
<i>Topic 1.</i> Basic concepts in technical modelling	-Acquisition of knowledge, skills and competences related to technical modelling. -Acquaintance with basic concepts related to technical modelling-model, types of models, design, construction.
<i>Topic 2.</i> Design of technical objects. Design methods. Design, technological and operational documentation	-Acquisition of knowledge, skills and competences related to the design of technical objects. -Acquaintance with basic concepts related to the design of technical objects and design methods - central design, parallel design and rectangular design.
<i>Topic 3.</i> Construction of technical objects. Principles, methods and requirements for structures.	-Acquisition of knowledge and skills related to the construction of technical objects and the role of construction in technology and entrepreneurship education.
<i>Topic 4.</i> Models of technical objects. Creation of 3D models of technical objects.	-Acquisition of knowledge, skills and competences in creating 3D models of technical objects. - Creation of a computer 3D model of technical objects.

Topic 5. Technical models in technology and entrepreneurship education.	- Formation of skills for the analysis of technical models that are appropriate for the purposes of technological training. - Acquaintance with technical models and construction analysis, ergonomic and technological requirements, age characteristics.
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Module II

Topic	Objectives and tasks of the topic
Topic 1. Introduction to Robotics. Nature, functions and operation of robots.	- Acquisition of knowledge about robotics and robots. - Getting to know the principles of robotics, the functions and operation of robots.
Topic 2. Construction and modelling of educational robots.	- Acquisition of knowledge and skills for constructing educational robots. - Getting to know and working with modular construction systems.
Topic 3. Programming learning robots.	- Familiarity with different learning robot programming environments and languages. - Acquisition of learning robot programming knowledge and skills.
Topic 4. Models of a robotic workplace.	- Learning about different models of robotic workplace. - Creating a model of a robotic workplace.
Topic 5. Models of an automated technological process.	- Acquisition of knowledge about an automated technological process. - Creation of Models of an automated technological process.

Conditions for formation of technological competence:

- Implementation of the competence approach in professional training of students;
- formation of professionally important qualities and readiness to manage transformative activities;
- fostering interest in innovations in professional activity; inclusion in the productive activity of students; use of modern pedagogical and information technologies.

The formation of the technological competence of the future teacher of technology and entrepreneurship is carried out through a variety of interactive teaching methods: explanation, demonstration, exercise, modern visualization methods, interactive learning tools, computer tests, development of STEM projects.

Levels of formation of technological competence are:

Basic level:

Knowledge: The student has basic theoretical knowledge of technology, technological objectives and 3D modelling.

Skills: The student is able to perform simple tasks using technological tools and software for 3D modelling and programming robots.

Attitudes: The student has a positive attitude towards learning and using technology but limited confidence in applying it independently.

Middle level:

Knowledge: The student has good understanding of technological principles and ability to understand more complex concepts.

Skills: Proficiency in using a variety of technological tools and software for different tasks. designing and building 3D models of technical objects in technological education and creating technical models in a STEM educational environment

Attitudes: The increased confidence in using technology and a proactive approach to learning new tools and techniques.

High level:

Knowledge: The student has in-depth knowledge.

Skills: The student has skills in using advanced technology tools and software; ability to use technology innovatively in teaching and training. Constructing and programming educational robots in technological education.

Result: formation of technological competence of student.

This model is the basis for the formation of technological competence of future teachers of technology and entrepreneurship, and each component of the model solves its part of the problems in the process of training future teachers of the technical faculty, but only in unity can they make this process effective and efficient.

Technological competence is dynamic and flexible in relation to educational technologies, it is transformed in the conditions of the emergence of new technologies that meet the requirements of the educational standard. The formation of technological competence on the teacher's process is based on the inexhaustible training and adaptation to new technological trends. Let teachers develop their knowledge, skills and attitude towards technology, so that they can effectively integrate it into the educational process and prepare their students for success.

5 CONCLUSION

The technological competence of student future teachers includes the ability to effectively use modern technologies in the educational process. Technological competence is essential for the preparation of future teachers in today's dynamic technological changes. To be effective and innovative in their work, students must understand the key role of technology. The design and construction of technical objects fosters the development of technological literacy and competence by promoting the application of knowledge from various subject areas, including physics, electrical engineering, and informatics, through the creation of models of technical objects and the use of educational robotics. The creation of models of technical objects helps to separate, describe, and study the most important characteristics and functions of technical objects, provoking active participation of students in the learning process and manifestation of creativity, technical thinking, and technical creativity.

At the same time, the effectiveness of the implementation of the developed model can be ensured by introducing a mechanism for the development of the technological competence of the future teacher in technology and entrepreneurship, among which information technology and robotics occupy an important place.

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Digital Competencies: What Have We Done and Where Are We Going?

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Abstract. In the digital era, the competencies required for effective teaching have expanded beyond traditional pedagogical skills to include digital literacy and technological fluency. This paper examines the evolution of teachers' digital competencies, tracing their development from the early adoption of educational technology to the present day. By providing a historical overview, the paper explores the previous and current state of digital competencies among teachers, examining both the benefits and challenges associated with their integration into educational practices. It critically analyses the advantages of enhanced digital competencies, such as increased student engagement and personalized learning, alongside the drawbacks, including the digital divide, burnout, and the pressure for the growing need for continuous professional development. The paper also discusses how digital competencies align with modern educational frameworks and anticipates future trends, such as the use of innovative software and AI tools. Ultimately, it seeks to offer a comprehensive understanding of where we stand today and the path forward in preparing teachers and students to meet the evolving demands of digital education.

Keywords and phrases: Digital competencies, Teachers' competencies, Software, AI tools.

1 INTRODUCTION

In an increasingly digital world, the demand for digital competencies has never been greater. As technology continues to infuse all aspects of life, educational systems worldwide are tasked with equipping students not only with basic digital skills but also with the critical thinking and problem-solving abilities necessary to navigate a complex digital landscape. This implies a deeper analysis of the current state of digital competencies, the challenges faced by educators and institutions, and the future directions needed to ensure that all learners are prepared for success in an increasingly digital and interconnected world. Through a review of existing literature and educational practices, this expository paper will illuminate not only what has been accomplished but also the pathways that must be built for future generations of digitally competent individuals equipped to thrive in the 21st century.

2 DIGITAL COMPETENCIES

Key competencies for lifelong learning (LLL) encompass a range of skills, knowledge, and attitudes that enable individuals to adapt and continuously grow in a rapidly changing world. These competencies are essential for personal development, social inclusion, and employability throughout one's life, and they include digital competence.

Digital competence is a term used to describe the ability of individuals (citizens, students, or teachers) to use information technology (IT) effectively in specific contexts. This term encompasses various skills such as: digital skills, e-competences, e-skills, etc. While these terms are often used interchangeably, they refer to different concepts and are not synonymous (Rizza, 2014).

2.1 *The role of the digital competencies in education*

As digital transformations continually reshape the world, it is essential for newer generations to develop advanced levels of digital proficiency. Students' learning habits, needs, and circumstances have evolved

significantly from a decade ago, necessitating that educational institutions adapt to these changes. Schools must be equipped to provide an educational, didactic, and safe response to the needs of students.

In education, digital competencies offer tools that enhance student engagement and learning. By using digital resources such as interactive simulations, multimedia, and virtual experiences, students can explore complex topics in a hands-on manner, making abstract concepts more accessible and relatable (Redecker, 2017). These resources create dynamic learning environments where students can pursue personalized interests and explore subjects at their own pace, which has been shown to deepen understanding and foster critical curiosity in ways traditional methods may not achieve (Gallardo-Echenique et al., 2015).

On the other hand, teachers' digital competencies are crucial for effective education in the 21st century, as these skills enable them to integrate technology meaningfully into their classrooms. With the increasing reliance on digital tools for learning, teachers need to be proficient not only in using technology but also in selecting the right tools to enhance student learning. According to the European Framework for the Digital Competence of Educators, teachers must develop skills across several areas: instructional design, digital content creation, and safe technology use, (Redecker, 2017). These competencies help educators to create engaging and interactive learning environments, adapt lessons to individual needs, and ensure that students use technology responsibly.

Teacher training in digital skills has been shown to improve overall educational quality, as digitally competent teachers are more likely to implement effective technology-based practices and personalize learning experiences for diverse students. According to Basilotta-Gómez-Pablos et al. (2022), digital competence is now a critical skill that educators must possess to effectively prepare students for the demands of the future. Cabero et al. (2020) also emphasize the importance of digital competencies for both citizens and educators, highlighting its role in fostering a digitally literate society.

2.2 Distance learning

The COVID-19 pandemic additionally revolutionized educational systems worldwide, compelling the adoption of distance learning. This abrupt shift posed significant challenges for both students and teachers as they navigated the new landscape of remote education. With schools closed and over 1.6 billion students affected, educational institutions rapidly shifted to online platforms to ensure continuity in learning (World Economic Forum, 2020). This sudden transition highlighted both the potential and challenges of remote education. While online learning increased accessibility and flexibility, allowing students to learn at their own pace, it also exposed issues such as decreased student engagement, isolation, and the digital divide.

Adapting to distance learning required not only technological adjustments but also innovative teaching methodologies and resilient learning strategies. The pandemic accelerated the integration of digital tools in education, highlighting the essential role of digital competence in ensuring the continuity of learning (Müller and Goldenberg, 2021). The experience underscored the necessity for robust digital competencies among educators to effectively deliver quality education in any circumstance, thereby ensuring the continuity of learning in times of crisis. Despite all challenges, the pandemic underscored the importance of digital literacy and the need for robust educational technologies to support remote learning (Akpen et al., 2024).

2.3 Digital competencies framework in education

The Digital Competencies Framework in education is a structured approach to integrating digital skills and literacies into learning, preparing students and educators to navigate an increasingly digital world. This framework outlines the competencies necessary for students to thrive in digital environments and for educators to effectively integrate technology in teaching.

European Commission has developed a series of frameworks to improve digital competencies across different sectors. The three key frameworks are: DigComp (for citizens), DigCompEdu (for educators), and DigCompOrg (for educational organizations). In addition to DigComp, many countries and institutions have tailored frameworks to align with their educational goals. Embedding a digital competencies framework into education offers various benefits. For students, these frameworks build transferable skills, increase employability, and prepare them for active, responsible participation in digital societies (Punie & Redecker, 2019). For educators, a structured approach to digital competencies provides guidance on effective, equitable

technology use in classrooms and helps them address students' digital literacy needs. However, challenges such as varying access to digital resources, disparities in digital skills, and the need for continuous professional development for educators can hinder the framework's effectiveness (OECD, 2020).

In Serbia, the Digital Competence Framework aligns with the European Digital Competence Framework (DigComp 2.0) and is adapted to the country's specific needs, (European Commission, 2017). It emphasizes developing digital skills across various educational levels, from primary schools to higher education. The Serbian framework includes Information and Communication Technology (ICT) and computing as standalone subjects in vocational schools and promotes digital skills through formal and non-formal education (Ministry of Education, Science and Technological Development of Serbia, 2022).

3 WHAT HAVE WE DONE?

3.1 The historical review

The concept of digital competencies in education has evolved significantly since the early days of computer science and information technology integration in schools. Its roots trace back to the introduction of computer literacy programs in the 1960s and 1970s, which aimed to familiarize students with basic computer functions. At that time, the focus was primarily on technical skills, such as understanding hardware and software basics, as well as simple programming. This early phase represented the groundwork for digital literacy, although competencies were narrowly defined as purely functional skills with technology. During the 1980s and 1990s, digital education initiatives became more widespread, and the emphasis expanded to include broader information literacy skills alongside technical knowledge. Governments and educational institutions started to recognize the value of preparing students for a workforce that would increasingly rely on digital tools and information management. The early 2000s saw the establishment of formal frameworks for digital competencies as digital technology became a central component of daily life.

The European Union's eEurope initiative in 2002 marked a significant milestone, urging member states to integrate digital competencies as part of their education systems to ensure an "Information Society for All" (European Commission, 2002). This initiative emphasized the need for citizens, including students, to develop skills to use digital tools, handle information, and engage with digital content ethically and safely. The UNESCO ICT Competency Standards for Teachers, launched in 2008, was another landmark document that provided a structured framework for digital competencies, specifically for educators. It outlined the need for teachers to develop technology-based pedagogies, guide students in digital literacy, and foster problem-solving skills (UNESCO, 2008). These standards were instrumental in shaping global awareness and prioritization of digital competencies within education systems, advocating for a more sophisticated integration of technology beyond functional skills.

Digital development of education in Serbia began in the early 2010s, supported by government initiatives and partnerships with international organizations like the European Union and UNICEF. One significant step was the launch of the *Strategy for the Development of Education in Serbia 2020*, adopted in 2012, which emphasized the need for integrating digital tools and competencies into the education system. This strategy outlined goals for modernizing educational infrastructure, promoting e-learning, and training teachers to use digital technologies effectively. Additionally, the Serbian government worked to enhance internet access in schools and provide digital resources, laying the groundwork for more comprehensive digital literacy initiatives.

The process accelerated in 2017 with the *Digital Skills Development Strategy*, which included specific objectives for building a digital foundation across Serbia's education system. This strategy emphasized the need for continuous teacher training, digital content in curricula, and accessible digital infrastructure, (Government of Serbia, 2017). In 2020, the COVID-19 pandemic further underscored the importance of digital readiness, leading to rapid advancements in remote learning solutions and increased investment in digital tools for education. Serbia's participation in the European Union's *Digital Education Action Plan* has continued to guide its efforts to develop digital skills, ensuring that the country's education system aligns with European standards, (European Commission, 2020).

3.2 The present time

The current state of digital competencies in education reflects a global movement to prepare students and educators for a technology-driven world, though significant disparities remain. Many countries have adopted frameworks which outline competencies like data literacy, digital content creation, and safe online behaviors (Punie and Redecker, 2019).

In summary, while progress continues, educational systems face challenges in providing equitable digital access and adapting to new technological demands. Digital competency frameworks evolve to meet these needs, aiming to equip students worldwide with comprehensive digital skills.

In Serbia, the push for digital competencies in education reflects the country's efforts to align its educational standards with European frameworks and global digital transformation trends. While there have been significant advancements in recent years, challenges remain, particularly in terms of equal access to digital resources and comprehensive integration across all educational levels.

In recent years, Serbia has increasingly focused on enhancing digital competencies among students and teachers. The Ministry of Education has introduced ICT as a core element in school curricula, especially in primary and secondary education. For example, coding and computational thinking are now introduced at earlier stages of schooling, aiming to build foundational digital literacy (Ministry of Education, Serbia, 2021). This shift aligns Serbia with the European Union's Digital Competence Framework (DigComp) and represents a significant step toward modernizing education.

Serbia's *Education Development Strategy 2030* highlights the importance of digital literacy, aiming to integrate digital competencies in various subjects rather than limiting them to standalone ICT courses. The strategy emphasizes that digital skills are essential not only for future employment but also for fostering a digitally literate society capable of critical and ethical engagement with technology (Government of Serbia, 2021).

Several key projects have been implemented to enhance digital competencies in Serbian schools such as: Digital Classrooms Project (initiative for equipping classrooms with digital devices), School Network for Development (Digital School), e-Education Portal (platform that provides resources, guidelines, and interactive materials for teachers, students, and parents, (e-Education Portal, 2020)), Coding and Robotics in Primary Schools (coding and robotics programs for primary school students).

In Serbia, various training programs aimed at enhancing digital competencies for teachers are offered by ZUOV (Institute for the Improvement of Education) and ZVKOV (Institute for the Evaluation of Education Quality). ZUOV provides training on integrating digital tools into teaching, workshops on digital literacy, and courses focused on using Learning Management Systems (LMS) for distance learning, as well as flexible online courses for professional development. Meanwhile, ZVKOV focuses on training teachers to assess digital skills, implement curricula that include digital competencies, and offers guidelines for effective use of technology in the classroom.

In conclusion, Serbia has demonstrated significant commitment to digital competencies in education through government initiatives and strategic frameworks. However, addressing issues of equitable access, teacher support, and sustained funding will be crucial to ensuring that all students and educators in Serbia can benefit fully from a digitalized education system.

3.3 The challenges

While Serbia has made strides in digital education, several challenges arised concerning the adoption of digital competencies across all educational settings:

- **Digital Divide:** Rural and remote areas in Serbia still face limitations in internet access and digital infrastructure, creating disparities in access to digital learning tools. The Digital Classrooms Project aims to address this gap, but many schools remain underserved, which impacts the equitable development of digital competencies.
- **Teacher Training and Support:** While there have been efforts to train teachers in digital literacy, not all educators have access to regular, advanced training.

- **Funding and Resources:** As in many countries, Serbia faces financial constraints that impact the rollout of digital initiatives.
- **Student Engagement and Curriculum Integration:** Although digital skills are included in the Serbian curriculum, there is still work to be done to integrate these skills in a way that connects with students' interests and real-world applications. More emphasis on project-based learning, collaboration with industries, and exposure to advanced technologies could enhance student engagement and better prepare them for the digital economy.

Serbia's strategic focus on digital competencies aligns with its broader goals of meeting EU educational standards. Future improvements could include further investments in ICT infrastructure, particularly in rural areas, and enhanced training programs for teachers. Collaborations with the private sector, non-profits, and international organizations could also support sustainable development by providing resources, expertise, and funding for digital education projects.

4 WHERE ARE WE GOING

The future development of educational digital competencies is expected to evolve significantly, as educational systems worldwide seek to keep pace with rapid technological changes and the shifting demands of the global economy. As technologies like artificial intelligence (AI), machine learning, and data science become increasingly influential in various industries, educational frameworks are beginning to address these skills within their curricula.

4.1 Artificial intelligence

The future use of AI and software in education holds immense potential to revolutionize teaching and learning. AI tools in education are transforming classrooms by enabling personalized learning, streamlining administrative tasks, and enhancing accessibility, (World Economic Forum, 2024). Tools like adaptive learning platforms and intelligent tutoring systems adjust content based on each student's progress, offering support that helps students to learn at their own pace. Virtual teaching assistants and grading tools help teachers save time, providing quick feedback and assisting with repetitive tasks. Additionally, speech recognition and natural language processing tools make education more inclusive for students with disabilities or language barriers. Despite privacy and ethical concerns, these AI tools hold great promise for creating more personalized, efficient, and inclusive educational environments (Sadiku et al., 2021).

AI has significantly transformed educational practices and holds great potential for improving accessibility and fostering inclusive environments for diverse learners. Emerging AI applications, such as ChatGPT and other conversational tools, provide personalized interactions that offer instant support and enhance student engagement outside traditional classroom hours. Platforms like Knewton and Socratic by Google deliver educational content and step-by-step explanations, respectively, helping students to master foundational skills. Tools like Grammarly enhance writing skills through real-time feedback, while platforms such as Moodle and Edmodo facilitate communication and collaboration in online learning environments. Immersive technologies like software which support augmented reality additionally give students the possibility to explore virtual field trips.

Nevertheless, the discourse on AI tools in education is complex. There are arguments that AI can bridge learning gaps by offering customized experiences, enabling students who struggle in specific areas to receive targeted support (Eden et al., 2024). However, ethical concerns arise regarding data privacy, security, and potential bias in AI algorithms, necessitating careful consideration to ensure equitable benefits for all students. Additionally, reliance on AI may reduce essential human interaction, which is crucial for developing social skills and emotional intelligence. AI has significantly changed educational practices, and holds the potential to improve accessibility in education, creating inclusive environments for diverse learners. Looking forward, AI is predicted to play an increasingly integral role in both pedagogy and educational management, as long as the balance between innovation and ethical standards is present (Das et al., 2024).

4.2 The future of digital competencies

A crucial focus for future development is addressing digital equity to ensure that all students have access to the devices, internet connectivity, and digital skills training they need. Despite advances in digital education,

a "digital divide" remains, and particularly affects low-income, rural, and remote areas. Going forward, educational policies will likely emphasize universal access to digital tools and a commitment to improve digital infrastructure in underserved regions.

Given the rapid evolution of technology, digital competencies are no longer limited to initial education but are becoming essential for continuous learning throughout ones' career. Many educational systems are therefore moving toward flexible, modular approaches that allow individuals to update their skills over time. Programs like micro-credentials and online certifications are becoming popular as they allow learners to acquire specific digital skills in a short time frame, adapting to changing job requirements and technologies.

Some predictions are that AI will become essential in classrooms, offering learning paths that can significantly improve individual student achievement and motivation. AI-powered tools are expected to streamline administrative tasks, allowing teachers to focus more on creative and interactive teaching methods, ultimately reshaping the educational landscape.

4.3 The future of teaching and learning

The change of teaching and learning system is now the most obvious than ever. On one side, we have the education system which is still based on the traditional concepts, and on the other hand we have the emerging technologies which have been integrated in all aspects of our lives. The changes between then and now are reflecting in styles of teaching and learning, in resources, and in students' attitudes toward education and the skills they need to acquire.

The students, from kindergarten to university now use different resources for learning than before. The textbook, what used to be the only source of information, is now outdated. The students of the modern times justifies surpass of printed textbooks by the lack of time for reading them and rather choose digital sources of information because they offer information in fast speed and more creative mode (Engbrecht, 2018). However, this implies even more questions concerning the realization of the teaching and learning process, the existence of digital sources for learning, the adaptation of the curriculums, etc. As teachers, we should ask ourselves what is the most optimal mode for achieving the ideal conditions for learning and its outcomes, so that students are motivated for learning and that they, at the same time, achieve the expected learning outcomes.

The future of teaching and learning, shaped by digital technologies, promises transformative changes. Personalized learning will become a cornerstone, driven by AI-powered platforms that adapt content to individual students' needs and learning styles. Tools like virtual reality (VR) and augmented reality (AR) will offer immersive experiences, enabling students and teachers to explore complex concepts through simulations or interact with historical and scientific environments. Blended and hybrid models, combining online and in-person instruction, will provide flexibility and accessibility, while fostering global collaboration through digital tools that connect students across cultures.

Education will also focus on preparing students for the digital economy by emphasizing digital literacy, coding, and continuous skill development through micro learning and certifications. Technologies like AI-driven virtual tutors and chat bots will complement human educators, allowing them to focus on mentorship and fostering creativity. At the same time, efforts to bridge the digital divide and implement assistive technologies will ensure greater equity and inclusivity, making education accessible to all.

5 CONCLUSION

The journey of integrating digital competencies into education has grown from a focus on basic technical skills to a comprehensive approach that encompasses critical thinking, ethical awareness, and practical application. This shift underscores the importance of equipping students and teachers with the tools to not only use technology effectively but also to critically evaluate its implications and navigate its ethical dimensions.

However, these advancements come with challenges, such as addressing ethical concerns around data use, ensuring equal access to resources, and balancing the benefits of digital tools with the need for offline engagement. As technology continues to evolve, the emphasis will be on creating adaptable, inclusive, and engaging learning environments that meet the demands of an ever-changing world.

The concept of digital competence of tomorrow will encompass not only the ability to use technology but also an understanding of its impact, shaping future digitally responsible citizens prepared for the complexities of the modern world.

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Critical Distance - a Teaching Competence that is (not) Slipping Away in the Digital Age

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Abstract. Global social and economic changes, new digital achievements and the rapid flow of information have all led to a crisis of the traditional model of education. Today's educational institutions live a new reality, flooded with homo zappiens who evolved from homo sapiens, due to the influence of the dynamic environment and the digital-technological revolution. The contemporary world is turning attention from developing knowledge to developing and acquiring competencies. A special place among these competencies belongs to the digital competencies of teachers. The present study gives special attention to the mismatch between the digital demands placed on teachers, and the professional training courses and resources for the use of teaching technology. In the abundance of technological resources and digital tools, another competence becomes inseparable from the teacher's digital competences, and that is critical distance. To emphasize the importance of critical distance and digital competences, we turn to one of the most prevalent modern technologies - artificial intelligence. The paper analyzes the benefits of these digital tools, but it also inspects ethical dilemmas such as equity and inclusiveness, as well as possible misuse. The fear of the unknown is woven into human nature, therefore, the unclear definition of the concept of artificial intelligence combined with the absence of education for its use (be it teaching staff or wider population) and its critical examination, further mystifies AI.

Keywords and phrases: digital competences of teachers, critical distance, educational changes, artificial intelligence.

1 INTRODUCTION

Education today is an essential element of the social and economic development of society as a whole, which is why the issue of education levels deserves a priority social status. In this regard, significant emphasis is placed on fostering educational systems that support technical and technological development, economic progression, inclusivity, and sustainability. "It is a fact that education is constantly being transformed and changed in accordance with global social and economic conditions, and that the ways and locations of work are in transition, requiring a capable and qualified workforce that will be able to meet the demands placed upon it. However, this does not strictly indicate which direction these changes are gravitating toward, nor whether they are positively or negatively colored" (Marić Jurišin & Malčić, 2022, p.31). Amid this evolution, it is crucial to acknowledge the pervasive influence of consumerist and dehumanizing ideologies that can erode educational frameworks grounded in pedagogical integrity, reducing individuals to commodities or mere statistical entities. The contemporary educational landscape thus contends with dual pressures of rapid knowledge dissemination and the demand for heightened efficiency, as both students and teachers, face a context in which information may become obsolete before even a single standardized educational cycle concludes. Over the past two decades, the technological and informational revolution has undoubtedly taken precedence, aligning with global trends and emphasizing competencies over mere knowledge acquisition.

Educational reforms rarely occur by chance or through spontaneous shifts; however, it is effective to recognize that exceptions may arise within established frameworks. Educational reform is inherently tied to a nation's educational policy. As Marić Jurišin and Malčić (2022) contend "for an educational reform to be considered professional and sustainable, it must be comprehensive, addressing a spectrum of specific, individualized issues relevant to various stakeholders within the educational system - ranging from teachers and competencies to initial training of reform implementers, professional development and working conditions" (p. 33). Policy makers and reform process creators often overlook the fact that the success and outcome of the change largely

depend on the practitioners themselves. Each teacher's implicit, personal pedagogy thus emerges as a decisive factor, shaping both the process and outcomes of reform. Consequently, a developmental approach, rooted in the idea that teachers actively participate in and implement only those reforms that stem from their own personal and professional growth, proves to be the most effective pathway toward lasting change in educational practice (Marić Jurišin, 2015).

The most profound influence on contemporary life, and by extension on education, derives from the ongoing technological revolution, which has ushered us into a distinctly digital era. Recognizing the imperative to lay foundational pathways for developing digital competencies, this emphasis is mirrored legislative frameworks, such as Serbia's *Action Plan for the Implementation of the Education Strategy by 2020* and the *Strategy for the Development of Education and Upbringing in the Republic of Serbia by 2030*. Consequently, schools are undergoing significant transformation, including the integration of the *Digital World* subject for younger primary students, the establishment of competency standards for teachers, the implementation of electronic grade books, and the exploration of artificial intelligence applications. The COVID-19 pandemic brought teacher digital competencies into sharp focus, revealing critical gaps in practice, varied experiences among students and teachers, and presenting an opportunity to "reconcile the familiar with the novel and unexplored" (Stevanović, 2024, p. 430). This period underscored an urgent need to transition from traditional teaching methods to more contemporary, innovative approaches grounded in digitalization and to explore the potential of integrating artificial intelligence within educational processes.

Social upheavals, global crises, and uncertainties have led to the emergence of new phenomena that also represent potential problems in the current educational context. Three predominant phenomena are particularly notable: 1) deprofessionalization within educational system; 2) an overemphasis on intersectoral integration and cross-cultural competencies; 3) uncritical exaltation of information and communication technologies (ICT) as mechanisms for enhancing educational outcomes (Popović, 2019). In response to the unreflective celebration of ICT, one competency emerges as crucial in navigating the sheer volume of information sources—namely the development of *critical distance*.

2 TEACHER COMPETENCIES

The teaching profession increasingly faces dynamic demands, necessitating the continuous development and refinement wide array of competencies. This imperative is underscored in the Strategy for the Development of Education and Upbringing in the Republic of Serbia until 2030, which delineates standards for teachers' professional competencies. While the establishment of such standards can provide structure and consistency, it also presents certain limitations. Potential drawbacks include the risk of enforcing rigid frameworks, promoting uniformity, overemphasizing quantifiable metrics, and prioritizing specific technical behaviors at the expense of value-driven educational dimensions. Such approaches can inadvertently constrain critical thinking and compromise teachers' professional autonomy. The concept of "competency" is multifaceted, with various interpretations among scholars. Some conceptualize competencies as an integration of varied skills and abilities, with particular emphasis on digital literacy, communication, and cognitive skills (Catts & Lau, 2008; Dragojević & Marić Jurišin, 2021). Others argue for a more generalized set of competencies that include domain-specific knowledge, pedagogical-didactic-methodological, psychological, social, and digital skills (Đorđić, Šimonji Černak & Beljanski, 2021).

Within the European reference framework, eight foundational competencies are identified: (1) native language communication; (2) foreign language communication; (3) mathematical literacy and basic knowledge in science and technology; (4) digital competencies; (5) learning-to-learn skills; (6) civic engagement; (7) entrepreneurship and initiative; and (8) cultural awareness (Kovačević, 2011; Vrkić Dimić, 2013). This complex framework is shaped significantly by social and temporal contexts, highlighting the value of digital skills and "soft" skills, along with the need to achieve an "ideal" balance between them. In the educational context, soft skills encompass non-academic abilities such as positive values, communication skills, teamwork, emotional intelligence, empathy, creativity, curiosity, reliability, critical thinking, social responsibility, ethics (Subramaniam, 2013; Kanokorn, Pongtorn & Sujanya, 2014; Pešić et al., 2017). The Framework of Digital Competences – Teacher for the Digital Age 2019 identifies 24 competencies organized into 6 categories. The Digital Environment domain addresses competencies in security, ethical standards, data and device protection, health considerations, and community engagement. Digital Resources category includes competencies in internet research, resource evaluation, adaption and creation, management, protection, and sharing of digital

resources. The third category, Teaching and Learning, covers the planning and integration of technology in teaching, establishing engaging digital learning environments, and using learning management systems. In Assessment and Progress Tracking, competencies include both summative and formative assessments, the development of student and class e-portfolios, and the use learning analytics. The Student Support domain emphasizes inclusion, differentiated instruction, accessibility, and assistive technology. The final category is professional engagement, focuses on communication, collaboration, professional development in online environments, and maintaining e-portfolios.

Every day, new approaches, techniques, and procedures emerge in the application of technology in education, yet a significant discrepancy remains between the digital demands placed on newly qualified teachers and the training provided for the use of educational technology (Krumsvik, 2012; Lund, Furberg, Bakken & Engeliën, 2014; Instefjord & Munthe, 2017; Pettersson, 2018). Research underscores that a successful integration of ICT into teaching practices hinges on the alignment of three core elements: content, pedagogy, and technology (Koehler & Mishra, 2009). However, in practice, teachers often face the challenge of independently developing expertise in one or more of these areas. In addition to this digital competency, teacher should be well-versed in the opportunities and boundaries of artificial intelligence.

"This includes understanding how AI algorithm's function, knowledge of AI-driven platforms and applications, and proficiency in using AI-based educational resources" (Mandić, 2024, p. 86). Proficiency in AI extends to the interpretation, tracking, and analysis of data generated through AI.

3 ICT TOOLS AND THE USE OF ARTIFICIAL INTELLIGENCE IN EDUCATION

Monitoring contemporary digital trends presents a major challenge for the educational system. The speed and intensity of these changes are in significant contrast to the sluggishness and structure of the educational system itself, and it often happens that by the time certain "technological innovations" are implemented in practice, they are no longer considered "innovations.". A fundamental requirement for successful integration of information and communication technologies in education is a comprehensive understanding of ICT tools and their accessibility. The available tools today can be conditionally divided into: media-sharing platforms (Slideshare, LiveWorksheets, Padlet, Wizer); communication tools (Zoom, Skype, Google Meet, Google Classroom); creative learning tools (Adobe Spark, Learning Apps, Blendspace, Moovly); learning management systems (Moodle, Loomen, WebCT, Claroline); educational gaming tools (Wordwall, Kahoot, Wizer, Quizlet); and artificial intelligence based applications (Ljubić-Klemeš, 2016, as cited in Đurić, 2021; Stanić & Stanić, 2023).

The development of modern technologies has led to the advancement of artificial intelligence and changes in the perception of reality and communication channels with the world. This shift is reflected in the emerging generation, often referred to as a "homo sapiens" generation, a cohort raised with a profound digital literacy, for whom the computer screen as a primary medium for exploring and understanding the world (Vrcelj, Klapan & Kušić, 2009). Although the origins of artificial intelligence trace back to the mid-20th century; the term itself encompasses a continually evolving concept that remains subject to ongoing academic debate and refinement. The concept of artificial intelligence encompasses a variety of definitions, with one of the more comprehensive describing it as "a technology that uses machines to simulate human perception, cognition, reasoning, decision-making, and other processes" (Stanić & Stanić, 2023, p. 42). Examining the foundation of "intelligence," we can infer that artificial intelligence is inherently linked to learning and decision-making informed by prior experiences, which are derivatives of human perception. Within scientific discourse, artificial intelligence is categorized into three primary types based on functionality: ANI (Artificial Narrow Intelligence), AGI (Artificial General Intelligence), and ASI (Artificial Superintelligence). The first type, known as ANI (Artificial Narrow Intelligence), represents a limited, task-specific level of intelligence, designed to perform narrowly defined activities (e.g., Siri and Alexa). The second type, AGI (Artificial General Intelligence), remains theoretical but is projected for potential development in the near future. AGI would emulate human intelligence in its entirety, including the capacity to solve problems in novel contexts – an attribute that differentiates it from ANI. The highest conceptual tier, ASI, represents a speculative pinnacle of intelligence, surpassing human cognitive abilities and knowledge. While ASI currently exists only as a theoretical construct, its future development remains an open question within AI research (Stanić & Stanić, 2023).

In recent years, artificial intelligence has gained substantial traction in the educational sector, with its integration commonly referred to as Education 4.0—an evolution aligned with the Fourth Industrial Revolution (Stevanović, 2024). Although the use of AI within the educational process in the Republic of Serbia remains largely unregulated formally, this does not imply its absence from educational practices. Among the most popular AI-powered tools in education are platforms such as Moodle, Canva, Microsoft Teams, Zoom, Google Meet, as well as plagiarism detection tools like Turnitin, Copyscape. Additionally, language learning applications (Duolingo), virtual tutoring systems for science disciplines (Squirrel and Brainly); and widely used conversational AI tools like ChatGPT have become integral to modern educational methodologies. The application of ChatGPT in educational practice has the potential to fulfill diverse educational functions: enabling personalized learning, supporting individualized providing adjusting the pace of learning, real-time support for students, easier understanding and mastery of the curriculum, access to expansive data networks. Furthermore, it can serve as a valuable resource for research, grant educators' deeper insights into students' learning styles, specific interests and capabilities, and even enhance administrative efficiencies (Kuleto, Mihoreanu & Dinu, 2023; Stanić & Stanić, 2023). The use of these tools has not been without challenges in practice, even though artificial intelligence is no longer a domain of educational futurism but has become our reality.

4 ETHICAL DILEMMAS, ADVANTAGES, AND DISADVANTAGES OF ARTIFICIAL INTELLIGENCE

In line with the fundamental idea behind the development of artificial intelligence, numerous advantages it brings to the educational process are evident. These include easier and more efficient access to information, simplified searching and research, simultaneous translation, interpretation of facts and content, plagiarism detection, time and resource savings, personalized learning, easier assessment, motivation enhancement, and predicting student development (Stanić & Stanić, 2023), to name just a few benefits. On the other hand, the question arises about the drawbacks and risks associated with the widespread use and reliance on artificial intelligence. Primarily, it reduces creativity, the development of divergent thinking, and encourages laziness among students. In line with this, the question arises whether the rise of artificial intelligence will lead to a decline in human intelligence. Furthermore, how will its use impact the thought process and reasoning of users? Among the potential risks associated with AI are issues such as data misuse, dependence on technology, concerns about data privacy, and transparency (Kuleto, et al., 2023). Moreover, the seemingly easy accessibility of AI does not guarantee knowledge about its proper use, either among teachers or students. In practice, systemic training is often reduced to a statistical error, with teacher competence largely dependent on their enthusiasm, creativity, and personal resources. As a result, the inadequate use of modern technologies often negatively outweighs their potential benefits in practice.

The very term "artificial" is, by its definition, challenging, as it implies something that is either "beyond human" or "less than human" (Budić, 2023). In addition to this terminological issue, even more significant is the concern surrounding security and ethics, which arise from the rapid development and (mis)use of artificial intelligence, both in education and more broadly. Among these concerns are questions regarding the "interaction of artificial intelligence with human rights, such as the right to privacy, issues of discrimination, as well as trust in artificial intelligence and in those who manage it" (Budić, 2023:53). Artificial intelligence can also negatively impact equality. If biases are not eliminated, the system will express them in the same way humans do, which can further lead to discrimination (Bostrom & Yudkowsky, 2019). Other concerns include academic integrity (whether a machine can replace a teacher), the lack of legal regulations, student data privacy, gender discrimination, inclusivity, accessibility, and commercialization... (Kuleto, et al., 2023).

Legal regulation, or rather its absence, in the field of artificial intelligence usage represents another significant challenge. "The question arises whether legal regulations can be adopted quickly enough to keep pace with the development and progress in this area, or whether it should be governed by ethical norms, as the only rules capable of setting boundaries for AI use. What is our understanding of ethics, and is it sufficient to ensure the management of the AI implementation process in education in a way that preserves the integrity of the teaching process and positively impacts the improvement of education quality?" (Stevanović, 2024:430). In other words, does our society have a consensus on the ethical rules that should govern the use of AI? It is important to note that although the Government of the Republic of Serbia adopted the Strategy for the Development of AI for the period 2020-2025, based on which the Ethical Guidelines for the development, application, and use of reliable and responsible AI were also adopted, these are still not binding norms that would legally regulate this

field. The mentioned guidelines are based on principles of explainability, confidentiality, dignity, fairness, and the prohibition of harm (Conclusion on the adoption of ethical guidelines for the development, application, and use of reliable and responsible artificial intelligence, 2023). Within the Ethical Guidelines, high-risk AI systems are identified, including education, professional development, and training. Education and professional development and training deserve this status primarily due to the significance of the field in question and the potential impact of AI usage on individuals.

All these issues, challenges, and ethical dilemmas bring us back to the question of teachers and teaching competencies. In the literature, we encounter (un)justified concerns and the question: *Will artificial intelligence replace teachers in the educational process?* However, what still favors the teacher in this open race with time, information, and the market is precisely critical thinking and a critical approach to reality. The use of AI in education does, in fact, change the role of the teacher but cannot replace them. Through the use of modern teaching methods and strategies, the teacher remains responsible for fostering creativity, empathy, socialization, interaction, the development of critical reflection and thinking, as well as comparing information obtained through AI with data gathered through traditional methods.

5 CONCLUSION

The attractive offerings provided by artificial intelligence should be approached without judgment but with a critical perspective, taking into account both the benefits and the shortcomings of such systems. Every innovation involves prior knowledge, risk, and caution, and this should be the approach in this case as well. Educational policymakers must anticipate any potential misuse and ensure fairness and inclusivity in every aspect of school life. Schools and districts are expected to provide all students with equal opportunities in terms of access to and benefits from artificial intelligence in education. Teachers must be provided with continuous support and adequate training to incorporate artificial intelligence into education effectively. Given the expansion of innovations within the digital sphere and the competency demands placed on teachers, we believe that special attention should be paid to ethics, critical thinking, and potential abuses within the contemporary flows of the digital age. It is essential to encourage proactive thinking that promotes the use of AI in daily life, including education, while also finding the right balance by nurturing a critical stance toward the results of artificial intelligence at every stage of its development. At present, there is societal awareness of the need to regulate this area, but also an understanding that this requires significant financial investments to meet all necessary prerequisites. In order to prevent the uncritical glorification of information and communication technologies in education, it is essential to focus on people—on the human aspect. Technology serves humanity, and a teacher's digital competence is directly linked to their critical awareness and implicit pedagogy. This is precisely what creates a strong connection between digital and "soft" skills. Critical awareness as a teacher competency in the digital age represents the ability of educators to analytically, responsibly, and reflectively utilize digital technologies in the educational process, considering their pedagogical, ethical, and social dimensions. This competency is essential for empowering teachers to provide students with high-quality education in a world increasingly shaped by technology. In an era where digital technologies are rapidly evolving and transforming the educational landscape, critical awareness enables teachers to make informed decisions and guide students toward the effective and responsible use of technology. This competency ensures that digital tools are employed in ways that genuinely enhance learning rather than merely reflecting technological trends. Teachers with well-developed critical awareness become facilitators who help students navigate the complexities of the digital world, fostering their intellectual, emotional, and social capacities. In conclusion, it is important to recognize that technology provides us with tools, but only a critical mind can shape the future.

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SCIENTIFIC PAPERS

Analysis of the Knowledge of Primary Education Students for Following Subjects in Higher Education Related to Informatics

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Abstract. In this paper, our goal is to check the level of knowledge about basic IT concepts and the use of basic applications among students from Primary Education, with a special emphasis on students in the ninth grade, as students who will soon continue their education in one of the secondary schools and most of them later in higher education institutions. This information is important to us because at a large number of faculties students have a subject in which a large part of the material taught to students in primary and secondary education is repeated and is related to basic information concepts. That is why it is important for students to learn and remember the basic IT concepts, to know how to use the basic applications that are used every day and to deepen the knowledge acquired earlier during their education.

Key words and phrases: IT concepts, Primary Education, applications, Informatics, Higher Education

1 INTRODUCTION

The subject Computer Applications is studied in the first year of the Mathematics Department at the Faculty of Computer Science at Goce Delcev University Stip. In the teaching program of the mentioned subject, information topics necessary for elementary knowledge of computer technology as well as the applications that are used on a daily basis are studied. More about the topics studied in the subject Computer Applications can be found in (Elena, Mirjana, & Zoran, 2023a) and (Elena, Mirjana, & Zoran, 2023b). The weak basic knowledge of information concepts among some of the students, as well as the students who are transitioning to secondary education, prompted the idea of creating this research. The same reasons were for the introduction of the Computer Applications subject in the first year in the curriculum of the study program teaching Mathematics. By introducing this subject, students renew the knowledge acquired previously, and are trained to use the applications that would be used the most during their studies. We are witnessing more and more that in the Primary Education, but also in the Secondary Education, topics that cover Programming are forced in the Informatics classes, and the basic terms in the Informatics are in a way neglected because they are only mentioned and during the classes they are not dealt with the basic applications. It causes situations where students are not familiar with these concepts through everyday life. The problem with weak basic knowledge of information technology terms among some of the students will always be present. This is a problem all over the world because we are all oriented more towards topics that are more commonly accepted and more interesting. This problem has become especially popular with the last global pandemic when the teaching was conducted online.

We are witnessing how the program for Informatics classes with the new concept is combined with the subject of Technical Education and the importance of Informatics is decreasing more and more. By introducing the subject of Technical Education as an integral part of the Informatics program, the hours planned for information technology concepts are reduced and the opportunity is given to omit or reduce the hours needed to work with computer applications. (Mile, Marija, Emil, & Nevena, 2012) present the state of the curriculum in Macedonian primary and secondary schools, concerning informatics, the most recent changes and plans for near future. The

methods of teaching Informatics are very important. The extent to which methods such as visual learning, aural, verbal, physical, logical, social and personal are applied in the study of information subjects has been examined in (Mirjana, Aleksandra, Biljana & Natasa 2021). Teaching practice proves the importance not only of using new methods and digital tools, but also of creating didactic applications to facilitate the teaching process in elementary schools (Veronika, 2018), (Ladislav & Takáč, 2021), (Aliya, 2022). Changes in the teaching process and in the holding of Informatics classes have occurred during the pandemic with Covid-19 virus. Research for the functioning of the educational process during the pandemic with Covid-19 can be found in (Elena & Mirjana 2022). The use of interactive applications in class of subject Computer applications will be very useful. (Blagoj, Marija, Mirjana, & Aleksandra, 2016) demonstrates a successful e-learning application developed with Adobe Captivate, which is a powerful tool for creating e-learning content. The ability of the professor to maintain IT skills is very valuable. An analysis of the teachers' ICT competencies and their skills can be found in (Aliya & Veronika 2023).

In this paper we present an analysis of the knowledge of primary education students for topics related to Informatics. The paper is structured as follows. In Section 2, we describe methodologies for performing the analysis. Main results from the research can be seen in Section 3. Discussion for the results is given in Section 4. The last Section 5 is a conclusion of our work.

2 METHODOLOGIES

For the purpose of this paper, the testing for the knowledge of Information Technology concepts for students from primary education was done through a questionnaire which can be seen in Appendix A.

As an opportunity to see this situation in primary education, we conducted an examination of the students through anonymous questionnaires, which allow to properly test the knowledge of the students. As a test group, 3 classes in the primary school of St. Cyril and Methodius from St. Nikole were selected. The students are from classes 9-1, 9-2 and 9-4 with a total number of respondents of 50 students, which will give a clear picture of the students' readiness for working with a computer, working with Microsoft Office and knowledge of hardware and software, during their transition from primary to secondary education. The questionnaire itself consists of 15 questions that cover the syllabus of the Computer Applications subject and are appropriately formulated to be comprehensible to students who in their formal education deal with the same topics in the Informatics subject for the sixth and seventh grades. According to this, the questionnaire can be divided into several parts, according to the type and topic of questions that it addresses: Components of the computer, Units of measurement in computer technology, History of computer technology and current state, Internet and Internet services, E-mail, Windows operating system, MS Word, MS Excel and MS PowerPoint.

As a survey sample, only students from the 9th grade, who have studied the subject 2-3 years ago, were taken, so solving the questionnaire relies on the knowledge of Information Technology, mostly on the practical application of what was previously learned, as well as on logical thinking. In doing so, it is considered that the research includes students from different socio-economic backgrounds.

Finally, a conclusion from the results is obtained and an idea for the change in the teaching process in future is made.

In context of the analysis, we will make a clear division into genders, boys and girls, in order to show trends in knowledge between male and female students. The information from the testing will also serve to see the students' ability to create activities in other subjects, such as making a presentation in the Macedonian language class, creating a table in the Natural sciences class, etc.

3 MAIN RESULTS

The first question in the questionnaire is about the availability of information technology in students' homes. Students who have access to a computer at home will have an easier time mastering the various computer applications they encounter in computer science classes. The question refers to the availability of a computer at home, a laptop, a desktop or both, which means that smartphones, tablets and other electronic devices are

excluded, for compatibility with the program in the Computer Applications subject. Students have the option not to answer the question if they do not have any of the answers offered. The results can be seen in Figure 1.

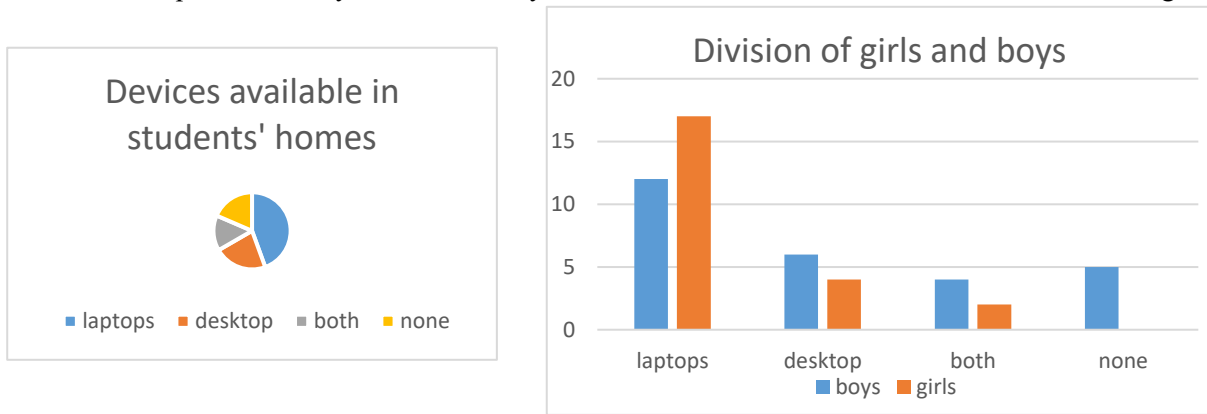


Figure 1: Answers to the first question

The second question, what is hardware, was answered correctly by 42 respondents, and incorrectly by 8. If we divide by gender, girls have a higher percentage of correct answers, 22 correct answers, and boys have 20 correct answers. From this we can conclude that a large number of respondents have good knowledge of computer hardware. Most of those who answered the question incorrectly represent the part of those who do not have a computer at home, so we can conclude that owning an IT device and working with it is an important factor in knowing computer components.

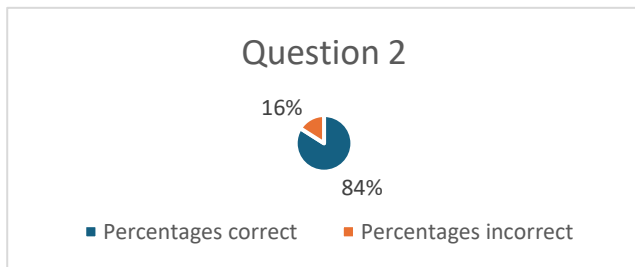


Figure 2: Answers to the second question in percentages

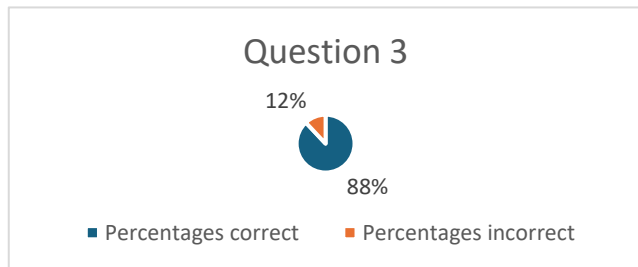


Figure 3: Answers to the third question in percentages

The third question was about keyboard familiarity i.e. of its appearance and layout of buttons. This question follows the trends of answers from the previous question so that 44 respondents answered correctly and 6 respondents from the three departments answered incorrectly. We can also notice that boys have a higher percentage of correct answers 24, compared to girls who have 20 correct answers. Figure 2 and Figure 3 show the answers of the second and third question respectively.

We got similar results for the fourth question, 42 correct versus 8 incorrect answers. The knowledge of measurement units is satisfactory, most of the respondents know the binary number system which is used by the computer, i.e. they know which digits are the basis. 44 respondents answered the fifth question correctly, and 6 incorrectly. Among the boys, 23 respondents answered correctly, and among the girls, a total of 21 respondents answered correctly.

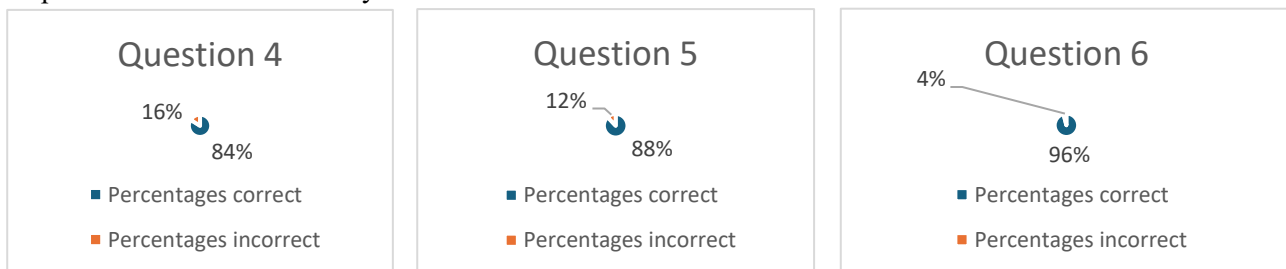


Figure 4: Answers to the fourth, fifth and sixth question

The question 5 that is related to the printer as an output peripheral device, i.e., its function, has the largest number of correct answers. 48 of the respondents answered this question correctly, and two respondents answered incorrectly. According to the gender division, 25 of the boys answered correctly, and among the girls, 23 answered correctly and 2 answered incorrectly.

The answers of the fourth, fifth and sixth question can be seen in Figure 4. If we group the questions from the second to the sixth of hardware as the first group of questions, we can notice that the results obtained are satisfactory. There are a total of 220 correct answers and 30 incorrect answers, which is quite a satisfactory result. If we divide again by gender, we have 125 answers from each gender. Among boys we have 113 correct answers. Among girls we have 107 correct answers, as we can see in Figure 5. The conclusion is that the knowledge of computer hardware is quite solid.

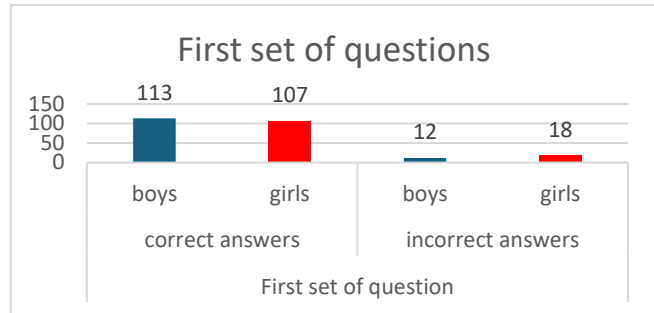


Figure 5: Answers of the first set of questions

The second group of questions is related to knowledge of the Internet and e-mail as an indispensable part of working with a computer and knowledge of information technology. And this group of questions is composed of 5 offered questions from 7 to 11.

The seventh question about how we measure Internet speed shows us that the number of correct answers is not much higher than the number of incorrect answers. Perhaps because the units of measurement for speed are similar to the units of measurement for data storage, students have trouble distinguishing between the corresponding correct units of measurement.

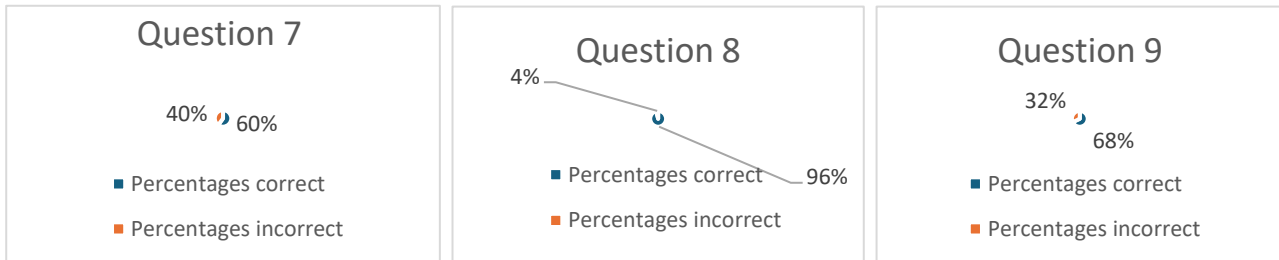


Figure 6. Answers to the seventh, eighth and ninth question

The eighth question is about the device that connects two or more networks, the router, which most students recognize because they have it in their homes.

The trend of difficulties in choosing the correct answer continues in the following questions. The ninth question was answered correctly by 34 respondents, and incorrectly by 16 respondents. Although most students use e-mail, this question causes difficulties for them. It happens because the email is created only once, and then users just log in. Figure 6 shows the answers of the seventh, eighth and ninth question.

The results for the tenth question can be seen in Figure 7. The next question 11 covering working with e-mail shows a different picture, most students work well with e-mail and can reply to an e-mail as we can see in Figure 7.

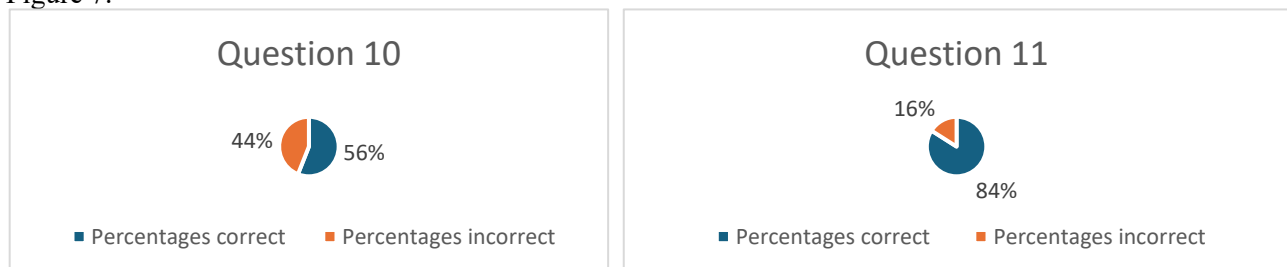


Figure 7. Answers to the tenth and eleventh question

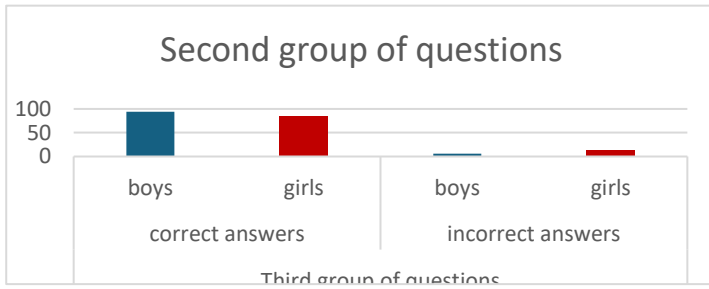


Figure 8. Answers of the second group of questions

If we summarize the questions from the second group from 7 to 11, we get that there are a total of 250 answers to all 5 questions from this group, 182 correct answers and 68 incorrect ones, as we can see in Figure 8. We can conclude that in the second group of questions there are more incorrect answers compared to the first group of questions.

The third group of questions is related to the Windows operating system, the company that produces IT, as well as computer applications that are part of the Office package, MS Word, MS Power Point and MS Excel. The correct answers to this group of questions are the most important because working in the Office program package students encounter a lot not only during their education but also afterwards during their work. There are four questions in this group.

We can see the correct versus incorrect answers in percentages for questions 12, 13, 14 and 15 in Figure 9.

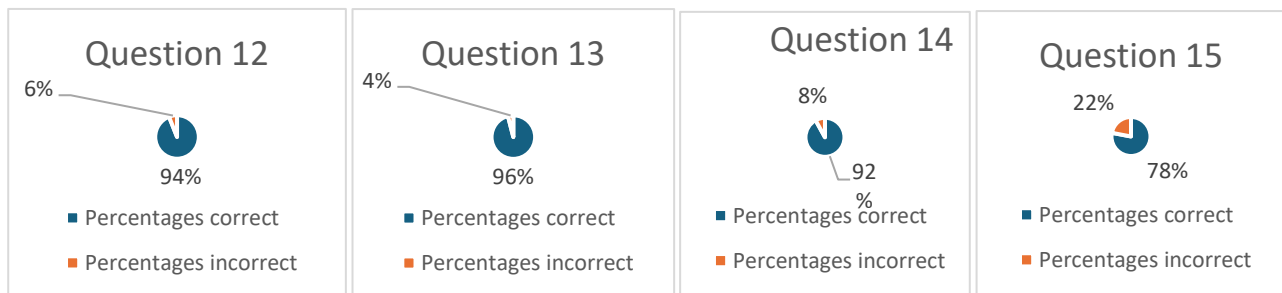


Figure 9. Answers to the twelfth, thirteenth, fourteenth and fifteenth question

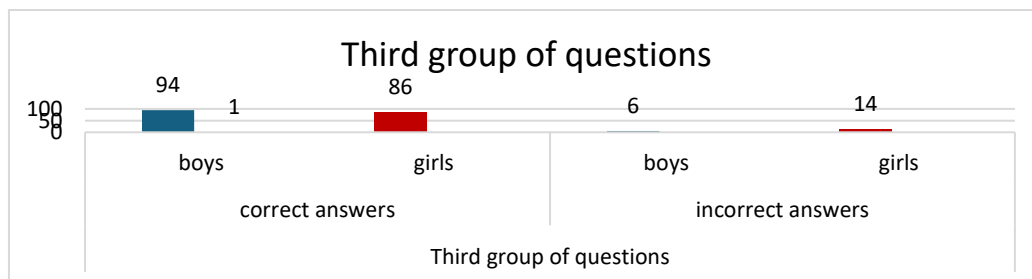


Figure 10. Answers of the third group of questions

From the results, we can notice that the question 15 has the most incorrect answers. The reason should be sought in the complexity and weaker representation of the Excel program in primary education. Students create presentations and write textual research, but they rarely use Excel to make a graph or table. This is more pronounced and evident among girls, which may be a conclusion that boys are more involved in creating projects for various subjects in Excel. In Figure 10, we can see the results of the third group of questions.

4 DISCUSSION

From the analysis we can see that most students have a laptop and there are only boys who do not have a computer of any kind. This means that most of the students are closer to technology and this can significantly help them during their education, and also in their further career. According to the fact that we live in a digital age, investing in computers and technology can significantly help students in carrying out their daily activities and gaining new knowledge. The schools should follow the trends and invest in computer equipment and new technologies. This can increase the interest of the students and their motivation to learn Informatics.

According to the three group of questions, we can notice that the boys have more correct answers than the girls. Perhaps this is due to the fact that boys are more interested in learning Informatics, and have more knowledge of basic concepts than girls. This may indicate to us that in the future special attention should be

paid to increasing girls' interest in Informatics. For this purpose, campaigns, seminars and workshops for promotion of new computer technologies can be organized.

Regarding our research, we could say that we have a limitation in the number of covered classes and respondents. In the future, we will direct our research on the analysis of more schools in order to obtain more results, to make a comparison and give directions for increasing the motivation of students to learn Informatics.

5 CONCLUSION

As a conclusion of our research on informatics, carried out in the primary school of St. Cyril and Methodius from St. Nikole, among students in the 9th grade, the need for greater inclusion of informatics and contents related to the use of computer applications in teaching is clearly seen. This need is most evident in the use of the Excel program as perhaps the program with the least representation in education, but also in terms of the Internet and work with electronic mail. In further secondary education, a large number of students will face questions related to previously studied content in the field of computer applications, and their readiness to successfully implement this content will largely depend on how much of the material they have mastered and how much their knowledge can be increased by introducing new techniques and strategies in primary education. Greater activity in creating projects with tables and graphs in the Excel program in other subjects, the usage of email in Macedonian language, English language classes, etc. can help to make up for the omissions in informatics. This will give students a greater opportunity to be ready to face the challenges during their further education.

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APPENDIX A: QUESTIONNAIRE - A LIST OF QUESTIONS AND SUGGESTED ANSWERS

Questionnaire on knowledge of Information Technology intended for students from Basic education

Circle one of the answers offered:

1. What computers do you use at home?

- a) Desktop b) Laptop c) Both

2. Hardware is:

- a) the machine part of the computer system
b) the program part of the computer system
c) the machine and program part of the computer system

3. The keyboard has function keys from:

- a) F1-F10 b) F1-F11. c) F1-F12

4. The first hand calculator was called:

- a) Computer b) Telephone c) Abacus

5. Which base number system has 0 and 1?

- a) decade number system
b) binary number system
c) hexadecimal number system

6. A device for displaying computer data on paper or foil is:

- a) Scanner b) Printer c) Speakers

7. In what measurement unit is the internet speed measured:

- a) Mbit/s b) MB c) GB

8. A device that allows several local networks to be connected into one is called:

- a) Modem b) Router c) Scanner

9. Internet service provider (ISP) is:

- a) a company that provides internet by connecting the user to other providers from other countries of the world.
b) a company that manufactures computers
c) the program for opening, viewing and moving through different web pages

10. The user to create a new web-based e-mail address through the page of the selected e-mail server should choose:

- a) Sign up\ Register b) Sign in\ Log in c) Sign out

11. Reply when working with electronic messages means:

- a) to send a reply only to the sender
b) to send a reply to the recipients specified in the CC
c) to delete the message

12. What is the most commonly used operating system for personal computers in the world:

- a) Windows b) Mac OS c) Linux

13. Which company produces the Windows operating system?

- a) IBM b) HP c) Microsoft

14. What is the name of the program for creating and editing presentations:

- a) Power Point b) Excel c) Word

15. What is the most popular charting program:

- a) Power Point b) Excel c) Word

Maintenance Management System and Organizational Behavior in Educational Institutions

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Abstract: This paper explores the relationship between maintenance management systems and organizational behavior in educational institutions. Effective maintenance management plays a crucial role in creating a stable and functional work environment, which directly impacts employee motivation, productivity, and overall job satisfaction. Given that educational institutions are increasingly striving to improve their operational processes, analyzing the causal relationships between these factors becomes extremely important. The aim of this paper is to examine how maintenance management of technical systems can affect organizational behavior and vice versa, and to propose strategies for improving both areas to achieve better organizational performance.

Keywords and phrases: management, resources, education, organizational behavior.

1. INTRODUCTION

Management of maintenance systems and organizational behavior represent two key aspects of the functioning of any organization, especially educational institutions, where the quality of infrastructure and work environment have a direct impact on the success of the educational process (Armstrong & Taylor, 2017). Maintenance system management includes all activities aimed at preserving and enhancing the functionality of physical and technical infrastructure (Ali & Anwar, 2020). In educational institutions, including schools, universities, and other educational centers, this infrastructure is essential for providing quality education. Maintenance encompasses not only physical aspects such as buildings, classrooms, and laboratories but also IT systems and equipment that enable modern teaching.

The introduction of this paper sets the framework for exploring the cause-and-effect relationships between maintenance system management technical systems and organizational behavior. Specifically, the question arises as to how maintenance management and organizational behavior intertwine and influence each other in the context of educational institutions. Efficient maintenance management not only ensures the continuity of the educational process but also contributes to the overall well-being of employees and students by reducing stress and increasing motivation (Bakker & Demerouti, 2017). Additionally, Al Jomaih et al. (2024) emphasize the importance of awareness and training in reducing stress and increasing efficiency in organizations. On the other hand, an organizational culture based on trust, open communication, and collaboration can significantly enhance maintenance processes, making them more efficient and better adapted to the needs of users. This paper analyzes these interconnected factors through a theoretical literature review and empirical research. The goal is to determine how maintenance system management affects organizational behavior and vice versa, in order to develop recommendations for improving both aspects in educational institutions. The research will include an analysis of existing maintenance

management models, a review of key organizational behavior theories, and empirical research conducted through surveys among employees in educational institutions. The results of this research will provide a deeper understanding of these dynamic processes and offer a foundation for future research and practical interventions in the field of management and organizational behavior.

2. *MAINTENANCE SYSTEM MANAGEMENT and ORGANIZATIONAL BEHAVIOR*

The theoretical section of this paper lays the foundation for understanding the main concepts, models, and previous research related to maintenance system management and organizational behavior. In this section, we will review the basic definitions, key theories, and models, as well as research findings that connect these two aspects in the context of educational institutions.

Maintenance System Management: Maintenance system management refers to the comprehensive management of resources and activities necessary to preserve and enhance the functionality of physical, technical, and technological infrastructure within an organization (Creswell & Creswell, 2017). Maintenance involves a set of planned and unplanned activities, including preventive measures, repairs, part replacements, and the implementation of new technologies to ensure system longevity and reliability. In educational institutions, maintenance management directly impacts the quality of the educational process. For example, well-maintained infrastructure and equipment enable uninterrupted teaching, contributing to a positive experience for both students and teachers. Additionally, efficient maintenance management can significantly reduce the operational costs of the institution, freeing up resources to improve curricula and other key functions.

Organizational Behavior: Organizational behavior studies the behavior of individuals and groups within an organization and how these behavioral patterns affect the overall efficiency and culture of the organization (George & Jones, 2019). The main factors influencing organizational behavior include motivation, leadership, teamwork, communication, organizational culture and values, and how employees are engaged and integrated into work processes (Bakker & Demerouti, 2017). In educational institutions, organizational behavior is particularly important because it affects the quality of interactions between teachers, students, and administrative staff (Zohar & Hofmann, 2019). A positive organizational culture that values innovation, collaboration, and continuous learning can significantly improve the quality of education and the satisfaction of all participants in the educational process (Grant & Parker, 2020).

The Connection Between Maintenance Management and Organizational Behavior: Numerous studies suggest a strong correlation between maintenance system management and organizational behavior. Efficient maintenance management can create a stable work environment that supports positive organizational behavior, while proactive organizational behavior can improve the efficiency and effectiveness of maintenance (Podsakoff, MacKenzie, & Podsakoff, 2019). When the maintenance system in educational institutions is efficient, it leads to fewer unforeseen breakdowns, fewer work interruptions, and reduced stress for employees. In a stable and predictable environment, employees tend to be more motivated and engaged, contributing to a better work atmosphere and higher job satisfaction (Dessler, 2019). Moreover, trust in management increases in such environments, further strengthening collective responsibility and employee loyalty. On the other hand, positive organizational behavior can facilitate and improve maintenance management. Motivated and engaged employees are more likely to recognize and report issues with infrastructure and equipment, allowing management to take proactive measures and reduce the risk of major failures (Yukl, 2017). A culture of open communication and collaboration further contributes to faster and more efficient resolution of maintenance issues (Garvin, 2018).

The theoretical framework of this paper provides a basis for understanding the dynamic relationship between maintenance system management and organizational behavior. Through a review of key theories and models, as well as an analysis of previous research, this section highlights the cause-and-effect relationships between these factors and their impact on the efficiency and success of educational institutions. In the subsequent sections, these theoretical foundations will be used as a basis for testing hypotheses and analyzing the results of empirical research.

3. RESEARCH METHODOLOGY

The research will be conducted among the teaching staff of the primary school "Miloš Crnjanski" in Žabalj, with the aim of investigating the connection between maintenance system management and organizational behavior.

Research Subject: The subject of this research is to examine the impact of efficient use of material resources and organizational behavior on the functioning of educational institutions.

Research Problem: Insufficient efficiency in the use of material and technical resources and teaching aids in educational institutions can potentially negatively impact the quality of teaching and educational outcomes. This problem includes questions such as: whether school directors ensure optimal resource utilization, to what extent teachers use teaching aids to improve the quality of education, and whether their organizational behavior aligns with expected norms.

Research Aim: The aim of this research is to determine how the efficient use of material resources, combined with organizational behavior, contributes to the improvement of educational institutions' performance.

Research Task: To analyze how material resources influence organizational behavior within educational institutions, identify key factors that facilitate or hinder the efficient use of those resources, and propose strategies for improving resource management and organization to enhance overall institutional efficiency.

Hypotheses

Main hypothesis: An efficient technical maintenance system significantly improves organizational behavior in educational institutions

Sub-hypothesis 1: Institutions that implement proactive maintenance management have higher levels of employee satisfaction, leading to improved productivity and reduced staff turnover.

Sub-hypothesis 2: Positive organizational behavior, characterized by high motivation and collective responsibility, increases efficiency in reporting faults and resolving maintenance issues, thereby reducing operational costs and increasing overall efficiency.

Sample: The sample will include teaching staff at the primary school "Miloš Crnjanski" in Žabalj, comprising teachers of all subjects. The total number of teaching staff is 40, which is sufficient for conducting research within a single educational institution and allows for relevant analyses pertaining to the specific conditions of the school.

Inclusion Criteria

- ❖ School employees in the position of teacher.
- ❖ Actively engaged in the educational process for at least the past six months.
- ❖ Willingness to voluntarily participate in the research.

This sample was chosen because the teaching staff has direct interaction with the school's infrastructure and can provide relevant feedback on the quality of maintenance management and its impact on their daily work experience and organizational behavior.

Instruments: The questionnaire will be the primary tool for data collection. It will consist of several sections covering the following aspects:

1. Demographic data: Questions related to age, gender, work experience, and educational background of the respondents.
2. Organizational behavior: Questions assessing various aspects of organizational behavior, including motivation, job satisfaction, teamwork, communication, and perception of organizational justice. The questions will be formulated using a scale (from 1 to 6) to enable quantitative expression of teachers' attitudes and feelings. Within this dimension, there are 20 questions.
3. Maintenance system management: Questions assessing the teaching staff's perception of the effectiveness of maintenance management in the school, including items related to the optimal use of material and technical resources and continuous use of teaching aids. Within this dimension, there are 3 questions.

The questionnaire will be created and distributed electronically, using a platform such as Google Forms, to ensure easier access and completion for all respondents. The questionnaires will be taken from the Rulebook on Quality Standards for Institutional Work, Službeni glasnik RS - Prosvetni glasnik, No. 14/2018 dated August 2, 2018, specifically the section related to school organization, and the management of human and material resources.

4. RESEARCH RESULTS and ANALYSIS

Table 1. shows the demographic data.

Table 1.

Category	Data
Gender Structure	Male: 11 (31.4%), Female: 24 (68.6%)
Age Structure	20-30 years: 3 (8.6%), 30-40 years: 12 (34.3%), 40-50 years: 20 (57.1%), 50-65 years: 0
Educational Structure	Master's degree or higher: 15 (42.9%), Bachelor's degree: 20 (57.1%), Associate degree: 0
Years of Service in Educational Institutions	0-10 years: 5 (14.3%), 10-20 years: 17 (48.6%), 20-30 years: 13 (37.1%), 30-40 years: 0

In Table 2. the results of material and technical resources are presented.

Table 2.

Question	Analysis	Conclusion
Does the organization encourage innovation?	48.6% of respondents give scores of 3 and 4, while only 5.7% give the highest score of 6, indicating moderate support for innovation.	It is necessary to strengthen support for innovative initiatives among employees.
Is there a formal process for knowledge transfer?	40% give a score of 3, while 25.7% give a score of 4, indicating the existence of a formal process but with room for improvement.	The process of knowledge transfer through formal channels needs improvement.
Does the organization encourage long-term planning and strategy?	31.4% of respondents give a score of 4, while 22.9% give a score of 3, indicating moderate encouragement for long-term planning.	The organization needs to focus more on long-term strategic goals.

In Table 3. the results of respondents' organizational behavior are presented.

Table 3.

Question	Analysis	Conclusion
Do employees get time for learning?	42.8% of employees rate positively (scores 5 and 6), while 28.6% give lower scores (2 and 3).	More improvement is needed to provide opportunities for learning.
Is there a reward system for employees who learn?	37.1% of employees think there are no significant rewards for learning.	It is necessary to introduce reward policies that will motivate continuous learning.
Do employees receive honest feedback?	45.7% believe there is honest feedback, while 28.5% do not share this opinion.	Improving communication channels is required for better employee openness.
Are employees asked for opinions by others?	45.7% rate this positively, while 14.3% think this is not sufficiently practiced.	Encouraging inter-employee communication is essential.
Is there mutual trust among employees?	40% of employees rate the level of trust as high, while 28.6% give lower scores.	Work on strengthening trust within teams is required.
Can teams adapt their goals?	34.3% believe teams can adapt their goals, while 21% rate this lower.	Teams need to have greater autonomy to adapt goals.
Do teams correct their goals based on discussion?	48.6% rate this positively, while 44.3% give lower scores.	More effective ways to incorporate discussion and data into decisions are needed.
Does the organization act on team recommendations?	54.3% of employees are unsure whether the organization will act on their recommendations.	Strengthening trust between teams and management is necessary.
Does the organization measure performance?	37.1% of respondents give a score of 3, while 28.6% give a score of 4, indicating moderate efficiency.	Improving the performance measurement system is needed.
Does the organization share knowledge with employees?	31.4% give a score of 5, while 22.9% rate it lower.	Knowledge sharing is present, but optimization is needed.
Does the organization measure the effect of training investment?	40% give a score of 3, while 22.9% rate it higher.	The evaluation process of training impact is underdeveloped and requires improvement.
Does the organization recognize employee initiatives?	25.7% give a score of 3, while 20% give a score of 1 and 2, indicating dissatisfaction.	It is necessary to enhance recognition and reward for initiatives.
Do employees have control over resources?	28.6% rate it as 5, while 22.9% rate it lower.	Improving control over resources is needed.
Does the organization support risk-taking?	Scores of 3 and 4 are most common, with the least scores of 6, indicating limited support for risk-taking.	Strengthening support for innovation and risk is needed.
Does the organization promote systemic and global thinking?	Scores of 3 and 4 are most common, showing moderate support.	Further advancement in promoting systemic thinking is required.
Does the organization collaborate with the local community?	The most frequent score is 3, at 31.4%. Indicating a solid ↓ of collaboration.	Better engagement with the community is needed to meet shared goals and interests.

*Hypothesis Testing***Main Hypothesis:**

Effective technical maintenance management significantly improves organizational behavior in educational institutions.

The results indicate that employees generally agree that directors are satisfied with the management of material and technical resources, though there is a need for further improvement. A score of 3, given by 57.1% of respondents, suggests that resource management is not optimal but meets basic standards. However, since there is a positive perception of resource usage, it can be said that efficient maintenance management has the potential to contribute to improved organizational behavior, though it has not yet been fully realized. Based on this data, the hypothesis is partially confirmed, with a recommendation for further improvements.

Sub-Hypothesis 1:

Institutions that implement proactive maintenance management have higher levels of employee satisfaction, leading to improved productivity and reduced staff turnover.

The data indicates a relatively satisfactory level of use of teaching materials in schools, with 48.6% of respondents giving a score of 3. However, 20% of respondents expressed dissatisfaction by giving a score of 2 in this area. Additionally, trust among employees is rated as high, but there is room for improvement in team collaboration. These findings suggest that there is a satisfactory level of management of material and technical resources, but a proactive approach and further engagement can enhance employee satisfaction. The hypothesis is confirmed, but with a need for a more proactive approach.

Sub-Hypothesis 2:

Positive organizational behavior, characterized by high motivation and collective responsibility, increases efficiency in reporting malfunctions and solving maintenance problems, thereby reducing operational costs and increasing overall efficiency.

The data shows a high level of employee readiness to cooperate, with 45.7% agreeing that teams have the freedom to adjust their goals, and 48.6% acknowledging the importance of group discussions for decision-making. However, 44.3% of employees are not convinced that their suggestions for maintenance improvements are taken into account. This indicates a foundation for efficiency in problem-solving and motivation, but communication with management is crucial for fully realizing these advantages. The hypothesis is confirmed, with an emphasis on improving communication between teams and management.

Discussion

The research results partially confirm the main hypothesis, indicating that effective maintenance management contributes to organizational behavior, but significant room for improvement remains. Respondents recognize the basic functionality of resource management, but the dominant rating of 3 (57.1%) suggests the need for a more proactive approach. The sub-hypotheses confirm the connection between proactive management, employee satisfaction, and collective responsibility, but limitations were identified, such as insufficient consideration of employee suggestions (44.3%). Key recommendations include improved communication, more proactive strategies, and more efficient resource management to achieve full potential.

5. *CONCLUSION and DIRECTIONS for FURTHER RESEARCH*

The conclusion of this research highlights that the management of maintenance systems and organizational behavior significantly impacts the functioning of educational institutions, particularly in terms of the efficiency of using material-technical resources and the quality of the teaching process. Although the research was conducted on a sample of teaching staff from one primary school, the results suggest broader implications regarding resource management and organizational dynamics in educational institutions. The use of resources, both within the school and those available externally, is a key factor in ensuring the continuous quality of the educational process.

The participants generally expressed satisfaction with the management of material-technical resources, but the research also indicated a need for further improvements. Most participants believe that resources are being used adequately, but there is also a perception that school principals, as well as broader management, could improve the efficiency of resource management. This is particularly relevant to the optimal use of teaching tools and material-technical resources that are employed to enhance the quality of teaching. Although the results show that teachers consistently use these resources, there is clear room for

improvement to achieve higher employee satisfaction and better educational outcomes. Additionally, the research emphasized the importance of using external resources, such as cultural, scientific, and industrial institutions, in teaching and learning. However, participants were divided on this issue—while some believe these resources are being utilized satisfactorily, a significant portion feels that external resources are underused. This finding suggests that educational institutions could benefit from more intensive collaboration with external partners to provide additional learning opportunities and professional development for both teaching staff and students.

Organizational behavior, as an integral part of the daily operations of educational institutions, was shown to be a key factor influencing teaching efficiency and the overall functioning of the school. Participants demonstrated a high level of motivation and readiness to work in teams, as well as openness to sharing opinions and providing honest feedback. However, some participants pointed out the need for improved communication within teams and between staff and management. There is a need for further strengthening interpersonal relationships and trust among employees, as well as enhancing communication between teaching staff and management, to create a more positive work environment that fosters professional development and work efficiency.

In conclusion, the results of this research provide a basis for concluding that effective management of material-technical resources and developed organizational behavior can significantly contribute to improving the quality of teaching and the overall functioning of educational institutions. There is room for improvement in resource management, as well as in encouraging collaboration with external institutions to improve the educational process. Additionally, the further development of organizational behavior, through improved communication channels and strengthening trust among employees, can significantly contribute to work efficiency and improving interpersonal relationships within educational institutions. The recommendations from this research include strengthening proactive management, establishing clear mechanisms for resource use, and fostering an organizational culture that encourages collaboration, innovation, and continuous learning. In this way, educational institutions can create a stable and supportive environment for both teachers and students, leading to long-term improvements in the quality of education.

Based on the findings of this research, several key areas for further investigation have emerged:

1. **Broader Research in Different Educational Institutions:** Since this study was conducted in a single primary school, future research could include a variety of educational institutions (e.g., high schools, universities) to provide a broader understanding of the impact of maintenance management and organizational behavior on the educational process.
2. **Comparative Analysis:** A comparison between schools with different approaches to maintenance management could identify which methods and strategies yield the best results in terms of organizational behavior and educational quality.
3. **Long-term Monitoring of Organizational Changes:** Research that tracks changes in organizational behavior and education quality after the implementation of recommended measures in maintenance management would offer valuable insights into their long-term effects.
4. **Study of Specific Aspects of Organizational Behavior:** Future studies could focus on specific aspects of organizational behavior, such as motivation, teamwork, and leadership, and how they relate to the efficiency of maintenance management.
5. **Examining the Impact of External Collaboration:** Investigating the extent to which collaboration with external institutions (e.g., cultural, scientific, and industrial organizations) can improve the educational process through more effective use of external resources is another promising research direction.
6. **Development of New Maintenance Management Models:** There is a need to develop and test new models for resource management in educational institutions, emphasizing innovative solutions and technologies that can enhance efficiency.
7. **Qualitative Research:** Conducting qualitative studies, such as interviews and focus groups, would provide deeper insights into internal dynamics and challenges by exploring employees' perceptions of organizational behavior.

These directions can help further refine and improve the understanding of how maintenance management and organizational behavior contribute to the effectiveness and quality of education.

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Using Data Warehouse for Forecasting Student Success

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Abstract. This paper explores the significance of data warehouse, the application of data analysis using multidimensional databases, and the advanced functionalities of Microsoft Excel, for forecasting the success of students. The goal of the study is to identify key trends and patterns that can help improve educational policies. Data from the faculty's relational transactional database was loaded into a data warehouse created in a dimensional model. Using SQL Server Analysis Services (SSAS), an OLAP cube was formed to enable complex data analysis. Subsequently, the data was connected to Microsoft Excel, allowing for the presentation of information in the form of charts and forecasting future values using advanced functions. The result of the paper includes analyses that can assist in enhancing enrollment policies, teaching methods, capacity adjustments for future generations, organization of teaching staff, structuring of classes, and defining marketing strategies and faculty promotion.

Keywords and phrases: Data warehouse, OLAP, Forecast, Student

1 INTRODUCTION

The subject of this paper is the analysis of enrollment data and student performance at the Faculty of Economics, University of Banja Luka. The aim is to identify key trends and patterns that can assist in improving educational policies. For the practical part of the research and the assessment of student performance, a data warehouse was created using a dimensional model with Microsoft SQL Server database management system. For the purpose of this research, the student service and the network administrator of the Faculty of Economics provided data on students and exams for the first cycle of studies, covering the period from the 2018/2019 academic year until April 2023/2024.

Databases represent a fundamental part of most information systems and play a key role in data management. Proper database management ensures that data is easily accessible, accurate and useful, significantly contributing to the success of data analysis and visualization. Without a clear purpose, data analysis can be ineffective. Data, in itself, is not useful if the user does not have a clearly defined purpose or specific question they wish to explore.

With the help of SAP Power Designer (trial version), a dimensional data model was created for the purposes of building a data warehouse. SQL Server Analysis Services (SSAS) was used as an analytical tool for data processing, while Visual Studio with the SQL Server Data Tools (SSDT) add-on served as the development environment for the project. Once the data model was implemented as a database on the server, the data was analyzed and visualized using advanced functionalities in Microsoft Excel. To automate the data update process, SQL Server Integration Services (SSIS) was used. Through SQL Server Agent, SSIS packages were scheduled to run daily at midnight, enabling the automatic execution of the ETL process.

The term decision-making refers to the process of choosing one of two or more alternative actions in a given situation, undertaken to achieve a goal in the near or distant future. The decision-making process includes: setting objectives to be achieved, identifying problems (in achieving those objectives), finding and evaluating alternative actions, implementing the chosen action, and assessing the results achieved (Balaban and Ristic,

2006). Most decisions are made under conditions of uncertainty, where the probability of outcomes is unknown.

A database report is a document containing data that is extracted from the database and presented in an organized manner for specific purposes. It is often used to analyze patterns and trends, make decisions, or track progress in an understandable format (Database Report, 2024). Reports can be anticipated and defined during the design phase of an information system, and such reports are referred to as standard reports. Advanced users can be enabled to create new reports using specific mechanisms, which are known as *ad hoc* reports (Krneta, 2023).

2 METHODOLOGY

A data warehouse, a specific type of database, is a system used for reporting and data analysis and is considered a key component of business intelligence. Business intelligence is a broad term encompassing processes such as data collection, data management, data analysis, reporting, and data visualization, all aimed at supporting decision-making. Elements of business intelligence include primarily internal and external data, the ETL process, data warehouses, OLAP technology, and data presentation to users. Internal data belongs to the organization and is typically generated through transactional systems (OLTP – Online Transaction Processing), while external data is sourced from outside the organization.

A data warehouse is a system that retrieves and consolidates data periodically from the source system into a dimensional or normalized data store. It usually keeps years of history and is queried for business intelligence or other analytical activities. It is typically updated in batches, not every time a transaction happens in the source system. Data in data warehouse is updated using a standard mechanism known as ETL at specified time intervals, where data is extracted from the operational source system (Rainardi, 2008).

ETL (Extract, Transform, Load) process involves extracting data from one or more OLTP systems, cleaning the data, transforming it into an appropriate format, and then loading the data into the data warehouse (Krneta, 2023). The process of designing a data warehouse is called dimensional modeling. Dimensional modeling allows for the visualization of data in a way that the database, in whole or in part, is represented as a cube with three (data cube) or more dimensions (hypercube). The cube shape indicates that multiple dimensions can be used simultaneously to categorize the data (Aleksić Marić, 2008).

The data warehouse processes multidimensional data, commonly referred to as a data cube. In principle, any data cube can be represented by a set of normalized tables, and a data warehouse can be represented by a set of data cubes. A typical ERD method to describe high-dimensional data using data tables is star schema. The attributes and their data of each dimension are stored in a table, called dimensional table in the present context. The values of the primary key of the table represent the levels of this dimension. The center of the star schema is called the fact table (Wang and Wang, 2022).

A multidimensional database is a form of database where the data is stored in cells and the position of each cell is defined by a number of hierarchical called dimensions. Each cell represents a business event, and the value of the dimensions shows when and where this event happened. The other terms that people use for a multidimensional database are hypercube, cube, OLAP cube, multidimensional database (abbreviated as MDB, MDD, or MDDB), and multidimensional data store (MDDS). Multidimensional databases are typically used for business intelligence (BI), especially for online analytical processing (OLAP) and data mining (DM) (Rainardi, 2008). OLAP (Online Analytical Processing) is an extension of data warehousing and encompasses a category of applications and technologies designed for the collection, management, processing, and presentation of multidimensional data for analytical purposes. OLAP systems feature a specialized query language called MDX (Multidimensional Expressions), which is based on SQL and allows for querying data from multidimensional cubes (Krneta, 2023). SQL is a tabular query language that returns data in columns and rows. In a multidimensional model, there can be rows, columns, and other dimensions. Conceptually, every data point in measure group is intersected by every level on every dimension in the cube. This allows for multidimensional navigation through the data (Hughes, 2020). A Data Mart is a type of data warehouse that contains summarized data for specific organizational segments or particular groups of business processes within a company (Krneta et al., 2008).

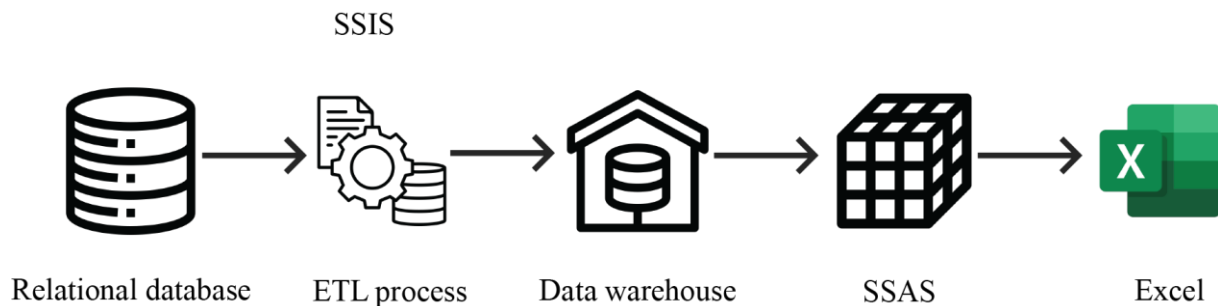
For presenting data to users, client tools may include (Krneta, 2023):

- Reporting tools – use predefined queries and provide management with web-based or paper-based reports that can be printed.
- OLAP tools – enable complex queries over large volumes of data, data manipulation and graphical data representation. They support fast ad hoc analysis, dimension selection, dimension rotation drill-down and drill-up.
- Statistical tools that use statistical methods for data analysis.
- Data mining tools – assist users in searching for patterns and relationships within organizational data.

Data presentation also involves data visualization, which means displaying data using charts or diagrams. Data visualization facilitates user understanding of the data. Reports can be created as static graphical reports, or users can be allowed to interact with the visual representation, enabling them to select the dimensions to be displayed in the report.

3 PRACTICAL METHODOLOGY IMPLEMENTATION

The complete research process consisted of the following steps: designing the dimensional model of the data warehouse and the data warehouse itself, designing the ETL process (data extraction from the relational database, data transformation, and data loading into the data warehouse), analytical processing and aggregation of data, and connecting Microsoft Excel to the OLAP cube for data analysis. The process is illustrated in the following figure.



3.1 Dimensional Data Warehouse Model

After creating the relational model of the transactional database and populating it with data from a staging database, a dimensional model of the data warehouse was developed using the previously employed tool, SAP PowerDesigner.

As explained in the previous section of the paper, the dimensional model consists of fact tables and dimension tables, which, as seen in Figure 2, are prefixed with "Fact" for the fact table and "Dim" for the dimension tables. Data warehouse tables have a slightly different structure compared to relational databases. For the purpose of optimizing the data warehouse and facilitating easier data access, the dimensional model is denormalized and implemented in a star schema. Only columns significant for data operations and analysis are retained in the tables. Typically, a dimensional model uses a single fact table, which stores various numerical values representing quantitative business transactions, along with multiple dimension tables that further describe the fact table. However, in certain situations, having multiple measure tables may be beneficial or necessary to ensure flexibility and optimization of the data warehouse. Figure 2 depicts a model designed to provide different perspectives on data analysis through the *Fact_Exam* fact table, within the context of the corresponding dimensions in a star schema.

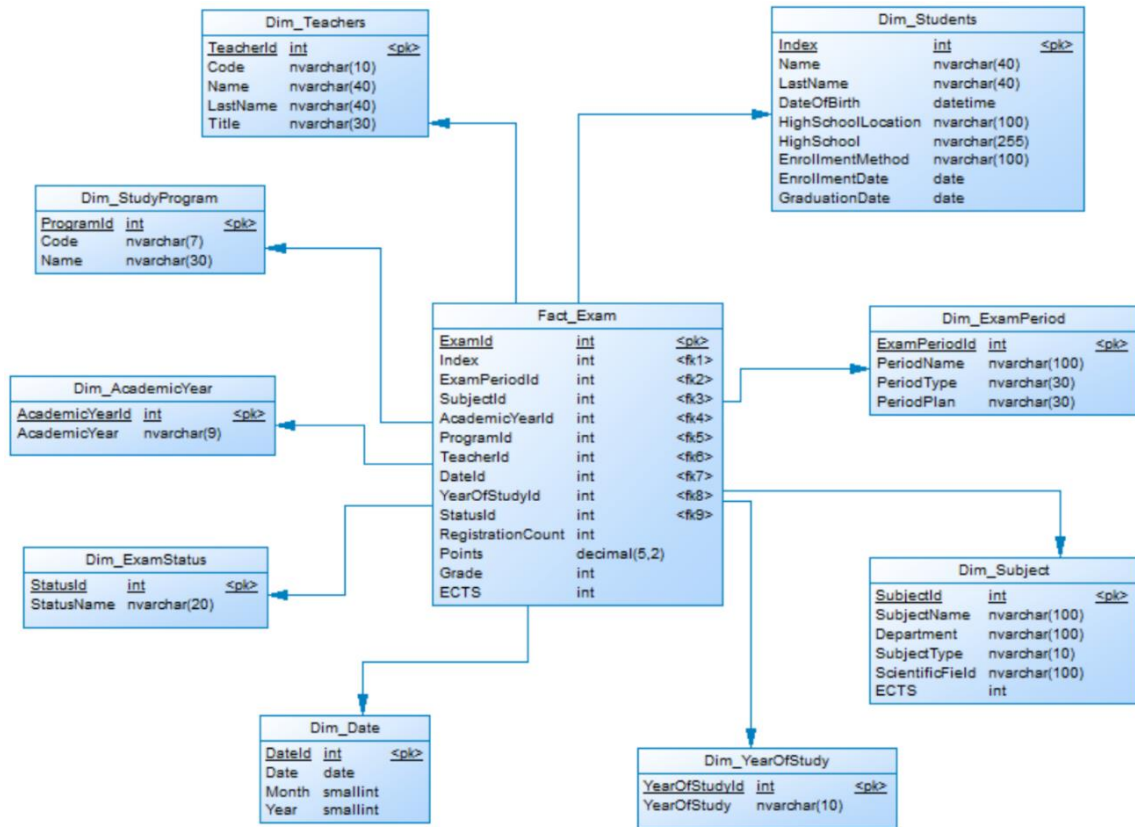


Figure 2: Dimensional data warehouse model – Fact_Exam

3.2 Forecasting Algorithms in Microsoft Excel

Excel, as one of the most popular tools for working with data, allows users to create forecasts based on historical data using the *Forecast* function, visualize data through charts, and analyze predicted values. Two data series are required: a series with dates (timestamps) and a series with corresponding values. The time series must have equal intervals between data points. Functions that predict future values based on past data use advanced machine learning algorithms, such as exponential triple smoothing (ETS). Excel offers five such functions, and one of them, the *Forecast sheet* function, was used in this paper.

Exponential smoothing forecasting in Excel is based on the AAA version (additive error, additive trend and additive seasonality) of the Exponential Triple Smoothing (ETS) algorithm, which smoothes out minor deviations in past data trends by detecting seasonality patterns and confidence intervals. This forecasting method is best suited for non-linear data models with seasonal or other recurring patterns (Cheusheva, 2023).

The basic equations for this method, also known as the Holt-Winters additive method, are as follows (Triple Exponential Smoothing, n.d.):

$$\text{Overall smoothing: } S_t = \alpha \frac{y_t}{I_{t-L}} + (1 - \alpha)(S_{t-1} + b_{t-1})$$

$$\text{Trend smoothing: } b_t = \gamma(S_t - S_{t-1}) + (1 - \gamma)b_{t-1}$$

$$\text{Seasonal smoothing: } I_t = \beta \frac{y_t}{S_t} + (1 - \beta)I_{t-L}$$

$$\text{Forecast: } F_{t+m} = (S_t + mb_t)I_{t-L+m},$$

where:

y - observation

S - smoothed observation

b - trend factor

I - seasonal index

F - forecast for m periods ahead

t - index denoting a time period.

3.3 Example of Student Performance Forecast

In the following figure, known values are represented in blue, while future trends are shown in orange. The prediction was made for the next three academic years, up to the 2026/27 academic year. A more detailed analysis revealed that the majority of the most successful students completed their high school education in Banja Luka. Accordingly, below is the prediction of the trend of the average grade of students from Banja Luka.

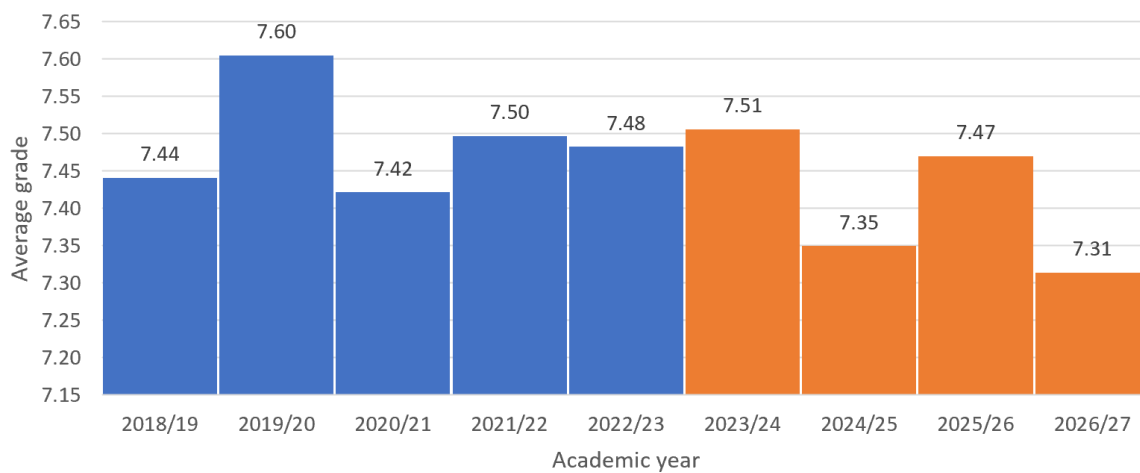


Figure 3: Predicting the average grade of students who completed high school education in Banja Luka

To create the previous chart, it was necessary to define a measure for the average grade. Excel works on the principle of dragging columns into desired fields (row, column, filter, or value), so the creation of this measure involved the application of MDX (Multidimensional Expressions) language. Specifically, the measure was created using MDX functions that allow the calculation of the average value based on the data from the "Grade" and "Fact Exam Count" columns.

Since the 2023/24 academic year is the current academic year and data is available only up to the second term of the January-February exam period, i.e., the beginning of the April term, this year is not representative and predictions have been made for it.

Since future predictions are based on historical data, they may not be precise. To assess the accuracy of the forecast, an evaluation was performed for a year for which average student grades are already known. In the previous academic year, 2022/23, the average grade was 7.48, while the business intelligence system predicted an average grade of 7.49. This represents an error of 0.01 or 0.13%.

4 CONCLUSION

The application of data warehousing for analyzing student and exam data and forecasting student performance, using analytical tools and advanced features of Microsoft Excel, demonstrates the advantages of the proposed approach. By using dimensional databases, or data warehouses, data analysis becomes faster and more efficient. Relational databases are optimized for transactional operations, whereas dimensional databases are designed for efficient analysis of large volumes of data. SQL Server Analysis Services (SSAS) provides advanced analytical functionalities such as OLAP, data mining, and automatic creation of OLAP cubes. When working with large amounts of data, direct analysis in Excel can be slow and demanding. Working with data from Analysis Services eliminates the need for extensive coding, as the data is already aggregated. This also reduces the number of queries and the load on the transactional database, thereby enhancing its stability and performance. Another advantage of this approach is the creation of reports by selecting different measures and dimensions. The integration of SSAS with Excel allows users to quickly and easily gain insights into the data,

with real-time data availability. Given that Excel has advanced tools for data visualization and analysis, which facilitate the understanding and interpretation of complex information within the data warehouse, the proposed concept significantly contributes to business decision-making processes.

Detailed insights into the presented data related to forecasting student performance can assist in improving admissions policies, teaching methods, adjusting capacities for future generations, organizing teaching staff, structuring courses, enhancing curricula, and defining marketing strategies and faculty promotion.

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Analysis of the Impact of Organizational Learning on Organizational Conflicts in Domestic Companies

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Abstract. The empirical research presented in this paper is based on determining the existence of the impact of organizational learning on organizational conflicts. The aim of this study is to explore and analyze how organizational learning influences the occurrence of conflicts within an organization. Within the theoretical framework, key concepts of organizational learning are examined, along with their interdependence with organizational culture, structure, and performance. The paper also addresses the definition of organizational conflicts, including a consideration of their causes, consequences, and strategies for managing and resolving them, in addition to presenting the research findings. Special attention is given to the analysis of how learning processes can contribute to the understanding, prevention, and resolution of conflicts within organizations, and how conflicts, in turn, may affect the efficiency and outcomes of the learning processes.

Keywords and phrases: Organizational learning, organizational conflicts, domestic companies.

1 INTRODUCTION

Due to today's competitive and uncertain environment, organizations could effectively respond to external challenges by becoming more learning-oriented, where individuals and teams are encouraged to continually learn and grow, and knowledge is shared and disseminated throughout the organization. This can enable the organization to better understand its environment and respond to changing circumstances in a more effective and efficient manner. By evolving into a learning organization, the organization could continuously improve its ability to adapt and change through the acquisition and application of new knowledge and skills. An unstable, uncertain, complex, and ambiguous work environment creates the need to reduce employee turnover, burnout, and conflicts. Organizational learning and an appropriate management style should focus on encouraging and inspiring employees, which can effectively stimulate their internal potential, improve work capacity, and increase engagement. Contemporary learning theories assume that learning involves iterative processes of structuring and restructuring mental models. These processes are combined with other learning-related processes, such as sense-making, error correction, evaluation, reflection, and the like. All of these processes are essential for meaningful learning, whether applied in the context of collective, organizational, or individual learning. A collaborative environment in organizations is effective only if each learner independently performs their tasks. This highlights the importance of individual tasks and responsibilities, even within collaboration, especially as conflicts between individual solutions are often used to trigger effective collaborative learning. Thus, the significance of individual learning in organizations is reflected in employees' ability to analyze, solve, correct mistakes, reflect, and repeat the process as much as needed. These individual abilities or learning habits play a crucial role in any collective learning or work environment that employees may encounter (Reychav, 2015). Organizational learning plays a crucial role in achieving positive performance outcomes and establishing a healthy business climate. It facilitates the interaction between motivation for learning, organizational performance, and an innovative climate. Therefore, companies should foster motivation for organizational learning to enhance their innovative

capabilities and overall performance (Zhang, 2024). In addition to organizational and team learning, preparing individuals for teamwork is equally important. The success of a team often depends on the preparation of individuals through training, education, and interactive activities, as well as equipping them with tools that foster positive team dynamics and outcomes (Wilcox, 2022; Mapile, 2023). A widely adopted work arrangement is multiple team membership, which has beneficial effects on employees' acquisition of knowledge and skills. The relationship between multiple team membership and individual workplace learning represents a positive aspect for employees, especially for those with high socially prescribed perfectionism (Manole, 2022).

Conflicts are an integral part of business operations and cannot be avoided. In a globalized and dynamic environment, the need arises to manage conflicts in a productive and effective manner. Conflict resolution styles depend on various factors, including the national culture of employees, who, in accordance with their cultural background, will have certain preferences in resolving conflicts (Husaković, 2020). Managing organizational conflicts involves various approaches with specific characteristics, and their application is influenced by a large number of internal and external factors within the organization (Gwanyo, 2020; Kozina, 2023).

The aim of this paper is not only to identify the connections between organizational learning and organizational conflicts but also to offer practical recommendations for organizations to optimize learning processes and manage conflicts more effectively. Through analysis and discussion, this paper seeks to contribute to a better understanding of the complex relationships that shape the work environment and to highlight the importance of an integrative approach in developing organizational strategies for learning and conflict management.

2 THEORETICAL BACKGROUND

Large number of studies emphasize the inevitability of conflicts and their detrimental effects on organizations. However, the emergence of conflicts can also indicate an opening for changes and innovations, which is considered beneficial for the organization (Idam, 2020; Qayyum, 2022; Hashish, 2023). Conflicts can arise at the same organizational level, among colleagues, between superiors and subordinates within the organization, as well as between different sections and departments of the organization (Mikkelsen, 2018). When it comes to the causes of organizational conflicts, both internal and external factors are considered. Internal conflicts include unhealthy communication, avoiding issues that could be managed, problematic organizational structure, lack of diversity in the workplace, individual differences in personality and perception, flexible offices, and unmet expectations or needs. On the other hand, external conflicts involve issues that employees "bring" into the workplace, such as personal problems and stress. Additionally, personal attributes, such as race-based prejudices and generalizations, can lead to workplace conflicts that may or may not have a direct connection to the organization (Diin-Fitri, 2018).

Using organizational learning theory, the mechanism by which task conflict within an organization affects company performance can be explored. Knowledge integration and coordination of certain organizational projects can be identified as mediators between task conflict and organizational performance. Task conflict promotes knowledge integration but deteriorates project performance, while knowledge integration serves as a mediator between task conflict and the performance of a specific project (Jia, 2021). Briefing saves hours of reading time for employees, managers, and researchers by selecting only the best and most relevant information and presenting it in a concise, digestible format (Ricciardi, 2021). Team learning plays a crucial role in solving organizational tasks, while individual learning activities contribute to knowledge sharing within teams, thereby increasing team effectiveness (Anselmann, 2023). Furthermore, fostering an environment that encourages creativity is essential for organizations, and developing strategies for managing conflict in relationships, particularly those related to supervisory support and a positive affective tone, will help ensure that creative ideas are conveyed across organizational levels, even in the presence of dysfunctional conflicts. Support for collective learning is based on the careful design of activities that employees engage in, which reinforce individual learning, particularly in terms of identity development (Wake, 2022).

Organizational learning serves as a key mechanism for enhancing a company's ability to respond to challenges, including those related to organizational conflicts. Conflicts within organizations often arise from

disagreements, differences in the perception of goals, values, or communication styles between individuals and teams. Organizations that actively promote learning can significantly reduce the frequency and intensity of conflicts by developing communication, teamwork, and problem-solving skills. Through organizational learning processes, employees are equipped with tools and techniques for constructive dialogue, critical thinking, and resolving disagreements based on shared knowledge and common goals. Additionally, organizational learning fosters a culture of trust and openness, where conflicts are perceived as opportunities for growth rather than obstacles to work. In this way, organizations become more resilient to conflicts and better prepared to transform them into positive outcomes, thereby improving long-term efficiency and cohesion within work teams (Argyris, 1996).

3 METHODOLOGY

3.1 Subject and problem of research

In a broader sense, the subject of the research encompasses the examination of theoretical frameworks, models, and practices related to learning and conflicts within organizations, with particular emphasis on the mechanisms through which organizational-level learning can contribute to better conflict management, as well as the ways in which conflicts influence learning and development processes.

The specific problem involves identifying the factors that facilitate or hinder learning processes due to the presence of conflicts, understanding how conflicts can serve as drivers or barriers to learning and innovation, and determining strategies that organizations can apply to harmonize learning goals with conflicts. Additionally, the research aims to identify how organizational-level learning contributes to the perception, interpretation, and resolution of conflicts within the organizational context. This issue is particularly relevant in the context of globalization and technological advancement, which bring new challenges and opportunities for organizational learning and conflict management.

3.2 Research method

This paper represents a form of empirical and theoretical research in which the conclusions are drawn based on the conducted study. The research also examines various methods proposed by other authors and analyzes the results with the aim of deriving conclusions.

3.3 Research goal

Through the analysis of results and a systematic review of relevant theories and empirical research, this paper will attempt to address key questions, thereby contributing to the development of more effective practices for managing learning and conflicts within an organizational context. From the research goal arises the following research question:

RQ1: Does organizational learning in domestic companies have a statistically significant impact on organizational conflicts?

3.4 Research procedure

This research includes the use of standardized questionnaires evaluated on a Likert scale, with ratings from 1 to 7, where a score of 1 represents the statement "strongly disagree," and a score of 7 represents the statement "strongly agree." The questionnaires used for the research are:

- Organizational learning – to measure organizational learning, authors used a shorter version of the "Dimensions of the Learning Organization Questionnaires (DLOQ)" by Marsick and Watkins (2003). The questionnaire consists of 18 items and 7 dimensions: continuous learning, inquiry and dialogue, team learning, empowerment, embedded system, system connection, and strategic leadership.
- Questionnaire for measuring task, relationship, and process conflict – to measure task, relationship, and process conflict, a modified version of the questionnaire by Kuriakose (2019) was used. The scales for measuring task, relationship, and process conflict were adapted from the "Extended Intragroup Conflict Scale" (Jehn et al., 2008). The original work of Jehn (2005) developed the dimensions of task and relationship conflict, and in later work, a third dimension for process conflict was added (Jehn et al., 2008).

The questionnaire consists of 10 items and 3 dimensions: task conflict, relationship conflict, and process conflict.

This research also includes questions about the sociodemographic characteristics of respondents, which are answered categorically. Data collection is conducted via the Internet using an online questionnaire. In this study, the obtained data were processed using SPSS software version 21, employing statistical methods for data analysis and processing. The data were processed using the following statistical method:

- Regression analysis to analyze the influence of variables

3.5 Research population and sample

The research involved 101 employees at the middle management level. The companies where the respondents are employed are located in the Republic of Serbia, and their size, ownership structure, and industry vary, with the research covering both manufacturing and service companies.

4 RESULTS AND DISCUSSION

Regression analysis reveals the impact of dimensions of organizational learning on the dimensions of task, relational, and process conflict, as well as on the three individual dimensions of conflict within the organization. In this study, the dimensions of organizational learning were treated as a linear independent variable, while task, relational, and process conflict were treated as linear dependent variables. Table 1 presents the regression analysis of the dimensions of organizational learning on task, relational, and process conflict.

Table 1. Regression analysis of the dimensions of organizational learning on task, relational and process conflict

ANOVA ^a						
	Model	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	41.896	7	5.985	5.827	.000 ^b
	Residual	95.524	93	1.027		
	Total	137.419	100			
a. Dependent Variable: Task, relation and process conflict						
b. Predictors: (Constant), dim7: Strategic leadership, dim4: Empowerment, dim2: Inquiry and dialogue, dim5: Embedded system, dim3: Team learning, dim1: Continuous learning, dim6: System connection						

Based on the values and results presented in Table 1, it can be concluded that the dimensions of organizational learning influence task, relational, and process conflict.

The impact of individual dimensions of organizational learning on task, relational, and process conflict is shown in Table 2.

Table 2. Regression analysis of individual dimensions of organizational learning on task, relational and process conflict

Coefficients ^a						
	Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4.659	.467		9.977	.000
	dim1:Continuous learning	.078	.134	.085	.580	.563
	dim2:Inquiry and dialogue	-.499	.109	-.627	-4.574	.000
	dim3:Team learning	.144	.131	.159	1.095	.276
	dim4:Empowerment	-.272	.113	-.310	-2.415	.018

	dim5:Embedded system	.189	.123	.239	1.533	.129
	dim6:System connection	.087	.128	.102	.679	.499
	dim7:Strategic leadership	-.079	.118	-.099	-.664	.508
a. Dependent Variable: Task, relation and process conflict						

Based on the values and results presented in Table 2, it can be concluded that continuous learning, team learning, embedded systems, system connection, and strategic leadership do not influence task, relational, and process conflict. However, inquiry and dialogue, as well as empowerment, as dimensions of organizational learning, have an impact on task, relational, and process conflict.

The presented regression analysis demonstrates that while several dimensions of organizational learning do not significantly impact organizational conflicts, there are notable exceptions. Specifically, the dimensions of inquiry and dialogue, alongside empowerment, exhibit a significant influence on task, relational, and process conflicts within domestic companies. This finding suggests that fostering an environment where open communication and empowerment are prioritized can contribute to the mitigation or management of organizational conflicts. Inquiry and dialogue likely encourage more effective conflict resolution by facilitating open discussions and the exchange of perspectives, while empowerment may enable individuals to address and resolve conflicts more autonomously. These results present the importance of creating a learning culture that emphasizes employee participation and dialogue, as these factors are pivotal in reducing conflicts in the workplace.

5 FINAL CONSIDERATIONS

5.1 Scientific and social justification of the research

The scientific justification of this research lies in the need for a deeper understanding of how organizational learning can affect the occurrence and management of conflicts within organizations. This research contributes to the existing body of knowledge on the relationship between organizational learning and conflict management within organizations. The findings offer new insights into how certain learning practices within organizations can mitigate or exacerbate conflicts and this research helps in building a theoretical framework that can serve as a basis for further research, as well as for the development of strategies and tools to improve organizational learning in order to minimize conflicts.

From a social standpoint, this research holds significant practical implications for domestic organizations. As conflicts in organizations can have negative consequences for productivity, work atmosphere and overall business results, understanding how different aspects of organizational learning can contribute to reducing these conflicts is of great importance. Encouraging inquiry, dialogue, and empowerment may not only reduce conflicts but also enhance collaboration, innovation, and overall organizational performance.

5.2 Applicability of research results

The research results indicate which dimensions of organizational learning have the greatest impact on reducing conflicts, which provides managers with concrete guidelines for focusing their efforts. For example, given that exploration and dialogue have been identified as key dimensions that reduce all types of conflict, organizations can implement training programs that emphasize these aspects, which could lead to the harmonization of team relationships and increased effectiveness in solving tasks. Organizations can use these findings to develop specific programs that support continuous learning and team collaboration, which have shown a significant impact on reducing task-process conflict.

5.3 Research goal fulfillment

The research goal included examining the impact of organizational learning on organizational conflicts in domestic companies, as well as reviewing relevant studies for theoretical analysis and confirmation of the obtained results. By presenting and discussing the results of the research, it was determined that both parts of the set goal were fulfilled, that is, the influence of organizational learning on conflicts in companies in the territory of the Republic of Serbia was determined.

Based on the results of the regression analysis, the answer to the research question is given, i.e. there is a statistically significant impact of organizational learning on organizational conflicts in domestic companies. While not all dimensions of organizational learning, such as continuous learning, team learning, embedded systems, system connection, and strategic leadership showed a statistically significant effect on task, relational, and process conflicts, certain dimensions, namely inquiry and dialogue as well as empowerment, did demonstrate a significant impact. Therefore, the research question is validated for those dimensions that significantly affect organizational conflicts.

5.4 Limitations and directions for further research

This research offers valuable insights into the relationship between organizational learning and organizational conflicts. However, several limitations must be acknowledged. First, the scope of the research is limited to Serbian companies, which may restrict the generalizability of the findings to organizations in different cultural or economic contexts. The specific characteristics of the domestic business environment could influence the extent to which organizational learning practices impact conflict, making it important to replicate the study in other regions or industries to validate the results. Additionally, this paper only considers a limited number of dimensions within both organizational learning and conflict. While inquiry, dialogue, and empowerment were found to be significant predictors of conflict, future research could explore additional variables or dimensions of organizational learning that might also play a role in conflict mitigation or exacerbation. Moreover, the study focuses exclusively on task, relational, and process conflicts, which may not encompass the full spectrum of conflict types present in organizations. Expanding the scope of conflict types in future research would provide a more comprehensive understanding of the interplay between learning and conflict.

Future research should expand upon the findings of this study by exploring the relationship between organizational learning and conflicts in a wider variety of contexts, both geographically and across different industries, to enhance the generalizability of the results. Additionally, further studies should investigate other dimensions of organizational learning and conflict types not included in the current research, providing a more holistic view of how learning processes influence conflict dynamics within organizations.

6 CONCLUSION

This study provides insights into the relationship between organizational learning and organizational conflicts within domestic companies. The findings suggest that fostering open communication and empowering employees can mitigate conflicts within organizations, thereby enhancing organizational effectiveness and employee relations. It is important to consider how conflicts can act as a stimulus for knowledge integration and coordination within the organization, but also how they can negatively affect project performance. Although conflicts can have a potentially destructive impact, they can also foster organizational learning when directed toward productive problem solving. This paradox of conflict suggests that it is not the occurrence of conflict itself that is problematic, but the way in which the organization deals with it. In addition, the importance of multiple membership in teams and how it can contribute to individual and team learning shows that dynamic team structures can be useful for developing organizational capacity. In this sense, empowering employees through training and developing interactive activities that promote team dynamics can have far-reaching positive effects on organizational climate and performance. Overall, this research underscores the importance of targeted organizational learning practices in conflict management, offering practical implications for organizations aiming to create more harmonious and productive work environments.

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Python Chatbot: Virtual Assistant in Educational Process

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Abstract. This study explores the evolution and significance of chatbots in the context of artificial intelligence (AI). We trace the historical development of AI and the emergence of chatbots, examining their core features, functionalities, and applications across various sectors, particularly in education. The research includes a hands-on exploration of the chatbot creation process, demonstrating how these systems can be customized for diverse educational purposes. Our findings reveal that chatbots can significantly enhance human-computer interaction and improve learning experiences by providing instant support, personalized resources, and facilitating real-time feedback. We conclude with recommendations for future advancements in chatbot technology, emphasizing their potential to transform educational environments.

Keywords and phrases: Artificial Intelligence, Chatbot Development, Educational Technology, Human-Computer Interaction.

1 INTRODUCTION

Since the advent of industrialization and the first steam engine, society has shown a continuous drive to replace manual labor with mechanized solutions. In today's advanced technological landscape, chatbots have become essential tools, helping us navigate modern technological challenges. The origins of chatbots trace back to the 1960s with the development of ELIZA. Over the years, chatbots have been known by various names, including interactive agents, virtual assistants, and virtual humans—terms that, despite nuanced differences, are often used interchangeably.

Chatbots have since permeated all areas of modern life, stepping in wherever the human element can be supplemented or replaced. As AI-powered tools, chatbots leverage natural language processing (NLP) and natural language understanding (NLU) to accurately interpret user queries, adapting responses based on specific intents, while machine learning allows for real-time optimization. With AI and deep learning, chatbots continuously improve their accuracy, fostering natural and seamless interactions with minimal misunderstandings.

Historically, psychological and mathematical theories have contributed to the development of chatbots as we know them today. Unlike human employees who are bound by working hours and holidays, chatbots are available around the clock, addressing customer needs promptly. This instant availability improves customer satisfaction by reducing wait times and boosts economic efficiency by lowering operational costs. Chatbots can handle multiple users simultaneously and streamline support processes like answering calls, emails, or other online inquiries, ultimately enhancing service quality and reducing delays.

The paper by Adamopoulou and Moussiades (2020) provides a comprehensive review of chatbot design, architecture, and algorithms, discussing their functionality and evolution. It examines chatbot history, evaluation methods, and essential components such as ASR, NLP, response generation, and dialogue management. The paper also includes a case study on IBM Watson, covering security aspects and various

applications. This literature review highlights the historical progression, identifies limitations at different stages, and offers a categorization system. Additionally, it analyzes key technologies like pattern matching and machine learning, proposes a general architecture, and addresses crucial design considerations. The review explores applications, industry use cases, risks, and strategies for improvement, concluding with a forward-looking perspective on creating smarter chatbots.

Cahn's paper (2017) reviews chatbot design, architecture, and algorithms, including an analysis of chatbot functionality, history, and assessment methods. It discusses core elements like ASR, NLP, response generation, knowledge base development, dialogue management, and text-to-speech algorithms, concluding with a section on chatbot development, a case study on IBM Watson, and insights on security and applications.

Wei, Yu, and Fong (2018) present a framework for chatbot development, tracing AI's evolution and focusing on chatbot technology. They discuss chatbot history, features, and supportive technologies, and demonstrate the framework's viability for industrial use based on theoretical designs.

Rahman, Al Mamun, and Islam's (2017) paper examines cloud-based chatbot technologies, including IBM Watson and Microsoft Bot, while highlighting design and programming challenges due to the integration of AI, NLP, and dynamic functions. The review addresses current obstacles in chatbot development and anticipates future challenges.

Colace et al. (2018) focus on a prototype chatbot aimed at supporting university students in specific courses. Utilizing NLP and domain-specific ontologies, the chatbot interprets student queries and provides accurate answers. After implementation, an experimental study confirmed the model's efficiency and effectiveness.

Georgescu (2018) explores how conversational agents enhance daily life and education by offering accessible assistance across devices. In the educational field, chatbots present new methods for content delivery, student assessment, and real-time feedback, aligning with modern learning styles. This paper covers educational chatbot development, frameworks, benefits, challenges, and proposes a model to improve quality of life in educational contexts.

Building on the current importance of chatbots, this paper reviews their history, functionality, and modern applications, offering illustrative examples of the development process.

2 THE PROCESS OF CREATING A CHATBOT

To better explain the coded part, we will start from where the whole idea began. Initially, a file was created from which all responses would later be generated. A JSON file was structured to include metadata for training the chatbot, consisting of an intents list that contains tags, patterns, and responses. When the client inputs text, the bot can identify the relevant tag and classify the input accordingly. For instance, if the bot recognizes a greeting, it will provide a random response from a set of predefined replies. To enhance the training of the chatbot, we employ tokenization, a process that breaks down words, punctuation marks, and numbers into smaller, manageable units. For example:

"What cake flavors do you offer?"

["What", "cake", "flavors", "do", "you", "offer", "?"]

Then, we will add another NLP technique that finds the root of the word (stemming). For example:

"organize", "organizes", "organizing"

["organ", "organ", "organ"]

After applying the previously mentioned techniques, the process for handling a full sentence would be as follows.

For example, if we have the sentence: "Can I request custom cake designs?"

1.Tokenization will first split all the words: ["Can", "I", "request", "custom", "cake", "designs", "?"]

2.Then, all uppercase letters will be converted to lowercase: ["can", "i", "request", "custom", "cake", "designs", "?"]

3.Next, we will apply stemming to find the root of the words: ["can", "i", "request", "custom", "cake", "design", "?"]

4.After passing through the NLP techniques for tokenization and stemming, punctuation marks will be removed: ["can", "i", "request", "custom", "cake", "design"]

5.Finally, we obtain a bag of words represented in binary values: [0, 0, 0, 1, 0, 1, 0, 1]

This binary representation indicates the presence or absence of specific words in the sentence, which helps the chatbot process and understand the input effectively.

4.1. Code Examples and Explanation

We begin by creating a file named `nltk_utils.py`, where we import the necessary libraries: `numpy` and `nltk`. We also import the `PorterStemmer` class from `nltk.stem.porter`. The constructor of the `PorterStemmer` class is then used to create an object, which is stored in the variable `stemmer`. This object will be used later to find the root (or "stem") of words.

```
numpy as np
import nltk
# nltk.download('punkt')
from nltk.stem.porter import PorterStemmer
stemmer = PorterStemmer()
```

The `PorterStemmer` is part of the Natural Language Toolkit (NLTK) and is a common technique in NLP (Natural Language Processing) for reducing words to their base or root form, making it easier to analyze text by reducing variations of words to a standard form.

```
def tokenize(sentence):
    return nltk.word_tokenize(sentence)
def stem(word):
    return stemmer.stem(word.lower())
```

The two functions above are used for tokenization and stemming of words, respectively:

`tokenize(sentence)`: This function takes a sentence as input and splits it into individual words (tokens) using `nltk.word_tokenize()`. Tokenization is essential in NLP as it breaks down the input text into manageable units for further processing.

`stem(word)`: This function stems from a given word by first converting all uppercase letters to lowercase using `word.lower()`. It then applies the `stemmer.stem()` method to reduce the word to its root form. This step is crucial for ensuring that words like "designs" and "design" are treated as the same base word.

These functions help preprocess the input by normalizing and simplifying the words, making further analysis more effective.

```
def bag_of_words(tokenized_sentence, words):
    # stem each word
    sentence_words = [stem(word) for word in tokenized_sentence]
    # initialize bag with 0 for each word
    bag = np.zeros(len(words), dtype=np.float32)
    for idx, w in enumerate(words):
```

```

    if w in sentence_words:
        bag[idx] = 1
    return bag

```

The `bag_of_words` function is used to convert a tokenized sentence into a numerical representation known as a "bag of words." This representation is crucial for processing text data for machine learning models. Here's how it works:

1. **Tokenization and Stemming:** `sentence_words` contain the stemmed versions of the words from the tokenized sentence. This ensures consistency in word forms (e.g., "design" for "designs").
2. **Initialization:** `bag` is initialized as a numpy array of zeros with a length equal to the number of words in the vocabulary. Each element in this array represents whether a specific word from the vocabulary is present in the input sentence.
3. **Updating the Bag:** The function iterates through the vocabulary (words). For each word in the vocabulary, if it appears in the `sentence_words`, the corresponding index in the `bag` is set to 1. This binary representation indicates the presence or absence of each vocabulary word in the sentence.

This function helps convert text data into a format suitable for machine learning algorithms, enabling the chatbot to classify and respond to different inputs effectively.

4.2. Training the Chatbot Data

The chatbot is trained using the `train.py` file. Here's how the process works:

1. **Loading and Reading Data:** The script begins by opening and reading the JSON file, which contains the responses and associated metadata. This file includes the intents, tags, patterns, and responses used to train the chatbot.
2. **Creating Lists:** Several lists are created to store the "bag of words," tags, and patterns. These lists are populated using the data from the intents key in the JSON file. The previously defined functions for tokenization and stemming are used to process the input sentences, ensuring they are in a format suitable for training.
3. **Indexing and Searching:** A class with a constructor is created to enable indexing and searching by index during the training process. This class helps manage and retrieve data efficiently.
4. **Model Creation:** A model is created to train the chatbot using a neural network. The model includes:
 - Input Layer:** Accepts the bag of words representation of the input sentence.
 - Hidden Layers:** Several hidden layers process the input and extract relevant features.
 - Output Layer:** Provides a probability distribution over possible class (i.e., intents).
5. **Training the Model:** The model is trained using the prepared data. Each input sentence is processed through the network, producing output probabilities that represent the likelihood of each intent class. This helps the chatbot determine the most appropriate response based on the input.
6. **Forward Propagation:** The forward function is used to activate all layers of the neural network during training and inference. This function computes the output by passing input data through the network layers, updating weights, and generating the final class probabilities.
7. **Adding the Model and GPU Support:** Returning to the `train.py` file, we incorporate the model and check for GPU support. The training process includes optimization and loss calculation to ensure accurate responses. Finally, the data is saved.
8. **Creating chat.py:** In the `chat.py` file, necessary libraries are loaded. GPU support is checked, the JSON file and the previously saved training data are loaded, and the model's status is assessed. The chatbot interface is developed, including naming the bot and displaying introductory text. A while loop is used to import sentences, with an if condition to end the conversation. Sentences are tokenized and converted into the bag of words format, which the bot can recognize. A function is defined to generate responses with a 75% accuracy rate, based on prediction probabilities. For example, if "Hi" is entered, the bot searches for tags that might include "Hi" as a greeting. Once the appropriate tag is identified, the bot selects a response from predefined options.
9. **Routing and Flask Application:** A routing file is created to read the basic HTML file, enabling communication with the chatbot. This Flask application handles the exchange of sentences between the

bot and the user, modifying text into JSON format. When the code is activated, it opens a window and handles interactions like opening, closing, and clicking the SEND button through event-driven functions. A function selects the text input area, sends the sentences via POST requests to the prediction function, converts the text into a string, and specifies the JSON file format. After sending a POST request, the response is extracted and used to update the chat box. Error handling is also included.

10. Training Script Example: The examples below show how to train the model by calling the train.py script, with detailed information about the tags and the time required to find them.

4.3. Python-based chatbot as a virtual assistant for the educational process

Creating a Python-based chatbot as a virtual assistant for the educational process can greatly enhance both teaching and learning experiences. Here's an outline of how a Python chatbot can function as an educational assistant and some key elements it should include:

- Student Q&A Support: The bot can be designed to answer student queries about course materials, assignments, schedules, and other frequently asked questions (FAQs). This feature helps students get instant support, saving time for both students and educators.
- Resource Recommendations: Based on the student's queries or topics of interest, the bot can recommend relevant resources such as articles, videos, or practice exercises to help them deepen their understanding.
- Study Reminders and Notifications: The chatbot can remind students of upcoming deadlines, exams, and scheduled classes or events, helping them stay organized and manage their time effectively.
- Tutoring and Concept Reinforcement: By integrating natural language processing (NLP) and machine learning, the bot can tutor students on certain topics by providing explanations, examples, and quizzes for practice, reinforcing learning outside of class hours.
- Assessment and Feedback: The bot can conduct simple assessments through quizzes or flashcards, giving instant feedback to help students identify strengths and areas for improvement.
- Administrative Assistance: Beyond academic support, the bot can assist with administrative tasks, such as providing information on enrollment processes, campus facilities, or links to relevant forms and documents.

Some of the essential building blocks of a Python-based educational chatbot include:

- Natural Language Processing (NLP): NLP enables the chatbot to understand and interpret user input effectively, facilitating smooth interaction.
- Intent Recognition and Response Generation: This component helps the bot identify user intents (e.g., requesting resources, asking questions) and generate appropriate responses.
- Integration with Educational Resources: Connecting the bot to an educational knowledge base allows it to offer relevant resources, such as articles, videos, or course materials, to students.
- User Interface: An accessible interface, whether for desktop or mobile devices, is crucial for ease of use and convenience.
- Personalization and User Profiles: The chatbot can be programmed to recognize individual students, track their progress, and provide tailored responses, thereby enhancing the learning experience.

3 THE APPLICATION OF CHATBOTS IN EDUCATIONAL PROCESS

The application of chatbots in education enhances learning by providing instant, accessible support, helping students with information retrieval, lesson reviews, and practice exercises. Chatbots can deliver personalized assistance, answer questions, and engage students in interactive learning activities. They also aid teachers by automating routine tasks like grading and attendance, allowing more focus on student engagement. By simulating human-like conversations, educational chatbots foster a dynamic learning environment that complements traditional teaching methods, supports self-paced learning, and promotes continuous assessment and feedback.

A developed chatbot can be used as an assistant or learning aid in various ways to enhance the educational experience for both students and teachers. Here are some possible applications:

1. **Answering Student Queries:** The chatbot can serve as an on-demand resource, answering frequently asked questions (FAQs) related to course material, assignments, deadlines, or administrative issues. This frees up teacher time and ensures students get immediate support.
2. **Tutoring and Concept Reinforcement:** By guiding students through specific topics or exercises, the chatbot can help reinforce learning. It can provide explanations, examples, or even quizzes to ensure students understand concepts effectively.
3. **Personalized Study Plans:** Based on students' progress, the chatbot could offer personalized study plans, recommending resources, practice problems, or even adjusting topics based on students' understanding and performance in assessments.
4. **Feedback and Progress Tracking:** The chatbot can keep track of students' learning progress and provide personalized feedback on their performance in assignments, quizzes, or assessments. This helps students identify areas for improvement in real time.
5. **Interactive Study Companion:** Through quizzes, flashcards, or mini challenges, the chatbot can help students review and memorize information, making the learning process more engaging and interactive.
6. **24/7 Support and Assistance:** Unlike human educators, chatbots are available around the clock, providing support at any time. This availability allows students to get help with their studies outside of regular class hours, especially beneficial in different time zones or for students studying remotely.
7. **Automated Assessment and Grading:** The chatbot can assist in grading quizzes and assignments, especially for objective-type questions. This automation can reduce grading workload and provide instant feedback to students.
8. **Class Reminders and Notifications:** It can remind students of upcoming deadlines, exams, or class schedules, keeping them organized and on track.
9. **Language Practice and Improvement:** For language courses, the chatbot can engage students in conversation practice, helping them improve vocabulary, grammar, and fluency. It can correct mistakes and suggest improvements in real-time.
10. **Group Project Coordination:** The chatbot can facilitate communication and coordination among group members, assign tasks, and set deadlines, helping students manage collaborative projects effectively.
11. **Resource Recommendations:** Based on a student's learning needs or topics of interest, the chatbot can suggest additional learning resources like articles, videos, or exercises, expanding students' knowledge outside of class materials.
12. **Exam Preparation and Mock Tests:** To aid students in exam preparation, the chatbot could offer mock tests, track results, and provide tailored feedback on how students can improve.
13. **Teacher Assistance:** For teachers, the chatbot can assist by providing quick information about student progress, helping create reports, and tracking attendance. It can also alert teachers to students who may need extra help based on chatbot interactions.
14. **Motivation and Encouragement:** The chatbot can send motivational messages or study tips, encouraging students to stay engaged and productive, which can be especially helpful in long-distance or online learning environments.
15. **Real-Time Polling and Feedback Collection:** During live classes, the chatbot can be used to conduct polls, gather feedback, or engage students in discussions, providing teachers with instant insights into students' understanding and preferences.

By integrating a chatbot into the learning process, educational institutions can create a more interactive, responsive, and supportive environment that aligns with modern student needs and teaching practices.

4 CONCLUSION

In today's digital and highly interconnected educational environment, Python-based chatbots provide significant opportunities to enhance learning experiences by automating support, offering real-time resources, and facilitating self-paced learning. Starting from foundational concepts like Natural Language Processing (NLP), intent recognition, and personalized user profiling, chatbots in education represent a shift toward more responsive and flexible educational support systems. By leveraging essential chatbot building blocks, such as a user-friendly interface, educational resource integration, and customized student interactions, these tools offer tailored learning assistance that adapts to individual student needs and learning styles.

The implementation of educational chatbots can transform the teaching and learning process, providing accessible, round-the-clock support while allowing educators to focus on more complex pedagogical tasks. Through applications like tutoring, progress tracking, and interactive quizzes, chatbots can assist students in mastering content and reinforcing concepts outside traditional classroom hours. Moreover, by automating routine administrative tasks and facilitating class reminders and group coordination, chatbots contribute to streamlined educational processes and improved overall efficiency.

As AI and machine learning capabilities continue to advance, the role of educational chatbots will likely expand, offering even more sophisticated functionalities. By fostering dynamic, student-centered interactions, educational chatbots can create a more engaging and productive learning environment, thus enhancing both student satisfaction and educational outcomes. With continued development and adaptation to meet evolving academic needs, chatbots are poised to become an integral component of the modern educational landscape.

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Encouraging Creativity in Student Education

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Abstract. The rapid technological progress and social changes that characterize these days require solving problems in a different, more creative way. This is where the need for creativity arises, especially in education. Later, that creativity is transferred to business. One of the problems that causes a lack of creativity is the traditional way of education. For this reason, it is necessary to change the curriculum, as well as the methods of imparting knowledge to students, in order to stimulate and motivate creativity. Teachers are the ones who play a key role in motivating students' creativity. Their approach encourages or discourages students to express their ideas. It is very important for teachers to recognize and reward student effort. This paper will show the concept and importance of creativity in education, challenges and obstacles faced by both teachers and students in education, methods and strategies for stimulating creativity, as well as how creativity acquired or stifled during education affects people's later business.

Keywords and phrases: creativity, education, students.

1 INTRODUCTION

Creativity is not only limited to artistic domains, such as fine arts, literature, music, etc., but also occurs in areas such as technology, business, administration, education, production. Its "products" include tangible objects such as books, music, pictures, machines, but also ideas, processes, services, as well as work systems and production methods (Cropley, 2020). So, one of the key aspects of education, as already mentioned, is creativity. It enables students to develop their abilities in a critical and innovative way. An education that fosters creativity creates generations of students who are ready to face the challenges of the future. These students not only possess knowledge in various fields, but also the ability to apply that knowledge in innovative ways to solve problems and create new opportunities. Creativity in education is therefore necessary for the development of critical thinkers and leaders who will shape the future world (Krnjaić, 2015).

There are many challenges and obstacles in encouraging creativity among students, but also in the expression of creativity by students. One of the most important obstacles faced by teachers is the traditional form of education, which involves teaching theory and testing knowledge. In this way, the creativity of the teacher to better reproduce the material is stifled, but also the ability of the students to learn the material in a better way and later change it in a better way in practice. In addition, the volume of materials and resources that teachers possess are small, so this reduces their ability to encourage creativity. Also, the culture of a particular nation affects the degree to which teachers can or cannot stimulate creativity of their students (Munro, 2019).

One of the very important tasks of teachers in modern business is to encourage creativity of their students. The methods and strategies used to achieve this goal must be designed to encourage innovative thinking, freedom of expression and a critical approach to problems. There are a number of different approaches that can help teachers develop creativity of students, many of which require changing traditional educational practices and introducing new methods. Some of the methods for stimulating creativity are: brainstorming, simulations and roles, reflection method, critical thinking technique, etc. (Bell, 2016).

Creativity is considered a powerful "weapon" for organizations (Zhou, Zhong & Zhang, 2024). Companies today operate in a global market, where they are expected to provide innovation to the market. This can only be achieved with creative employees. Through their education, creative employees were stimulated to develop their creative abilities. These are mostly people who are more willing to accept risks, accept and adapt to changes more easily, solve problems in a different and more innovative way (Gundry, Ofstein & Kickul, 2014).

2 THE TERM AND SIGNIFICANCE OF CREATIVITY IN EDUCATION

Creativity, i.e. creative behavior can be defined as unusualness, innovation, statistical rarity or uniqueness of solving a certain problem or situation (Guilford, 1967). Creativity means doing things in ways that are new and, on the other hand, effective in achieving the desired result. The result can range from abstract actions, like a new way of looking at something, developing new experiences, to concrete results like creating a new product (Crompton, 2020).

In the educational system, creativity can be seen as the ability to recognize new ideas, solve problems in unconventional ways and use imagination to create something original. One of the main reasons why creativity is important in education is its ability to connect theoretical knowledge with practical application (Patston, et al., 2021, Kaplan, 2019). For example, in mathematics or science, a creative approach allows students to experiment and explore different ways of solving problems, rather than blindly following given formulas and procedures. This encourages critical thinking and gives them the confidence to develop their ideas, which makes them more versatile and adaptable in different situations (Milićević, Pejić & Kompletić, 2016).

In today's world, where technology and social needs are constantly changing, students who possess creative abilities have a greater chance to successfully respond to challenges and take advantage of opportunities presented to them. For example, through interdisciplinary learning, students can develop flexibility in thinking and become prepared for different career paths, rather than focusing on one narrowly specialized field. Technology plays an increasingly important role in education, and creativity can be used to make innovative use of digital tools. Students can use technology to create content, such as videos, digital drawings, multimedia presentations, and blogs, thereby developing digital competencies that are critical for the 21st century (Guaman-Quintanilla, et al., 2023). This not only prepares them for the job market, but also helps them explore their interests and develop a sense of independence in learning.

In schools, emphasis is often placed on memorizing and reproducing information, while creativity helps students develop a deeper understanding and application of acquired knowledge in real situations. Thus, traditional curricula, which rely on repetition and memorization, can often lead to monotony and loss of interest in students (Wang, 2022). When teachers integrate creative methods into their lessons, such as projects, discussions and simulations, students feel more engaged and motivated. In this way, passivity in learning is reduced, and active involvement and research is increased. For this reason, it can be said that teachers have a key role in encouraging creativity in students. They need to create an environment where students feel that their ideas are valued and that they can experiment freely. Instead of evaluating only the accuracy of answers, teachers should value students' originality and unique approaches in solving tasks. This approach empowers students and encourages them to think outside the box, which develops the ability to solve problems innovatively (Stojanović, 2021). Although creativity is often believed to be an innate trait, it can be developed and nurtured through appropriate educational practices. When students are given the opportunity to experiment, explore and create in an environment that supports innovation, they develop their creativity, which can have long-term positive effects on their academic and professional journey. For many students, the opportunity to express their creativity can be a key factor in their educational experience, as it allows them to discover their interests and talents (Krueger, 2022).

3 CHALLENGES AND OBSTACLES TO ENCOURAGE CREATIVITY IN HIGHER EDUCATION

One of the main challenges in fostering creativity from the earliest period of education to higher education is the traditional education system. The traditional education system implies learning and reproducing material almost by heart, which deprives students of freedom in learning and expressing their opinions. Thus, many colleges and universities still insist on learning through lectures and tests, where more attention is paid to

memorizing facts than to critical thinking and innovation. This approach can discourage students from exploring new ideas and approaches, as it gives the impression that the most important thing is to "learn the material", instead of developing the ability to think outside the box (Somolanji & Bogнар, 2008, Wang, 2022).

The challenge and obstacle that teachers still face is the lack of resources and time to encourage creativity. They are often under pressure to process an extensive curriculum within a limited time frame, which leaves little room for creative projects, discussions or research. Because of this, students are often not given the opportunity to experiment with ideas or explore problems in innovative ways. In addition, limited resources, such as laboratories, equipment, or software tools, can further reduce the opportunity for creative projects, especially in underfunded institutions. The lack of resources can be particularly observed in underdeveloped, less developed countries and in rural areas (Bullard & Bahar, 2023).

There are also cultural barriers that affect creativity in higher education. In some academic circles, original ideas and unconventional approaches may be met with resistance or criticism, as deviating from standard methods may be considered risky or frivolous. This climate can demotivate students to express their creative ideas for fear that they will be judged negatively or that their innovation will not be appreciated. This problem is particularly pronounced in disciplines traditionally viewed as "rigorous" or "precise", where adherence to established methods and standards is expected (Vezzali, et al., 2016).

4 METHODS AND STRATEGIES FOR ENCOURAGING CREATIVITY OF STUDENTS

Encouraging creativity of students is a key aspect of modern education. There are many methods and strategies that teachers could use to stimulate creativity of students, but the first step is to create an environment that supports creativity. When an atmosphere is created where questions are welcome, there is no one right answer, and different ideas are valued, students feel free to express their creativity (Veno, 2023). In this way, students learn to think critically and innovatively, as they are encouraged to look for solutions that are not immediately obvious. Teachers can also use stimulating work in small groups to encourage creative collaboration. In group work, students can share ideas with each other, exchange perspectives and develop creative solutions together. This encourages teamwork and develops communication skills, while at the same time allowing each student to contribute to the joint project in a unique way. Group work can result in more innovative and comprehensive solutions, as students use their individual strengths for a common goal. Technology is another important tool for encouraging creativity of students (Palma Pires, 2023). Today, digital tools and resources, such as graphic design, video editing, animation and programming software, allow students to experiment and create in innovative ways. Teachers can use these tools to enable students to develop their own projects, from creating digital artwork to programming interactive applications. The use of technology encourages creativity, but also develops digital skills that are crucial for modern society (Grieshaber, et al., 2021, Palma Pires, 2021).

Some of the concrete methods by which teachers can develop and stimulate creativity of students are (Guaman-Quintanilla, et al., 2023, Veno, 2023, Palma Pires, 2023, Zhang & Ma, 2023, Nair & Mahan, 2023, Vigors, 2023, Oudenampsen, et al., 2023):

- Project learning,
- Brainstorming,
- Simulations and roles,
- Reflection method,
- Lateral thinking technique,
- Interdisciplinary learning.

Project-based learning, which puts students at the center of the educational process, allows them to explore topics of interest, set their own goals, and solve real-world problems. This method allows students to develop independence, responsibility and innovation, because it gives them the opportunity to use different approaches in work, instead of following strictly defined steps (Zhang & Ma, 2023). Brainstorming is a technique where students can express their ideas freely, without fear of criticism. This process allows the generation of a large number of ideas in a short period of time, and all ideas are considered valid, regardless

of how unusual or illogical they are. After that, the ideas are analyzed, evaluated and further developed. This strategy not only encourages creative thinking, but also contributes to creating an open environment where students feel free to experiment and explore different perspectives (Veno, 2023). Through simulations and roles, students are placed in certain scenarios where they have to make decisions and solve problems from the perspective of certain characters or situations. These methods encourage critical and analytical thinking, as well as the ability to adapt to new and unexpected circumstances (Guaman-Quintanilla, et al., 2023). In the Republic of Serbia, the Commissioner for the Protection of Equality organizes a competition for undergraduate and master's law students: Trial simulation "Condemn discrimination", where theoretical knowledge is practically applied and creative argumentation strategies are developed (Ravnopravnost, 2024). Reflection allows students to look back on their work, consider their ideas and think about how they could improve their approaches. This method helps students develop self-awareness about their creative process and learn from their mistakes and successes. Through regular reflection, students become more aware of their creative capacities and better able to recognize opportunities for innovation (Vigors, 2023). At the University of Iran, medical students use reflective essays to analyze their clinical experiences, which helps them develop critical thinking and professional competence (Khoshgoftar & Barkhordari-Sharifabad, 2023). The technique of lateral thinking is based on the idea that problems can be solved with unconventional approaches, outside of established patterns of thinking. Students are encouraged to look for alternative solutions, rather than relying on obvious answers. Through this technique, flexibility in thinking is developed, which allows students to be more open to different options and possibilities (Nair & Mahan, 2023). Interdisciplinary learning connects different fields of knowledge, such as art, science, technology and social sciences, thus enabling students to apply acquired knowledge in new and creative ways (Oudenampsen, et al., 2023, Veno, 2023, Palma Piers, 2023). At the Massachusetts Institute of Technology, programs like the Media Lab bring together students from different disciplines to work on collaborative projects, resulting in innovative solutions at the intersection of technology, art and design (Team DigitalDefynd, 2024).

5 THE INFLUENCE OF CREATIVITY IN EDUCATION ON LATER BUSINESS

Creativity in business is defined as the ability of an individual to produce original and useful work. When employees show creativity at work, they develop new responses, which are useful for solving certain tasks and problems in the organization (Amabile, 2013, Kovač, et al., 2024). For this reason, it can be freely said that creativity in education has a very strong influence on the later business of an individual. Through education that fosters creativity, individuals develop a range of skills that help them not only adapt to change, but also be leaders in creating new ideas and approaches in the business environment.

One of the most important ways in which creativity in education affects later business is the development of problem-solving skills. Creative education encourages students to seek unconventional solutions and explore different perspectives when facing challenges. In the business world, problems rarely have simple solutions, and those who are able to recognize different options and use innovative approaches have an advantage in making strategic decisions (Kruger, 2022). Creativity in education also develops adaptability and flexibility, qualities that are essential for doing business in modern society. An education system that fosters creativity teaches students not to be rigid in their thinking and to be open to change. This adaptability is later transferred to the business, where employees and leaders must respond to market changes, technological innovations and new customer demands. People who have developed creative skills through education often become innovative leaders, ready to take risks and recognize new opportunities (Vukadinović, 2022). Creativity in education enables people to develop cooperation and teamwork skills. Students involved in creative projects often work in teams, where they have to share ideas with each other, listen to different perspectives and come up with solutions together. These experiences develop important communication and collaboration skills that are crucial in the business world (Stolaki, Satratzemi & Xinogalos, 2023).

Creativity in education fosters an entrepreneurial spirit. Educational systems that foster creativity often encourage students to recognize opportunities and risks, which is essential for entrepreneurship. Students who have been exposed to creative education often develop the confidence and motivation to start their own businesses or to bring about innovative changes within existing organizations (Fillis & Rentschler, 2010). Creativity developed through education also contributes to the advancement of innovation in various industries. Companies that hire creative individuals often get employees who are capable of improving

existing processes, technologies or products, or even creating entirely new ways of working. Innovation is critical to the long-term growth and success of companies, and creative individuals play a central role in that process (Gundry, Ofstein & Kickul, 2014). Creative education also encourages critical thinking, which is another important factor in the business world. Students who have learned to question established assumptions, analyze different aspects of a problem and form their own conclusions become employees who make better decisions. Critical thinking enables employees to look at problems from multiple angles, to recognize potential risks, and to make decisions that are based on thorough analysis rather than assumptions or instinct. This ability is especially important in jobs that involve strategic decision-making, risk management and development planning (Alvarez-Huerta, Muela, Larrea, 2022, Almulla, 2023).

Using modern technologies to encourage creativity is of key importance for strengthening 21st century skills, such as: critical thinking, digital literacy, problem solving. In primary education, while playing, various applications (Minecraft Education) can be used to develop creative problem-solving skills. In secondary education, various multimedia tools can be used to create presentations, VR (Virtual Reality) applications for simulations, etc. In higher education, different data analysis software (MATLAB) or different VR and AR (Augmented Reality) can be used to experiment in the environment. All skills and traits, developed through creative education, make individuals more capable and competitive in the labor market, and companies that recognize and nurture these qualities have a greater chance for success and long-term development.

6 CONCLUSION

Creativity in modern education plays one of the most important decisions. Traditional ways of transmitting the material, but also its adoption, have a much smaller effect on the subsequent application of the acquired knowledge. Educational programs should generally be more adapted to the needs that the later labor market demands. Too much material, which is only presented to students and learning the same, without expressing opinions, discussion has no long-term effect on the acquired knowledge. For this reason, the changes should be made first of all. A big problem faced by teachers in Serbia is the lack of resources to stimulate creativity (various software, equipment, laboratories), and that problem should be solved in some way through different types of donations.

The teacher's task would be to create a creative environment in which students could freely express their ideas and thus develop their creative potential. There are various methods by which teachers can encourage students' creativity, such as brainstorming, reflection methods, simulations and roles, interdisciplinary learning. Working in teams also contributes to encouraging creativity, because then, through joint work, students come up with ideas. It is important to choose the most appropriate method for each teaching area, so that the effect is as good as possible. Also, it is important not to criticize, but to reward free expression of opinion.

The modern market today is looking for products and services that are different, more unique. In order to create such products/services, in addition to basic knowledge, employees must also possess creativity. The skills acquired by employees during education that stimulated creativity will be at a much higher level and will more easily respond to the demands of the market.

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Digital Dialogue in the Function of Optimizing the Time Allocation of Dominant Roles in Class

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Abstract. This research was conducted with the aim of taking a more detailed look at the time distribution of the periods of dominance of individual participants in the teaching process during 45-minute classes. It is part of a series of studies related to the effects of applying digital dialogue in face-to-face teaching. Nine lessons conducted using traditional teaching methods and nine lessons using digital dialogue in the classroom were recorded and analysed. The time periods of teacher dominance, student dominance, and periods of silence were measured during regular lessons. The data were digitized and displayed graphically. The analysis relies solely on numerical data and does not take into account the quality of the interaction. The results show significant differences in this regard, depending on the teaching methods used. It was observed that classes with digital dialogue enable greater student participation, better-balanced class dynamics, and provide the teacher with the role of facilitator.

Keywords and phrases: digital dialogue, interactive teaching, hybrid learning.

1 INTRODUCTION

Effective time management in class is one of the key factors for optimizing the learning process and achieving educational goals. The way time is allocated between different activities directly affects student engagement, understanding and retention of information. One of the biggest challenges in teaching is finding the right balance in how to divide time between the dominant roles: teacher lectures, student activities and quiet periods. Each of these roles is very important in the learning process, especially from the aspect of maintaining students' attention for as long as possible during the lesson.

The art of teaching consists of the means by which a teacher holds the attention of his class. By attention we do not mean only the absence of noise. The only satisfactory attention is the one that everyone gives voluntarily and consistently during the entire lesson and in which the mental attitude of the class is actively engaged together with the teacher in the preparation of their own lesson (Berliner, 1990).

Starting from this principle, pedagogical practice knows different methods for maintaining the attention of pupils and students in class. One of them is a conversation through a series of questions and answers, through dialogue. Conversation is perhaps the teacher's main pedagogical tool. Dialogue in the classroom can be considered a very specific use of speech - one that actively uses language, as a cultural tool and a psychological tool to enhance learning.

Classroom dialogue is a tool that can be used to help students build knowledge as they explore and build on their own and others' ideas (Cook, Major, Hennessy, Ahmed, & Calcagni, 2018). In this way, the conceptualization of learning is broadened, going beyond the idea of knowledge acquisition to include students' involvement in knowledge-building practices (James, 2008).

On the other hand, information technologies have entered the education system with a bang. Educational methods and information technologies are still searching for the optimal combination of software and pedagogical solutions.

Work is being done every day to introduce new technologies into educational experiences. We can point to experiments, pilots, and prototypes, but overall, they are small-scale, with no guarantees, or often no funding for progress. Virtual reality is being used to bring science to life, transport classes on virtual trips and market universities to potential future students (Salmon, 2016).

Research on the interaction between classroom dialogue and digital technology is a growing field of study. Most of the research on the impact of digital technology on productive dialogue in the classroom is based on the sociocultural perspective of education (Major, Warwick, Rasmussen, Ludvigsen, & Cook, 2018).

Examining the use of digital technology in classrooms, we show how understanding affordances, as broad categories that refer to a range of "possibilities for action," can inform empirically based analyzes of the "realized possibilities" of a specific technology (Louis Major, 2019).

Digital technology has the potential to expand conventional conceptions of dialogue to include sign-mediated activities and non-face-to-face or asynchronous dialogic interactions (Louis Major, 2019). At the same time, dialogue can also 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 (Georghiadis, 2012).

In recent years, the use of digital dialogue in teaching has been growing (Fig. 1). The concept itself has already been proven in tests of knowledge and increased interaction in face-to-face teaching (Randelović, Veljović, Stanojevic, & Paunović, 2016). Teaching practice indicated the need for the development of specialized software, which would enable and document digital dialogue in the classroom. Such systems are used in order to increase the interaction of students and lessons in class, obtain the critical opinion of each student individually and create an environment for cooperative and active learning (Derek, 2009).

The concept of digital dialogue (Digital Dialogue, DD) as a system for creating a higher degree of interaction between teaching subjects - via Wi-Fi (Wireless-Fidelity) technology, mobile software applications and devices and teaching methods, which include training and testing via the Internet (Web Based Training, Internet Based Test - iBT), ensures that the entire flow of the teaching process during one course is transferred to electronic form, enriched with interactive multimedia and placed in appropriate databases. The dynamics of the activity is still controlled by the lecturer in interaction with the students (Randelović, Janev, Milošević, & Paunović, 2015).

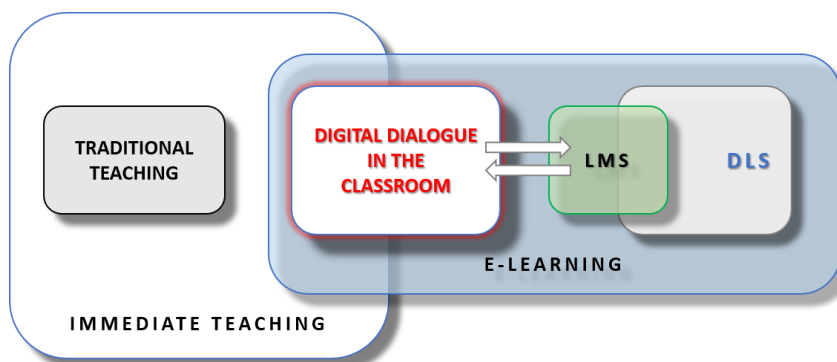


Figure 1. The position of digital dialogue in a hybrid learning system (Randelović, Janev, Milošević, & Paunović, 2015)

This paper describes specific research on the effects of the application of digital dialogue in face-to-face teaching. The analysis of the time distribution of the dominance of the activities of students, teachers and the time of silence in the class is presented.

Previous research leads to the conclusion that optimizing the time distribution of dominant roles during class can often be essential for improving the efficiency of the entire teaching process and educational results. A structured approach to time management, based on cognitive science principles such as Hermann Ebbinghaus' forgetting curve (Ebbinghaus, 1913), can significantly improve knowledge retention by introducing regular

intervals to refresh and confirm accepted material. Today, the Ebbinghaus chart is becoming a way to estimate the time it takes people to learn a new skill and evaluate performance (Nang, 2018).

With careful management, using digital dialogue, a balance between active teaching, student participation and quiet reflection, lessons can be structured to maximize engagement and facilitate deeper understanding.

2 METHODOLOGY AND EXPERIMENT DESCRIPTION

This research is based on the methodology and results of the experiment, which is described in the papers (Randjelović, Jevtić, & Janković, 2023) and (Randjelović, Jevtić, Stanojević, & Veljović, 2024). Applied case study methodology that also has an experimental aspect. By processing the obtained results of this experiment, new data were obtained, which were not previously processed and were not presented in the previously mentioned works. In this paper, the research includes new, additional data and a different analysis is applied.

For the research sample, data were collected from classes that use digital dialogue and those that use traditional methods. It was ensured that the sample was representative and that both approaches were equally represented. The research was conducted in the 2022/23 school year, in the secondary state school, ETŠ "Nikola Tesla" in Niš, Serbia. 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. Three departments of the same grade, educational profiles Computer Electrical Technician and Information Technology Electrical Technician, 3rd grade, were selected. Classes have approximately the same number of students (from 25 to 30).

The research was conducted by 3 teachers who taught the same classes, but different subjects. Those classes where the type of teaching was realized - the processing of new material was selected. A camera was placed in the classroom for each class, so that it records all changes in the activities of the teacher, students and the time of silence during the class (Randjelović, Jevtić, & Janković, 2023).

During the lesson, the periods of dominance of teacher, student activity and quiet time are marked. A special Java application was created for this job, which allowed simple identification of the change in the dominant carrier of activities and measurement of the duration of each of them (Fig. 2). During the lesson, periods of dominant activity of the teacher, students and periods of silence alternated. At the end of the measurement, the Java application determined the average values for all 18 classes held and provided data export, in the appropriate format, for further analysis. Namely, all the obtained data were exported in the form of a document as a .csv file, which is suitable for processing in Excel tables. Based on the obtained .csv files, tables and graphs with the measurement results were created.

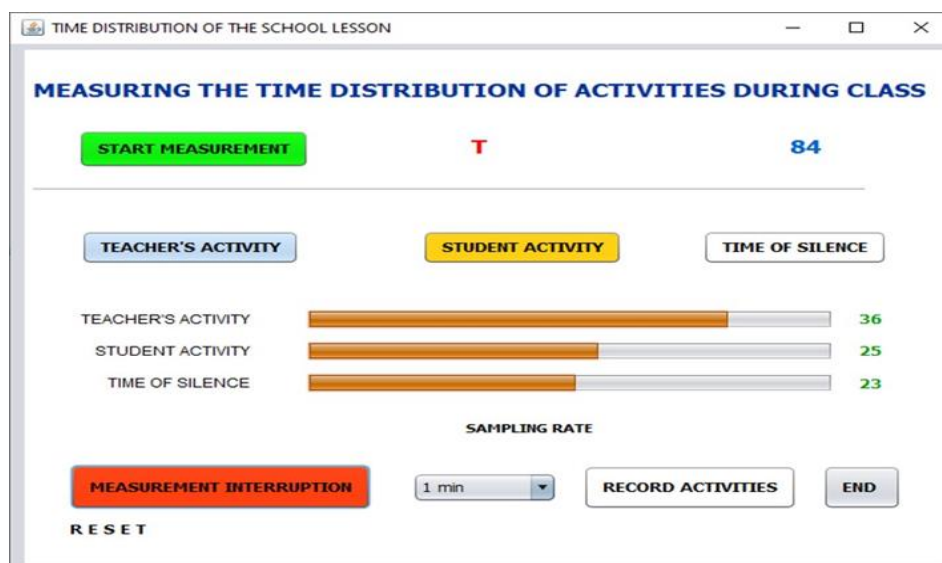


Figure 2. The user interface of the application for measuring the time distribution of activities in class

In classes that are realized using the digital dialogue method, the teacher who leads the class, according to the regular curriculum, asks a short question every 3 to 6 minutes, related to the teaching material just presented. At that moment, through another specially created web application - Digital Dialogue, the question is forwarded to all students. The Digital Dialogue application was created with the aim of fostering intensive

interaction between students and teachers, and increasing students' retention of the presented material, referring to the research findings of Hermann Ebbinghaus (Ebbinghaus, 1913) (Nang, 2018), as shown in Fig. 3.

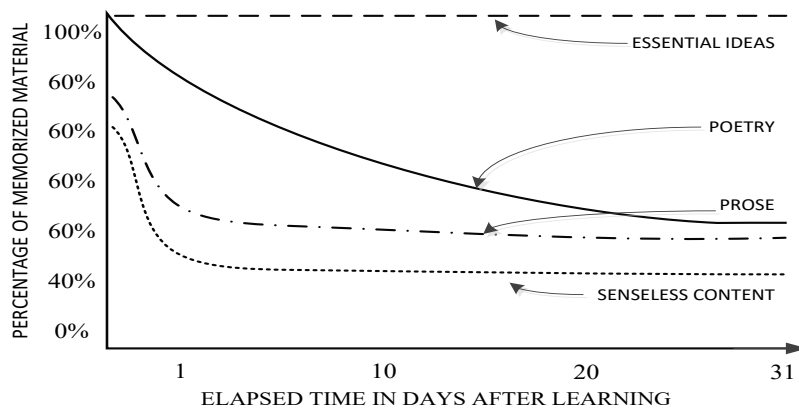


Figure 3. Ebbinghaus' forgetting curve (Ebbinghaus, 1913) (Nang, 2018)

At the beginning of the class, all students start the dedicated application for digital dialogue and log in to their account (Figure 4). They answer the teacher's question through their mobile devices. The teacher himself decides when to interrupt the time for the student's answer, depending on the difficulty of the question and the number of answers received. After that, the teacher's presentation continues to the next question (Randelović, Jevtić, Stanojević, & Veljović, 2024).

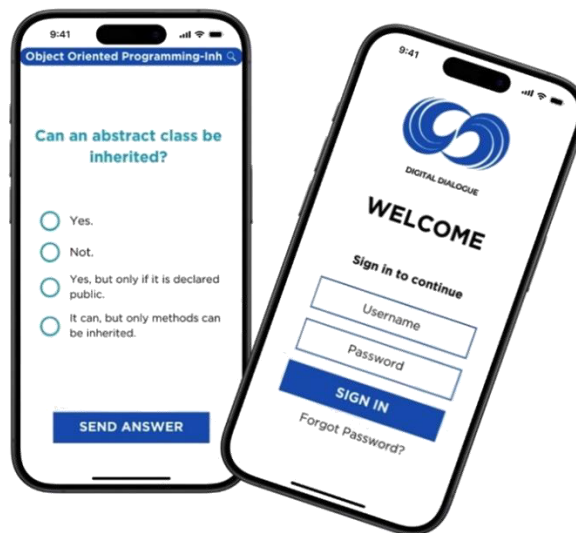


Figure 4. The user interface of the Digital Dialogue application

During the observation of the lesson, the activities of the teacher and students are recorded, and then for the purposes of statistics, they are sampled at intervals of 1 to 5 minutes. Each activity is classified into specific categories (egg, teacher's verbal activity - coded "P", student's verbal activity - coded "U", silence - coded "T"). The activity marked as P includes parts of the lesson in which the teacher presents the material, asks questions, gives assignments and concludes. At the moment when one of the students presents a remark or a question or when he answers the teacher's question, the previous activity is interrupted and a new activity is started, which is marked as U - the time in which the students speak. In the lessons that were implemented using the digital dialogue method, each of the students answers the questions raised through the Digital Dialogue application, in real time (Figure 4). The collected data is recorded in a database, where each category and each interval are clearly marked.

During the lesson, a count was made - how many times each activity (or activity category) appeared during the lesson. For example, how many times the teacher asked a question or how many times there was silence.

The sum of the frequencies of each category gives the total number of activities in each category for the entire class.

In the experiment, a modified Flanders analysis of verbal interaction was used to collect information (FIAC) (Flanders, 1960). Then, a frequency analysis was performed on the obtained results (Nystrand, Gamoran, Kachur, & Prenderg, 1997). This method was chosen because it is often used to quantify and analyze data obtained during the observation of various activities in the classroom. At the same time, it provides an insight into how often certain types of activities occur during the lesson, enabling the identification of patterns in the behavior of teachers and students.

At the end of the lesson, the frequency of activity was calculated for each method. At the same time, the percentage of time spent in each activity during both types of lessons was calculated. This includes time spent by the teacher or students in verbal or digital communication, silence, or working on assignments.

The focus was on the analysis of the 45-minute lesson, which compares the method of applying digital dialogue with the traditional method. The frequency and nature of the activities that take place during a lesson realized using traditional methods are compared with lessons in which digital dialogue is used. The aim of the described experiment is to get answers to the question, to what extent the use of digital dialogue can more effectively control and balance the time schedule of teacher, student dominance and silence time.

The expectation is that the results of the research test the hypothesis, which claims that in the teaching, which is realized by applying digital dialogue in the classroom, the distribution of time between the speech of the teacher and the students will be more balanced, compared to traditional teaching. By balancing the activities, the dominance of one of the actors can be reduced. It is also expected to confirm the assumption that digital dialogue enables faster and more detailed delivery of feedback among the participants of the teaching process, which can increase student participation in the dialogue and reduce the time spent in silence.

3 MEASUREMENT RESULTS

In the frequency comparison procedure, the results for both approaches were compared in order to identify differences in the frequency and nature of activities, and then patterns were identified, which should indicate the potential advantages and disadvantages of both approaches.

By sequencing a 45-minute lesson into 9 standard phases, average values for dominant activities were calculated. In Table 1, traditional teaching is coded as "TT", while teaching with the use of digital dialogue is coded as "DD". Time periods of dominant activities are presented in percentages.

Table 1. Total distribution of time by phases of teaching

Phase	Activity	Silence		Teacher		Students	
		<i>TT</i>	<i>DD</i>	<i>TT</i>	<i>DD</i>	<i>TT</i>	<i>DD</i>
1. phase	Introductory lecture by the teacher	40%	60%	40%	40%	20%	0%
2. phase	Questions to students and answers	0%	20%	60%	60%	40%	20%
3. phase	Continuation of the presentation of the material	0%	20%	60%	60%	40%	20%
4. phase	Students' questions and reflections	0%	20%	80%	40%	20%	40%
5. phase	Discussion and analysis of responses	0%	20%	80%	40%	20%	40%
6. phase	The final part of the presentation of the material	0%	0%	100%	40%	0%	60%
7. phase	Questions for students	0%	20%	100%	40%	0%	40%
8. phase	Discussion and feedback	0%	20%	40%	60%	60%	20%
9. phase	Conclusion and silence for reflection	0%	0%	40%	40%	60%	60%

Based on the collected data, the average distribution of the frequency of speaking activities of teachers and students, as well as the average frequency of silence during the 45-minute class, were calculated. The attached graphs (Figure 5) show how activities change over time, during both types of lessons, showing the dynamics of interactions.

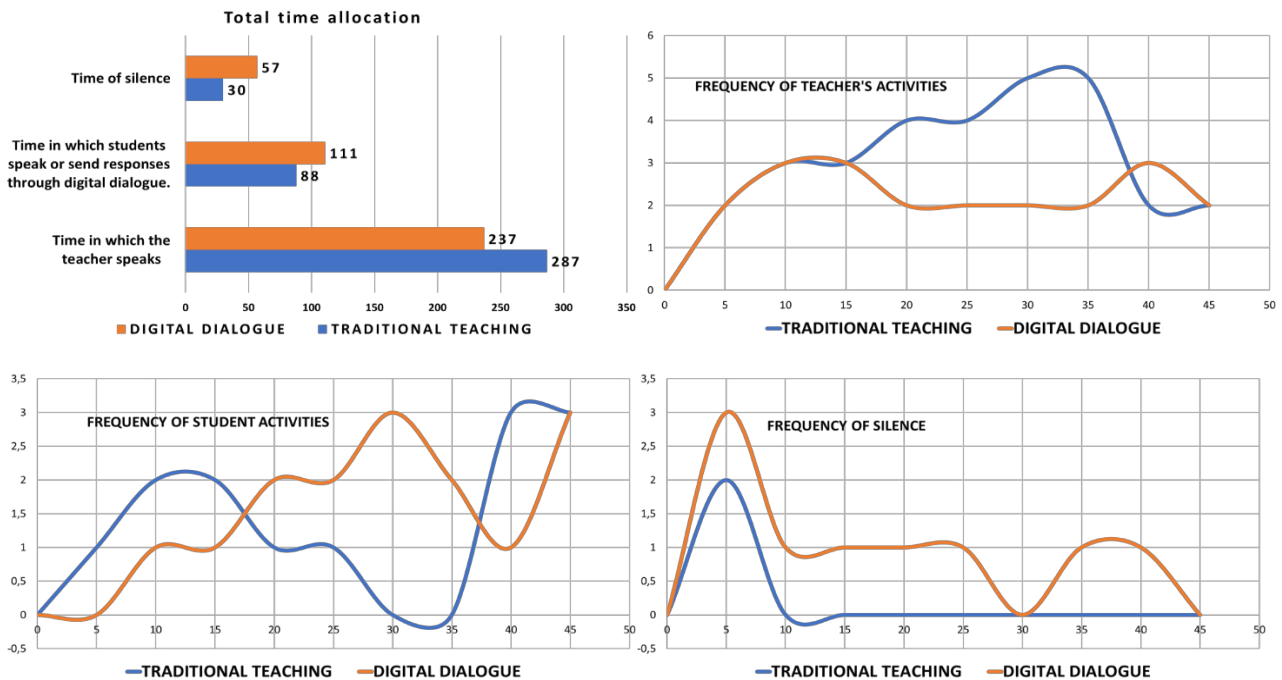


Figure 5. The results of measuring the frequency of teacher activity dominance, student activity and quiet time

4 DISCUSSION

Based on the data from the graph, it is possible to analyze the distribution of time among the participants of the educational process in traditional and digital teaching.

4.1 Traditional teaching

Traditional The time in which the teacher speaks (287 minutes during 9 hours) is the dominant part. This suggests a teacher-centered approach, where the teacher actively imparts knowledge. This model can be useful for providing detailed explanations, but it reduces the opportunity for active student participation.

The time students speak (88 minutes) is relatively short. This may indicate a lower degree of interaction and opportunities for active student participation. Insufficient time for discussion can limit their motivation and engagement.

The time of silence (30 minutes) is minimal, which may mean that the attention is constantly focused on the teacher, but also that the students do not have enough time for reflection or formulating answers.

From the aspect of the frequency of dominance of the participants, the specifics of the used teaching method can be clearly observed. Periods of silence are present only in the first 5 minutes, which may be a period of adjustment or organization before the teacher takes an active role. After that, the periods of silence disappear and the teacher becomes dominant. This pattern suggests that the teacher leads the whole process, with minimal breaks, directed towards frontal transfer of knowledge.

The teacher's activity (P) gradually increases from the beginning of the lesson, reaching its peak in the middle (30-35 minutes), when the students almost completely stop being active. This dominance of the teacher in the middle part of the lesson may mean that this is a period of intensive presentation of the material, which often happens in the traditional model of education, when students are expected to withdraw into a more passive role.

Student activity (U) is noticeably low during the first 35 minutes. Their activity begins only at the end of the lesson, which indicates that they are involved in discussions or questions only at the end, possibly as part of the conclusion or final review of the material. This pattern may mean that students are not sufficiently engaged in the learning process for most of the lesson, which may limit their retention of information, according to active learning theories.

4.2 Teaching using digital dialogue

The time in which the teacher speaks (237 minutes during 9 hours) is significantly reduced compared to the traditional method. The teacher still has an important role, but more time is left for other activities.

The time in which students speak or send answers (111 minutes) has increased, indicating a greater degree of interaction and participation. Digital dialogue clearly allows more students to engage in communication, even those who may be shy in verbal expression.

The silence time (57 minutes) is twice as long as in a traditional lesson, which may be a consequence of the time needed to think or write answers through a digital tool.

Graphs showing classes with digital dialogue depict a significantly more balanced distribution of activity between silence, professors, and students. Periods of silence appear throughout the lesson at shorter intervals, suggesting the presence of pauses in communication, which may allow students to think or process the material before engaging in discussion. Those quiet periods can be times when students are using technology (e.g. answering questions using digital tools), which contributes to better reflection and engagement.

The activity of the teacher (P) is much more evenly distributed compared to the traditional class. The teacher still plays an important role, but it does not dominate most of the time. His role is more of a facilitator, providing space for students to interact and contributing to a more balanced class dynamic. This pattern of activity can contribute to greater interaction and collaboration, which is key to more modern approaches to education.

Student activity (U) in a digital dialogue class is more even, with constant engagement throughout the class, not just at the end as in a traditional class. This indicates that digital dialogue encourages students to participate continuously, which is consistent with the theories of active learning and participatory education.

5 CONCLUSION

This research clearly indicates the significant advantages of using digital dialogue in the classroom, primarily in terms of a balanced distribution of activities, which is crucial for a deeper acquisition of knowledge. On the other hand, based on the obtained results, several directions for future research can be observed that could further improve our understanding of the impact of such methods, such as:

- Qualitative analysis of student responses - further research could be focused on analyzing the quality of student responses and contributions in both teaching models.
- Impact on long-term retention of information - through the use of Hermann Ebbinghaus's forgetting curve, it is possible to test how often material should be repeated using digital tools in order to achieve the best results.
- Personalization of dialogue - one could explore how personalized digital dialogue can enhance learning.
- Emotional involvement of students - how students feel during a traditional class where the teacher dominates compared to a class with digital dialogue where they are constantly active. Measuring students' emotional state during class could provide insights into their motivation, engagement and stress.
- Integration of additional evaluation tools - integration of other technologies, such as artificial intelligence systems, could further support the dynamics of digital dialogue. These systems could analyze student responses in real time, providing the teacher with feedback on each student's progress, leading to adjustments in pace and content.

Finally, based on this analysis, it can be concluded that classes with digital dialogue enable greater student participation, better balanced class dynamics and provide the teacher with the role of facilitator. Although this analysis provides useful insights into the dynamics of the teaching process, there are certain shortcomings and limitations that could affect the accuracy and comprehensiveness of the results. The analysis has, above all, a quantitative nature. The analysis relies exclusively on numerical data (frequency of silence periods, teacher and student activities), but does not take into account the quality of the interaction. Future research can further improve these approaches through personalization of content, long-term analysis of student performance, and

the implementation of artificial intelligence, which can significantly improve the quality of education in the 21st century.

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Metaheuristics Methods for Solving Capacity Vehicle Routing Problem: An Overview

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Abstract. The Vehicle Routing Problem (VRP) plays a vital role in logistics, supply chain management, and transportation planning. By providing effective solutions, VRP can significantly reduce costs, lower fuel consumption, and improve customer satisfaction. This makes VRP a critical focus for companies engaged in delivery services, public transit, and distribution networks. Given the NP-hard complexity of the problem, using exact algorithms for large instances is often impractical. As a result, this paper explains a variety of approaches, such as Genetic Algorithms, Tabu Search, Ant System, and Hybrid Metaheuristics. This overview serves as a resource for researchers and practitioners interested in applying metaheuristics to CVRP.

Keywords and phrases: Vehicle routing problem, Optimization, NP-hard complexity, heuristic and metaheuristic algorithm,

1 INTRODUCTION

Optimization is a crucial field of study in both theoretical and applied mathematics, computer science, and engineering, focused on identifying the best possible solutions to problems within a defined set of constraints. The essence of optimization lies in determining the optimal outcome for a given objective function, which could involve maximizing benefits, minimizing costs, or achieving other specific goals. This concept is fundamental across numerous disciplines, including logistics, finance, operations research, and engineering, underscoring its broad importance and wide-ranging applications.

Optimization problems are typically classified based on their structure and characteristics. The primary aim is to either maximize or minimize a function that represents the problem's objective, while adhering to constraints that limit the feasible solutions. These constraints might include resource limitations, physical laws, or other relevant restrictions.

Types of Optimization Problems:

Linear Optimization (Linear Programming): These problems feature linear objective functions and constraints. They are commonly solved using well-established techniques such as the Simplex method or Interior-Point methods (Dantzig, 1963; Wright, 1997).

Nonlinear Optimization: These problems involve nonlinear objective functions or constraints, requiring more advanced methods such as gradient-based techniques, Lagrangian multipliers, or heuristic approaches (Nocedal & Wright, 2006).

Integer Optimization (Integer Programming): In these problems, decision variables must assume integer values. This category includes scheduling and allocation problems, which are often tackled using branch-and-bound techniques or cutting-plane methods (Gomory, 1963; Nemhauser & Wolsey, 1988).

Combinatorial Optimization: This category focuses on finding the optimal solution from a finite set of discrete possibilities. Examples include the Traveling Salesman Problem (TSP) and knapsack problems, which frequently require specialized algorithms or heuristic methods (Korte & Vygen, 2008; Papadimitriou & Steiglitz, 1998).

Optimization problems often exhibit NP-complete or NP-hard complexity, where the number of possible solutions can be immense. The size of the search space represents all possible combinations of states of a solution. NP stands for "non-deterministic polynomial," meaning there is no deterministic algorithm that can find the best solution in polynomial time, but if a solution exists, it can be verified in polynomial time. A good example of this is Sudoku. NP-complete problems lie at the boundary between NP and NP-hard problems. What makes NP-complete problems significant is the "Cook-Levin" theorem, which states that any problem in NP can be transformed into a 3-SAT problem (which is NP-complete) using a deterministic approach in polynomial time. This implies that if a polynomial-time deterministic solution is found for one NP-complete problem, it could be used to solve all problems in this class. This leads to the famous question of whether "P = NP," one of the Millennium Prize Problems. On the other hand, NP-hard problems are those for which there is no known polynomial-time algorithm to find the best solution, nor is there a polynomial-time algorithm to verify whether a given solution is optimal. A classic example is chess: it is not possible to find the best move in reasonable time, and even if a move is proposed, proving it is the best one can take a considerable amount of time.

This paper analyzes the Vehicle Routing Problem (VRP) and several strategies for solving it. Since this problem is classified as NP-hard, obtaining exact solutions for large instances is nearly unfeasible. Therefore, heuristic and metaheuristic techniques are often employed. The paper will focus on the most common and fundamental variant of the problem, the Capacitated Vehicle Routing Problem (CVRP).

This paper presents a review of metaheuristic methods used to address the Capacitated Vehicle Routing Problem (CVRP). It organizes and describes several key approaches, including Genetic Algorithms, Tabu Search, Ant Colony Optimization, and Hybrid Metaheuristics. By offering this structured overview, the paper provides a valuable foundation for researchers and practitioners looking to implement metaheuristic techniques for CVRP.

2 THE VEHICLE ROUTING PROBLEM (VRP)

The Vehicle Routing Problem (VRP) is a combinatorial optimization and integer programming problem that aims to determine the most efficient set of routes for a fleet of vehicles to deliver goods to a specified group of customers. It is essentially an extension of the Traveling Salesman Problem (TSP). The concept was first introduced by George Dantzig and John Ramser in 1959 (Dantzig & Ramser, 1959), who also developed the first algorithmic approach to solving VRP, applying it in the context of gasoline deliveries.

The Capacitated Vehicle Routing Problem (CVRP) is a variation of the Vehicle Routing Problem (VRP) in which a fleet of vehicles, each with a fixed capacity, must serve a set of customers. The objective is to minimize the overall travel distance or cost while ensuring that no vehicle exceeds its capacity and that the demands of all customers are met.

For solving of this problem exist more group of methods:

- **Exact Methods:**
 1. Branch and Bound: Explores all potential solutions systematically.
 2. Branch and Cut: Combines branch-and-bound with cutting planes to reduce the search space.
 3. Dynamic Programming: Breaks down the problem into smaller subproblems, solving them recursively.
- **Heuristic Methods:**
 1. Clarke-Wright Savings Algorithm: A greedy method based on calculating cost savings for merging routes.
 2. Nearest Neighbor: A straightforward greedy approach that always visits the closest unvisited customer.
- **Metaheuristics:**
 1. Genetic Algorithms: Employs crossover and mutation techniques to search through potential solutions.
 2. Tabu Search: Avoids local optima by using a tabu list to keep track of previously visited solutions.
 3. Ant System: Simulates the way ants find optimal paths, applying this logic to routing solutions.

Definition of the problem (VRP): We begin with an overview of the key concepts related to the Vehicle Routing Problem (VRP). A client is an entity with a specific demand that requires service from a vehicle,

which can travel between clients and the depot—the location where the clients' demands are initially stored. The fleet refers to the total number of vehicles available. The movement of a vehicle between the depot and the clients incurs a certain cost. A route is a sequence of clients visited by a specific vehicle, starting and ending at the depot. The objective of the VRP is to serve all clients while minimizing the total cost of the routes for all vehicles. A visual example is provided in Figure 1 (note that, for simplicity, the graph in this figure is not complete).

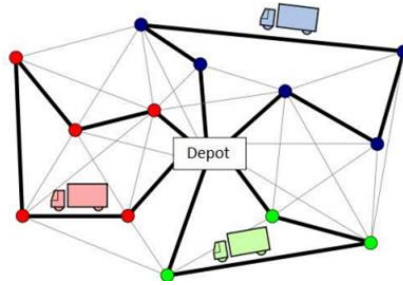


Figure 1. Vizuelization of VRP

The primary structure of the Vehicle Routing Problem (VRP) is a complete graph $G(V, E)$ where the V is a set of vertices and E set of edges. (Ibrahim, Abdulaziz, Ishaya, & Sowole, 2019)

An example of a vehicle routing problem involving multiple vehicles is the Multiple Traveling Salesmen Problem (MTSP), a variant of the Traveling Salesman Problem (TSP) where multiple salesmen are traveling around. We extend the previous detailed list with the following definitions to work towards the definition of VRP:

- m - where $m \geq 1$, is defined as the number of vehicles or the size of the fleet.
- $R_i = (v_0^i, v_1^i, \dots, v_{k_i}^i, v_{k_i+1}^i)$ is a vector that represents the route of vehicle i (with $v_0^i = v_{k_i+1}^i = v_0, v_j^i \neq v_l^i, 0 \leq j < l \leq k_i$) which begins and finishes at the depot. The length of the route R_i is a k_i ,
- $S = \{R_1, R_2, \dots, R_m\}$ it is the set of routes that represents the VRP solution instance.
- $C(R_i) = \sum_{j=0}^{k_i} C(v_j^i \neq v_{j+1}^i)$ -it is the route cost R_i .
- $C(S) = \sum_{i=1}^m C(R_i)$ - is a total cost of solution S that meets the following conditions: $R_i \cap R_j = \{v_0\}, \forall R_i, R_j (1 \leq i, j \leq m, i \neq j), \cup_{i=1}^m R_i = V$, to ensure that each customer is served exactly once, the route vectors are treated as a set. The objective of the Vehicle Routing Problem (VRP) is to minimize the cost $C(S)$ on the graph $G(V, E)$.

The problem isn't solely about visiting the customers; it also involves addressing their specific demands. In the definitions below, we will outline these additional requirements.

- Demand: $d = (d_0, d_1, \dots, d_{n+1})$ with $d_i > 0$ for each customer and n representing the total number of customers, the demand of the depot is indicated by d_0 , which is always set to $d_0 = d_{n+1} = 0$.
- Service time: denoted as δ , is a function that represents the time required to unload all goods at customer v_i for $\{i = 1, 2, \dots, n\}$. Typically, δ is influenced by the size of the customer's demand. Therefore, we will use the notation $\delta_i = \delta(v_i)$ consistently moving forward.
- The cost of the route R_i is now defined by

$$C(R_i) = \sum_{j=0}^{k_i} C(v_j^i, v_{j+1}^i) + \sum_{i=1}^{k_i} \delta(v_j^i). \quad (1)$$

3 METAHEURISTIC METHODS

In this section, we outline the key metaheuristics that have been effectively utilized to address the vehicle routing problem and provide a brief overview of the metaheuristics employed. Some other reviews are given in (Rezk, Olabi, Wilberforce, & Sayed, 2024) (Montoya-Torres, Franco, Isaza, & Jiménez, 2015)

3.1 Genetic Algorithms

Genetic Algorithms are arguably the most recognized type of metaheuristic algorithms, currently garnering significant attention worldwide. These algorithms are computer-based procedures that apply the principles of natural selection and genetics to develop solutions for a wide range of problems. The foundational concepts

were introduced by Holland (1975, 1992), while the effectiveness of Genetic Algorithms in addressing complex issues was demonstrated by De Jong (1975) and Goldberg (1989).

Genetic Algorithms (GAs) work by evolving a population of individuals, represented as chromosomes, through the creation of new generations of offspring in an iterative process until specific convergence criteria are met. These criteria may include a maximum number of generations, convergence of the population toward a set of similar individuals, or the attainment of an optimal solution. Ultimately, the best chromosome produced is decoded to yield the corresponding solution. GAs operates with a population of potential solutions rather than focusing on a single solution, allowing for the simultaneous exploration of multiple paths toward finding an optimal result. Each individual in the population represents a candidate solution to the problem at hand. In Holland's original framework for GAs, these solutions were typically encoded as strings of bits, with the specific interpretation of the bit strings varying depending on the problem being addressed.

The process of creating a new generation of individuals involves three key steps:

Selection Phase: This step entails randomly selecting two parent individuals from the population for the purpose of mating. The likelihood of choosing a particular member is typically proportional to its fitness, which helps prioritize higher-quality genetic traits while still promoting genetic diversity. In this context, fitness is a measure of value, utility, or desirability that should be maximized during the exploration of the solution space.

Recombination Process: In this phase, the genetic information from the selected parents is combined to produce offspring that will constitute the next generation.

Mutation: This step involves randomly altering some genes in an individual to further investigate the solution space and maintain genetic diversity. Mutations generally occur at a low probability, helping to introduce new variations into the population.

To solve the Vehicle Routing Problem (VRP) using Genetic Algorithms (GAs), each solution is typically represented by a single chromosome, which is a sequence of integers. Each integer either corresponds to a customer or a vehicle. The vehicle identifiers act as separators within the chromosome, marking the boundaries between different routes, while the sequence of customer identifiers defines the order of deliveries that a vehicle needs to complete along its route.

In the Figure 2, a possible solution for VRP with 10 customers and 4 vehicles is shown.

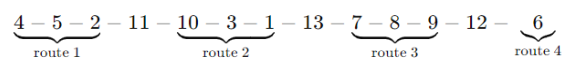


Figure 2. Sequence of routes

The expression in Figure 1, describes a sequence of routes, where each route is encapsulated within braces and labeled: Route 1:4 → 5 → 2; Route 2:10 → 3 → 1; Route 3:7 → 8 → 9; Route 4:6

The overall path connects these routes through nodes 11, 13, and 12. The flow can be interpreted as starting from route 1, moving through node 11, then following route 2, passing through node 13, continuing through route 3, passing node 12, and finally ending at route 4.

A common fitness function employed for solving the Vehicle Routing Problem (VRP) with Genetic Algorithms (GA) is expressed as:

$$f_{eval}(x) = f_{max} - f(x), \text{ where:}$$

$$f(x) = \text{totaldistance}(x) + \lambda \cdot \text{overcapacity}(x) + \mu \cdot \text{overtime}(x),$$

The overcapacity and overtime functions measure how much the capacity and time exceed the allowed limits. If none of the constraints are violated, the function f returns the total distance traveled. Otherwise, both the excess capacity and time are penalized by the weights λ and μ . The best solutions will have values close to f_{max} , while solutions that violate any restrictions will have their fitness values reduced by the penalties.

3.2 Tabu Search

The core idea behind Tabu Search (TS), as outlined by (Glover, 1986), is that it serves as a meta-heuristic layered on top of another heuristic. TS explores the solution space by iteratively moving from a solution s to the best solution within a subset of its neighborhood $N(s)$. Unlike traditional descent methods, the current

solution might worsen from one iteration to the next. To prevent cycles, solutions that share attributes with recently explored ones are temporarily marked as tabu, or forbidden. The period during which an attribute remains tabu is called its tabu tenure, and this can vary over different time intervals. The tabu status can be overridden under certain conditions—this is known as the aspiration criterion, which applies, for example, when a tabu solution is better than any previously discovered solution.

Deviating from a set path might initially appear to be a mistake, yet it can frequently result in positive outcomes. The Tabu method operates on this principle, but unlike random search techniques, it doesn't select new paths at random. Instead, the Tabu search posits that a new solution is only valuable if it prevents revisiting an already explored path. This approach promotes the exploration of new areas within the solution space, helping to avoid local minima and guiding the search toward the optimal solution.

An initial solution is typically generated using a heuristic, such as the cheapest insertion method. Once this starting point is established, local search is applied with one or more neighborhood structures, using a best-accept strategy to improve the solution. Many of the neighborhood structures used in Tabu Search are well-established and have been introduced in the context of various construction and improvement heuristics.

3.3 Ant System

The initial ant system for the Vehicle Routing Problem (VRP) was introduced by (Bullnheimer, Hartl, & and Strauß, 1997), focusing on the most basic version of the problem: the Capacitated Vehicle Routing Problem (CVRP).

For more intricate variations of VRP, (Gambardella, Taillard, & Agazzi, 1999) created a multiple ant colony system for the Time Windows version of the problem (MACS-VRPTW). This system features a hierarchy of artificial ant colonies that work in succession to optimize multiple objectives: the first colony aims to minimize the number of vehicles, while the second seeks to reduce the total distance traveled. The colonies collaborate by sharing information through updates of pheromone levels.

In the framework proposed by (Bullnheimer, Hartl, & and Strauß, 1997), the ant system consists of two fundamental phases: the construction of vehicle routes and the updating of trails. The details of the Ant Colony Optimisation (ACO) algorithm are discussed in this context.

Ant System Algorithm: After initializing the Ant System (AS), the two main steps—constructing vehicle routes and updating trails—are iteratively repeated for a specified number of cycles. Regarding the initial placement of the artificial ants, it has been determined that each customer should have an equal number of ants assigned at the start of each iteration. To enhance the quality of the generated solutions, the 2-opt heuristic is employed, which exhaustively examines all possible permutations achievable by swapping two cities, effectively shortening the vehicle routes.

In addition to this straightforward local search approach, candidate lists are introduced to aid in customer selection, determined during the algorithm's initialization phase. For each location d_{ij} , the set $V - \{v_i\}$ is sorted based on increasing distances d_{ij} to create the candidate list.

To tackle the Vehicle Routing Problem (VRP), artificial ants create solutions by sequentially selecting cities to visit until all cities have been included. If selecting an additional city would result in an infeasible solution due to vehicle capacity or the total length of the route, the ants return to the depot and initiate a new tour. In choosing a city that has not yet been visited, two factors are considered: the quality of the previous selection, which is reflected in the pheromone levels τ_{ij} associated with each arc (v_i, v_j) , and the attractiveness of the current city choice. This attractiveness, known as visibility and represented by η_{ij} , serves as the local heuristic function guiding the selection process.

Given that $\Omega = \{v_j \in V: v_j \text{ can be visited}\} \cup \{v_0\}$, the selection of city v_j for visitation occurs in the following manner:

$$p_{ij} = \begin{cases} \frac{[\tau_{ij}]^\alpha [\eta_{ij}]^\beta}{\sum_{k \in \Omega} [\tau_{ik}]^\alpha [\eta_{ik}]^\beta} & , \text{if } v_j \in \Omega \\ 0 & , \text{otherwise} \end{cases} .$$

The probability distribution is influenced by the parameters α and β , which determine the relative impact of the pheromone trails and visibility, respectively. Visibility is defined as the inverse of the distance between

cities, and this selection probability can be enhanced by incorporating problem-specific information. For instance, integrating savings and capacity utilization can yield improved outcomes.

Many recent studies combine metaheuristics to obtain more optimal results (Vidal, Crainic, Gendreau, & Prins, 2014). These hybrid approaches in metaheuristics effectively combine multiple optimization techniques to enhance solution quality and computational efficiency for the Capacity Vehicle Routing Problem. In (Lee & Lee, 2006), Genetic Algorithms (GAs) generate a diverse population of potential solutions, which are subsequently refined using local search techniques. Ant Colony Optimization (ACO) may construct solutions based on pheromone trails, followed by local search methods to optimize the routes (Vries & Arentze, 2007). Tabu Search (TS) can be integrated within a GA framework, using TS to refine the best individuals from the GA population (Taillard, 1999).

4 CONCLUSION

Genetic Algorithms (GAs), Tabu Search (TS), and Ant Systems (AS) are effective metaheuristic techniques for addressing complex optimization challenges, such as the Vehicle Routing Problem (VRP). GAs draw on concepts from natural selection and genetics, refining a population of solutions through processes of selection, crossover, and mutation to thoroughly navigate the solution space. Tabu Search enhances local search methods by employing a memory system that avoids cycles, encouraging the exploration of new regions and enabling it to escape local optima, thereby improving solution quality over successive iterations. Ant Systems simulate the behavior of ants in their search for food, using pheromone trails and visibility to probabilistically create solutions while integrating heuristics to boost effectiveness. Each of these approaches offers distinct advantages and can be tailored to various problem scenarios, making them indispensable tools in the realm of optimization. Accordingly, metaheuristic methods have proven to be powerful tools for solving the Capacitated Vehicle Routing Problem, providing a balance between solution quality and computational efficiency. Continued innovation in hybrid strategies and adaptive techniques promises to enhance their applicability in real-world scenarios, pushing the boundaries of optimization in logistics and transportation.

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Personalized Learning Environments Tailoring Education Through Technology

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Abstract. This research explores the integration of technology in personalized education, emphasizing the roles of education organizations, tools and techniques for personalized learning, and personalized learning environments. Education organizations must focus on curriculum design, teacher training, supportive policies, and comprehensive assessment methods. Adaptive learning technologies, interactive tools, learning management systems, and digital resources enable customization based on individual student data, enhancing engagement and outcomes. Flexible learning spaces and virtual environments support diverse learning styles, while student-centered plans and support systems address unique needs. Governments, enterprises, and individuals all contribute to advancing personalized education through investment, development, and active engagement. Collaborative efforts and continuous improvement strategies are essential for effective implementation. This comprehensive approach promises to improve learning outcomes, engagement, and preparedness for future challenges.

Keywords and phrases: personalized learning environments, education improvement, technology application.

1 INTRODUCTION

Personalized learning represents a significant shift in educational practices, emphasizing tailored educational experiences to meet the unique needs and preferences of each student. This approach moves away from the traditional one-size-fits-all model, instead recognizing the diversity in students' learning styles, paces, and interests. The evolution of personalized learning has been largely driven by the advancement of technology, which offers innovative tools and platforms that can adapt to individual student profiles. The integration of digital resources, interactive content, and flexible learning pathways helps create a more engaging and effective educational environment. This dynamic approach not only accommodates varying learning speeds but also supports the diverse intellectual and emotional needs of students (Zhang et al., 2020). Machine learning and artificial intelligence (AI) are at the forefront of this transformation, playing important roles in the realization of personalized learning environments. These technologies have the capability to analyze vast amounts of educational data to identify patterns and predict learning outcomes, thus enabling a more customized learning experience. Machine learning algorithms can dynamically adapt educational content in real time, providing students with exercises and materials that are most suitable for their current level of understanding and highlighting areas that need improvement. AI-driven systems also offer personalized feedback and recommendations, enhancing the learning experience by addressing specific needs and supporting continuous improvement. Through these systems, students receive more than just generalized instruction; they benefit from a tailored educational approach that can significantly boost their academic performance and motivation (Maghsudi et al., 2021; Munir et al., 2022).

The use of analytics in education further supports personalized learning by providing educators with detailed insights into student performance and engagement. Data collected from various educational activities can be meticulously analyzed to track progress, identify strengths and weaknesses, and tailor instruction accordingly. Analytics enable the development of data-driven strategies that optimize teaching methods and resources, ensuring that interventions are both timely and effective. This approach not only improves learning outcomes but also helps in creating a more responsive and adaptive educational system. Educators can use analytics to design targeted interventions, predict potential academic issues, and implement personalized learning plans that cater to the unique needs of each student (Larrabee S nderlund et al., 2019). Online platforms can harness these technologies to offer a range of personalized learning experiences, from customized lesson plans to interactive simulations that respond to individual student inputs. This flexibility is particularly beneficial in reaching students who might face barriers in conventional educational settings, such as those in remote areas or with special educational needs (Baxter & Hainey, 2024). Furthermore, the ongoing development and refinement of these technologies continue to open new possibilities for personalized learning. As machine learning and AI algorithms become more sophisticated, their ability to provide nuanced and highly specific educational recommendations will improve, leading to even more effective personalized learning environments. The continuous collection and analysis of educational data will improve the understanding of how different students learn, enabling the creation of more refined and effective teaching strategies (Dandachi, 2024; Gligorea et al., 2023).

The synergy of personalized learning, machine learning, AI, and analytics is reshaping the educational landscape. This innovative approach not only addresses the varied learning needs of students but also empowers educators with tools and insights to deliver more effective and meaningful instruction. The result is an educational system that is more adaptive, responsive, and capable of supporting individual student success (Almusaed et al., 2023; Chen et al., 2020).

The current literature largely focuses on technology integration in education but lacks a comprehensive framework that connects education organizations, personalized learning tools, and supportive learning environments in a cohesive model. This research aims to fill this gap by proposing a theoretical model that outlines the roles of these components in delivering personalized learning experiences. By analyzing the interplay between education organizations, technological tools, and learning environments, the study provides a foundation for future research and practical implementation in diverse educational contexts.

2 MACHINE LEARNING AND AI PERSONALIZED EDUCATION CONTENT

Machine learning and artificial intelligence (AI) are revolutionizing the field of personalized education, offering unprecedented capabilities in tailoring content to individual student needs. These technologies analyze vast amounts of data to understand learning patterns, preferences, and performance levels. This analysis allows for the creation of highly customized educational experiences that can adapt in real-time to a student's progress and changing needs (Munir et al., 2022). Conversely, if a student excels in a particular area, the system can present more challenging tasks to keep them engaged and motivated (El-Sabagh, 2021).

AI improves this process by offering personalized feedback that goes beyond simple right or wrong answers. Intelligent tutoring systems, powered by AI, can provide detailed explanations, suggest relevant study materials, and offer tips for improvement. This type of immediate and tailored feedback is important in helping students understand their mistakes and learn from them, supporting a deeper understanding of the subject matter. Furthermore, AI can simulate one-on-one tutoring experiences, making personalized learning more scalable and accessible to a broader range of students (Raj & Renumol, 2024).

One of the most significant benefits of machine learning and AI in education is their ability to create adaptive learning paths. Traditional education often follows a fixed curriculum, which can be limiting for students who learn at different paces. Adaptive learning systems, however, adjust the sequence and difficulty of content based on real-time analysis of a student's performance. This means that each student can follow a unique learning path that is optimized for their individual needs, allowing them to progress more efficiently and effectively (Tatineni, 2020). The ability to personalize content in this manner helps to keep students engaged and makes learning more relevant and enjoyable (Lee, 2023; Rosalina & Sen, 2022).

In addition to content personalization, machine learning and AI can also play a role in predicting and preventing academic challenges. Predictive analytics can identify students who may be at risk of falling behind based on their interaction patterns and performance data. Early identification allows educators to

intervene with targeted support before these students encounter significant difficulties. This proactive approach can be important in ensuring that all students have the opportunity to succeed, regardless of their starting point (Raj & Renumol, 2024). Automated grading not only saves time for educators but also ensures consistent and unbiased evaluation of student performance. This, in turn, allows teachers to focus more on providing personalized support and guidance to their students (Veluvali & Suriseti, 2022). Furthermore, as machine learning and AI technologies continue to evolve, their potential in personalized education content is likely to expand. Future advancements could lead to even more sophisticated systems that can understand and adapt to the emotional and motivational states of students, providing support that is not only academically effective but also emotionally intelligent. Such systems could offer encouragement during challenging tasks, suggest breaks when students appear fatigued, and celebrate achievements to boost morale and motivation (Whalley et al., 2021). The integration of machine learning and AI into education represents a transformative approach to personalized learning. The ongoing development of machine learning and AI promises to further enrich the educational landscape, offering new opportunities for personalized learning and academic success (Munir et al., 2022).

3 TOOLS TECHNIQUES AND ENVIRONMENTS FOR LEARNING

Paragraphs In the modern educational landscape, a wide array of tools, techniques, and environments are employed to improve the learning experience and accommodate diverse learning needs. These resources range from digital platforms and interactive technologies to innovative pedagogical strategies and varied learning environments. Each of these components plays an important role in creating a comprehensive and effective educational framework (Sahni, 2019). Digital tools have become integral to contemporary education, offering a range of functionalities that support both teaching and learning. Learning Management Systems (LMS) like Moodle, Canvas, and Blackboard enable educators to organize course materials, track student progress, and facilitate communication. These platforms often include features such as discussion forums, quizzes, and assignment submission portals, which streamline the educational process and provide a centralized hub for resources and interactions. Additionally, educational apps and software, such as Khan Academy, Duolingo, and Quizlet, offer interactive and engaging ways for students to practice skills and reinforce learning outside the traditional classroom setting (Lee, 2023).

Interactive technologies have further revolutionized learning by making it more engaging and immersive. Virtual and augmented reality (VR and AR) tools, for instance, create immersive learning experiences that can bring abstract concepts to life. In subjects like science, history, and geography, VR can provide virtual field trips or simulations that allow students to explore and interact with environments and scenarios that would otherwise be inaccessible. AR, on the other hand, can overlay digital information onto the physical world, enhancing textbooks and classroom materials with interactive 3D models and multimedia content. These technologies not only make learning more interesting but also help students understand complex concepts more deeply through experiential learning (Baxter & Hainey, 2024; Munir et al., 2022). Innovative pedagogical techniques are also important in modern education. Blended learning, which combines traditional face-to-face instruction with online learning, provides a flexible approach that can cater to different learning styles and paces. This technique allows students to benefit from the direct interaction with teachers and peers while also taking advantage of the self-paced, personalized nature of online resources. Flipped classrooms are another example, where students first engage with new content outside of class through videos or readings and then use class time for interactive activities, discussions, and problem-solving, supporting a more active and collaborative learning environment (Kassymova et al., 2020). Project-based learning (PBL) is another technique that has gained popularity for its ability to develop important thinking, problem-solving, and collaborative skills. In PBL, students work on real-world projects that require them to apply knowledge and skills from various disciplines. This hands-on approach not only improves understanding and retention of subject matter but also prepares students for the complexities of real-world challenges. Similarly, gamification, which involves incorporating game elements into learning activities, can increase motivation and engagement by making learning more fun and competitive (Larrabee S nderlund et al., 2019). Learning environments themselves are evolving to support these new tools and techniques. Traditional classroom setups are being reimagined to promote more interaction and collaboration. Flexible seating arrangements, access to technology, and spaces designed for group work and individual study are becoming more common. These physical changes are complemented by virtual learning environments (VLEs), which provide online spaces where students can collaborate, communicate, and access resources

anytime and anywhere. VLEs are particularly important for distance learning and hybrid education models, ensuring that all students have access to high-quality education regardless of their location (Sabah, 2023).

Collaborative platforms like Google Classroom, Microsoft Teams, and various educational forums and social media groups enable students to work together, share knowledge, and support each other's learning. These platforms facilitate peer-to-peer interaction and learning, which can be particularly beneficial for developing communication and teamwork skills. The sense of community and collaboration supported in these environments can improve motivation and engagement, making learning a more social and enjoyable experience (Chen et al., 2020; Zhang et al., 2020). Incorporating a variety of tools, techniques, and environments into education not only improves the learning experience but also ensures that it is adaptable to the needs of diverse learners. This multifaceted approach supports the development of a wide range of skills, from technical and academic to social and emotional, preparing students for success in an increasingly complex and interconnected world (Zhang et al., 2020). Based on the analyzed literature, a model for improving personalized education through technology is developed, as shown in Figure 1. This model illustrates the interconnectedness between the roles of education organizations, personalized learning tools, and the learning environment.

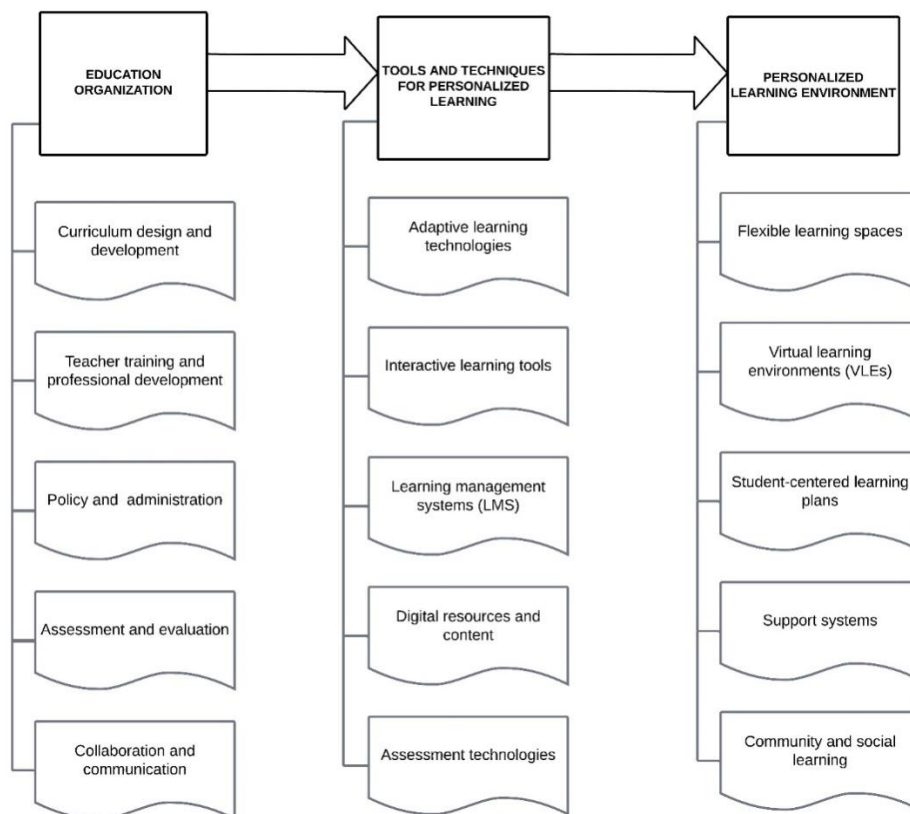


Figure 1. Model for improving personalized education and learning through technology

The model addresses key practical challenges in implementing personalized education through technology, specifically focusing on data privacy concerns and infrastructure limitations across different regions. Data privacy presents a significant challenge, as personalized learning environments rely on collecting and processing sensitive student data, including academic performance, learning patterns, and personal preferences. Implementing these technologies requires strict compliance with data protection regulations such as GDPR, which mandate robust controls over data collection, storage, and access. Educational institutions must integrate end-to-end encryption, anonymize data where possible, and establish strict protocols for data access and sharing. Developing these safeguards involves embedding cybersecurity measures directly into educational platforms and fostering a culture of data ethics among faculty and administrators.

Infrastructure limitations also pose a substantial barrier to implementing advanced learning tools, as technological disparities across regions impact feasibility. In urban and well-connected areas, schools can implement AI-driven systems, cloud-based Learning Management Systems (LMS), and immersive tools like VR and AR. In contrast, rural or underserved regions often face challenges such as unreliable internet, outdated hardware, or insufficient funding for technological investment. Adapting the model to these realities requires creating flexible solutions that can operate with limited connectivity and function on less advanced devices. For example, offline-compatible learning modules, downloadable content, and hybrid approaches that mix digital and physical resources can help institutions facing infrastructure challenges. Additionally, partnerships with local governments or private sector entities for funding and resource-sharing can assist in bridging these gaps.

The model's structure emphasizes adaptability within each component—education organizations, tools and techniques, and learning environments. Curriculum design should include options that support both tech-rich and tech-scarce settings, ensuring core learning objectives remain consistent regardless of the mode of delivery. Teacher training programs need to cover both high-tech instructional methods and low-tech alternatives to equip all educators for delivering personalized learning effectively. Institutional and governmental policies should reflect the importance of inclusive education, promoting equitable access to personalized learning by supporting regional needs and infrastructure improvements.

Personalized learning environments require flexible physical and digital spaces. Physical classrooms should incorporate areas for interactive, collaborative, and independent learning to accommodate diverse student needs, while digital platforms must ensure intuitive navigation and accessibility features. Virtual learning environments (VLEs) should support personalized learning across diverse student profiles, with built-in adaptive learning tools and analytics that provide actionable insights for educators and students alike. Assessment and evaluation mechanisms should include adaptable metrics that account for regional differences, ensuring fair evaluation of learning progress regardless of technological access.

Consider a rural school district introducing personalized learning technology despite limited infrastructure and data privacy requirements. With unreliable internet access and older devices, the district still seeks to implement adaptive learning tools that provide customized support based on each student's progress. The adaptive platform selected allows students to download learning materials during school hours, enabling offline access at home. For instance, the system continuously assesses a student's performance in real time and adjusts content accordingly: students struggling with a concept, like multiplication, receive similar exercises until they show improvement, while advanced students receive more challenging material to stay engaged. Teachers can access a dashboard with students' progress reports, which stores data locally and syncs during low-usage periods to ease internet strain.

Addressing data privacy is essential, as sensitive information is collected through this platform. The district anonymizes student data before storage and sets strict access protocols so only authorized staff can view reports, using secure logins on school-issued devices. To foster a secure culture, administrators provide cybersecurity training on practices like securing devices and managing student data ethically. Parents also play a role, providing consent through informative sessions explaining the platform's purpose and data protection measures. Teachers receive training to ensure effective use of the platform, including navigating the dashboard, interpreting data, and tailoring classroom instruction based on individual needs. For instance, if the platform highlights that several students struggle with reading comprehension, the teacher might create small-group sessions focused on reading strategies. Offline lesson planning is also emphasized, enabling teachers to blend digital insights with hands-on learning activities, particularly useful when internet access is inconsistent. The district adapts classrooms to support personalized learning through flexible seating, allowing both collaborative and individual work. Designated tablet stations enable students to access the platform during specified times without disrupting class activities. For virtual learning, teachers make downloadable modules available to minimize dependence on continuous internet access, and students without home internet can still progress using the downloaded materials.

Assessment practices reflect each student's unique learning journey, with metrics adjusted to account for varied technological access. For instance, while platform data highlights growth in specific skills, teachers

incorporate class participation and offline activities into the grading process to ensure fairness. Periodic reports offer timely insights, allowing teachers to modify learning plans as needed. To maintain improvement, the district holds regular feedback sessions with teachers, students, and parents. This feedback informs adjustments to the platform's use, while partnerships with local organizations help secure funding for eventual infrastructure upgrades, such as improved Wi-Fi and devices. Over time, these efforts enable a gradual shift from a primarily offline approach to a more connected, real-time adaptive learning environment.

4 SUGGESTIONS AND GUIDELINES

Based on the developed model presented in Figure 1 and the analyzed literature, the following guidelines and suggestions are provided for improving personalized education through technology:

- Invest in infrastructure to support digital learning by ensuring that schools have access to high-speed internet and modern technology. Develop and implement policies promoting the integration of personalized learning technologies in educational curricula.
- Provide funding for teacher training programs focused on the use of educational technology and personalized learning techniques. Establish national standards for data privacy and security to protect student information while using digital tools.
- Encourage public-private partnerships to support innovation and share resources between educational institutions and tech companies.
- Collaborate with educational institutions to develop and refine adaptive learning technologies and personalized educational tools. Offer internships and training programs to students, providing practical experience with technology and personalized learning environments.
- Establish learning communities and networks where educators can share best practices and resources related to personalized learning and technology. Promote interdisciplinary projects that integrate personalized learning technologies across different subjects and educational levels.
- Support a culture of continuous improvement in educational institutions, encouraging experimentation with new tools and techniques to improve personalized learning. Conduct regular assessments and feedback loops involving all stakeholders to evaluate the effectiveness of personalized learning initiatives and make necessary adjustments.
- Develop inclusive strategies to ensure all students, including those with special educational needs, benefit from personalized learning technologies.

5 CONCLUSION

The integration of technology in personalized education represents a transformative approach that addresses the diverse learning needs of students. This research highlights the important roles of education organizations, tools and techniques for personalized learning, and personalized learning environments in shaping effective educational experiences. Education organizations must focus on curriculum design, teacher training, supportive policies, and comprehensive assessment methods to create a robust framework for personalized learning. These foundational elements ensure that educators are well-equipped and that the necessary infrastructure and administrative support are in place to facilitate technology integration.

Future research should focus on empirical analysis of educational institutions that have implemented personalized learning technologies. This analysis would provide valuable insights into the effectiveness of different tools and techniques in various educational contexts. Longitudinal studies tracking student performance and engagement over time would be particularly beneficial in understanding the long-term impact of personalized learning. Additionally, research could explore the integration of emerging technologies such as augmented reality and AI-driven tutoring systems to further improve personalized learning experiences.

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Soft Skills in Secondary Education: A Basis for Competitiveness in the Job Market

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Abstract. Soft skills have become a crucial factor for competitiveness in the job market, particularly in the context of secondary education. This paper focuses on the impact of soft skills acquired during secondary education on students' success in gaining employment. The objective is to demonstrate the importance of soft skills in secondary education and explore how various teaching strategies can effectively prepare students for the challenges of the job market. Through an analysis of 96 job advertisements in a retail company, employer requirements regarding soft skills were examined. The results show that employers, regardless of the level of education required, expect candidates to possess at least two soft skills, with a particular emphasis on communication skills and teamwork. In line with the hypotheses, the findings confirm the significance of soft skills in the employment process and emphasize the need for secondary educational institutions to integrate the development of these skills into their curricula to adequately prepare students for future professional challenges and ensure long-term career success. This paper provides guidelines for educational institutions and policymakers on the importance of equipping students to meet the demands of the modern labor market.

Keywords and phrases: Soft skills, secondary education, employment, educational program.

1 INTRODUCTION

In today's dynamic work environment, soft skills have become essential for career success. During recruitment, these skills often play a decisive role in the selection of candidates, as companies seek employees who can resolve conflicts and enhance productivity (Velásquez, Gómez, Claudio & Ruiz, 2024). Although classes specifically dedicated to developing soft skills are rare, this does not reduce their importance (Mozgalova, Baranovska, Hlazunova, Mikhalishen, & Kazmirchuk, 2021). Employers increasingly value communication and teamwork skills, adaptability, and emotional intelligence, recognizing that these are as important as technical expertise.

There is a gap between the skills demanded by employers and the competencies possessed by high school graduates. Schools should promote the development of soft skills by ensuring students' psychological well-being (Saman & Wirawan, 2024). Governments and professional institutions should also provide soft skills development programs for teachers, regardless of the type of school, so that these skills can be passed on to students (Awodiji, 2024). For quality teaching, pedagogical knowledge, communication, adaptability, and emotional intelligence are essential. Teachers must actively participate in continuous professional development to improve their skills (Akbarovna, 2024). This approach not only enhances their teaching practice but also enriches students' learning experiences, contributing to the broader goals of education. Research findings (Lamberti, Aluja-Banet, Trinchera, 2021) indicate that students who later achieved high-paying jobs considered the development of soft skills during their education to be extremely significant.

Therefore, secondary education plays a crucial role in developing soft skills, as students transition from a structured school system to a more independent and competitive work environment, requiring appropriate skills.

2 RESEARCH METHODOLOGY

Research Problem

The connection between soft skills acquired during secondary education and the competitiveness of young people in the labor market has not been sufficiently explored. The question is to what extent soft skills influence students' employment and career success, and whether educational systems adequately prepare students for the demands of the labor market.

Research Subject

The subject of the research is the importance of soft skills acquired during secondary education for competitiveness in the labor market, with a particular focus on their role in the employment process. The research includes an analysis of 96 job advertisements in a retail company for the years 2023 and 2024, specifying the required soft skills for specific positions, as well as interviews with managers and employees in the human resources department about the significance of these skills.

Research Objective

The objective of the research is to highlight the importance of soft skills in secondary education and explore how different teaching strategies can effectively prepare students for the challenges of future careers. Through the analysis of job advertisements and interviews with employees, the study aims to demonstrate that soft skills are a decisive factor for employers and to encourage secondary schools to enhance the development of these skills within their educational programs.

Based on the defined research objective, two research questions arise:

RQ1: *Does the level of soft skills acquired by students in high school affect their success in employment?*

RQ2: *Does the role of soft skills vary depending on the type of job, and does their importance increase for highly skilled positions?*

3 THE IMPACT OF SOFT SKILLS ON COMPETITIVENESS IN THE JOB MARKET

Soft skills refer to a set of interpersonal and intrapersonal abilities that enable individuals to navigate their environment effectively, collaborate with others, and achieve their personal and professional goals (Lippman, Ryberg, Carney, Moore & Trends, 2015). Unlike hard skills, which are technical competencies specific to a job or task, soft skills encompass a broader range of attributes essential for success in any field. The challenge of securing and retaining employment has become increasingly difficult due to changes in educational systems, the flexibility of curricula, and the growing number of highly skilled workers. Consequently, students are now required to develop soft skills alongside their technical knowledge to unlock their full potential and gain a competitive advantage (Korniienko & Barchi, 2023).

Soft skills have a direct impact on students' work performance and professional development. Lepikhova identifies the structural components of socio-psychological competence, which include various characteristics such as socio-emotional intelligence, adaptability to social situations, individual and personal flexibility, advanced communication skills, situational control, social courage, energetic communication, and social trust (Lepikhova, 2004). Examples of soft skills include active listening, teamwork, leadership, empathy, creativity, adaptability, conflict management, and time management (Korniienko & Barchi, 2023). These competencies are highly valued by employers because they are crucial for creating a productive and efficient working environment. Research findings among students show that while they recognize the importance of soft skills for their academic success, they hold differing opinions on whether their educational institutions have adequately supported the development of these skills (Adriano, 2021). Non-cognitive skills, such as time management, resilience, perseverance, self-efficacy, goal-setting, reliability, and consistency, have demonstrated a positive influence on academic success (Heckman & Rubinstein, 2001).

The relevance of soft skills is becoming more prominent in an ever-changing environment. Survey results indicate that 86% of respondents have observed a growing importance of soft skills over the past 5–10 years, with companies increasingly valuing them over technical knowledge (Succi & Canovi, 2019). Schools and companies should collaborate not only to raise students' awareness of the importance of soft skills but also to encourage students to take personal responsibility for acquiring and developing these skills, allowing them to better adapt to labor market changes and enhance their employability.

Furthermore, research by Child Trends and FHI 360 has explored the relationship between soft skills and four key labor market outcomes: employment, job performance, earnings, and entrepreneurial success. The study identified five critical skills that help young people succeed: social skills, communication skills, critical thinking, self-control, and a positive self-concept. Young people equipped with these skills are more likely to secure employment, perform well at work, and earn higher wages (Lippman, Ryberg, Carney, Moore & Trends, 2015).

One of the main advantages of soft skills is that they can be cultivated not only through mandatory and elective educational components but also through extracurricular activities within educational institutions.

4 RESULTS AND DISCUSSION

The following section presents the results of the analysis of 96 job advertisements from a retail company for the years 2023 and 2024, as well as the key soft skills that employers expect from students upon completing their education and entering the job market.

Figure 1 shows the five soft skills that appeared most frequently in the job advertisements, regardless of the position.



Figure 1. The Most Sought-After Soft Skills in the Job Market

Communication is the ability to convey information clearly and appropriately, including both verbal and non-verbal elements, listening, and interaction. In the workplace, it contributes to better team coordination, increased productivity, and reduced misunderstandings. The ability to adapt communication style to different situations and people is essential for successful employment and career advancement.

Organizational skills involve efficient planning, prioritization, and resource management to achieve goals. These skills include task delegation, information management, and focusing on key activities. In a work environment, they enable the handling of multiple tasks simultaneously, enhancing productivity and reducing stress. Employers value these skills as they facilitate meeting deadlines and contribute to organizational success.

Teamwork refers to the ability to collaborate with others to achieve common goals. Effective teamwork leads to greater productivity, better ideas, and faster task completion. Team players are important for companies as they enhance efficiency, collaboration, and the overall work atmosphere.

Time management involves the ability to organize and allocate time effectively to accomplish tasks and goals within designated deadlines. This skill helps increase productivity, reduce stress, and improve work organization.

Independent decision-making refers to an individual's ability to assess situations, analyze information, and take action without the need for constant supervision or guidance. It allows for faster problem resolution and improves efficiency in the workplace.

The required soft skills may vary depending on the job position and description, as shown in Figure 2.

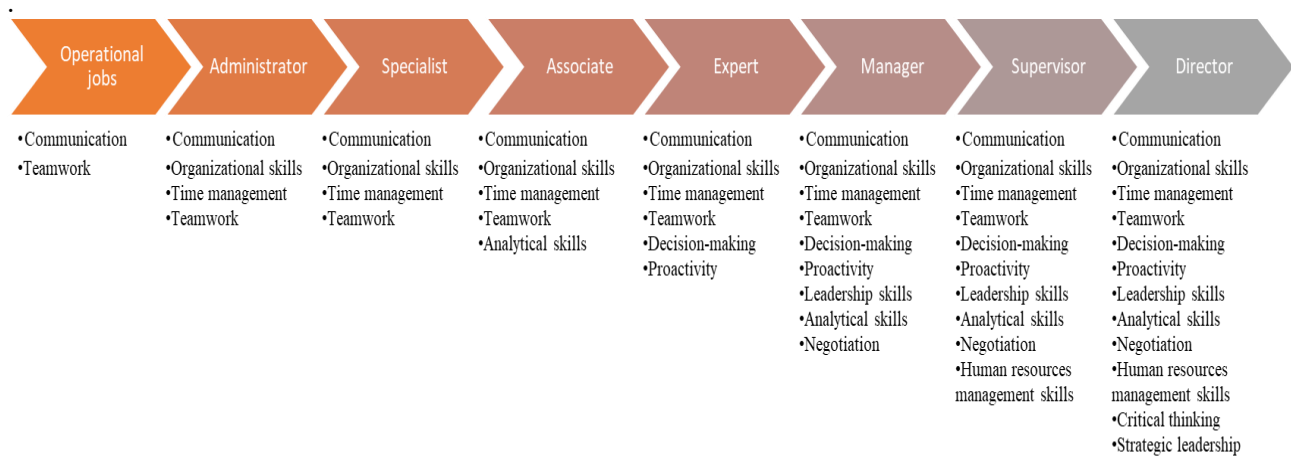


Figure 2. Soft Skills by Job Type

The research showed that employers, regardless of the level of education, work experience, or the specificity of the job position, expect candidates to possess at least two soft skills when applying for a job. These results imply that students must develop these skills by the time they complete their education to adequately adapt to the demands of the labor market. All analyzed job advertisements listed communication skills and teamwork as minimum required competencies. For higher-level positions, more soft skills are required from candidates.

The research provides answers to the proposed questions. First, the results demonstrated a significant correlation between the level of soft skills acquired during secondary education and students' success in employment, addressing RQ1. Additionally, the research showed that the importance of soft skills increases for highly skilled positions, answering RQ2. These findings emphasize the importance of integrating soft skills into the educational system to adequately prepare students for the challenges of the labor market. The research revealed that employers, regardless of the level of education, work experience, or the specificity of the job, expect candidates to possess at least two soft skills when applying for a position.

These results suggest that students, upon completing their education, must have developed these skills to adequately meet the demands of the job market. All analyzed job advertisements listed communication skills and teamwork as essential qualifications. For higher-level positions, more soft skills are required from candidates.

5 DISCUSSION

Candidates with well-developed soft skills are in high demand for most job positions, highlighting the importance of fostering these skills during education. Soft skills are not merely an addition to academic learning but form the foundation for career readiness. By integrating project-based learning, collaborative activities, and interactive discussions into the curriculum, educators can create environments that nurture these skills. Schools must recognize the significance of soft skills and develop comprehensive programs to prepare students for success. The findings emphasize the need for educational policymakers to prioritize the development of soft skills within educational frameworks. This includes providing training for educators on effective teaching strategies that promote soft skills and encouraging partnerships between schools and industries to ensure that curricula align with the evolving demands of the labor market.

Key organizational and pedagogical conditions include deepening knowledge about soft skills as essential professional competencies, creating informal settings for developing these skills, and employing various tools and methods of non-formal education (Mandro et al., 2023). According to a 2022 survey by the National Association of Colleges and Employers (NACE), 91% of employers prioritize communication skills when assessing potential employees, while 83% emphasize teamwork and collaboration. Similarly, recent graduates identified communication, critical thinking, and teamwork as the three essential competencies for their future careers, aligning with employer expectations (National Association of Colleges and Employers, 2022).

While this study has contributed to understanding the role of soft skills in secondary education and the labor market, further research is warranted. Future studies could explore the effectiveness of specific teaching methods and examine how cultural factors influence the perception and development of soft skills.

6 CONCLUSION

Research on soft skills in secondary education demonstrates that these competencies are essential for competitiveness in the modern job market. The findings clearly show that soft skills acquired during secondary education significantly impact students' success in securing employment, emphasizing the need to incorporate their development into educational programs. The growing awareness among employers of the importance of soft skills highlights the need for a more comprehensive approach to their development within the educational system. It is necessary to evaluate educational frameworks to ensure that soft skills are embedded in curricula and that teachers are trained in effective teaching strategies that promote these competencies. Implementing instructional strategies that foster the development of soft skills—such as collaborative activities, interactive discussions, and project-based learning—can significantly enhance students' ability to meet the challenges of the job market successfully. Additionally, strengthening cooperation between educational institutions and industries is recommended to ensure that educational programs align with market demands. Data shows that organizations value candidates who can collaborate effectively, communicate clearly, and adapt to changing environments. As industries continue to evolve, the demand for graduates with well-rounded skill sets will increase, making it imperative for educational systems to prioritize the development of soft skills. Further research is needed to clarify specific teaching methods and explore the influence of cultural factors on soft skills development. In conclusion, this study emphasizes that soft skills are not merely supplementary to formal education but a fundamental component that can significantly affect students' career success. Prioritizing these competencies will empower the next generation to navigate the complexities of the modern job market confidently and efficiently, ultimately contributing to a more adaptive and innovative workforce.

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Physical Violence in Primary Schools

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Abstract. This study has been shown the current problem of physical violence in primary schools to assess the existing situation and highlight issues that need to be addressed in the future. One of the main problems in tackling physical violence in primary schools is the lack of precise data on its prevalence. This diminishes awareness of the issue and complicates the implementation of effective prevention and intervention measures. The aim of this research is to determine the extent and nature of undesirable behaviour, specifically physical violence, among pupils in the lower grades at primary school "Olga Petrov Radišić" in Vršac. The research consists of documenting incidents of physical violence among pupils and analysing the results to reveal the actual prevalence of various forms of physical violence.

Keywords and phrases: physical violence, school, teachers, pupils

1 INTRODUCTION

It has been recently much discussion about physical violence in schools. The society we live in shows a trend of increasing physical violence, although many incidents are never reported. Physical violence in schools is not a new phenomenon. It has simply received more attention in recent years. Increased tolerance and reduced sensitivity to physical violence further contribute to the creation of a violent environment for children. Changes in social norms have led to new understandings of aggressive, violent, and unacceptable behavior among children and peers.

Physical violence in primary schools is a serious problem with potentially long-lasting negative consequences for victims, perpetrators and the school. A UNICEF study shows that 36% of children in Serbia have experienced some form of physical violence at school (Gazetić, 2022). Considering the seriousness of the issue, this paper will be beneficial for primary school teachers, parents, pedagogical-psychological services, and others who are involved in educational work and child education. The results of the research will help to better understand the problem of physical violence in primary schools, with the aim of developing effective measures for its mitigation and prevention. In addition to the quantitative analysis of physical violence in elementary schools, this paper is intended to serve as an impetus for other similar and more comprehensive studies that will lead to concrete changes, such as initiating training initiatives for primary school teachers and specialists on preventing physical violence among pupils in the first cycle of education.

2 THEORETICAL BACKGROUND

The impact of media and social networks on violence

Media and social networks have a significant impact on shaping the perceptions and behaviors of children and adolescents, including how they relate to physical violence.

Children often shape their behavior based on what they see on television, social media, in tabloids and in books. Violence in the media, especially due to its frequent occurrence, has negative consequences. One of these is the imitation of what they see. Additionally, violence can be perceived as a useful method for solving problems, leading to indifference toward violence and reduced empathy for victims of violence (Popadić, 2009.). The media often show unrealistic images of violence to increase their publicity, which can create a

distorted view of reality. Children who have an unrealistic perception of the world around them may find it harder to understand the seriousness and consequences of physical violence.

The impact of media can be extremely high, which is demonstrated by a European study in which Serbia stands out for the large number of children under the age of 13 in terms of time spent on social networks. Additionally, the use of social media varies daily among children aged 12 to 14, ranging from only 10 percent in Finland to as much as 86 percent in Serbia and Russia (2024, May 18). Retrieved from <https://www.unicef.org/serbia/koriscenje-interneta-i-digitalne-tehnologije-pregled-nalaza>.

In some countries like Germany and Slovakia, fewer than 10 percent of children aged 9 to 16 reported being disturbed by something online. In contrast, in the Czech Republic, Malta, Romania, Serbia, Spain, and Switzerland, more than 30 percent of children reported being disturbed by something on the internet in the past year.

In Serbia, six percent of children experienced peer violence online at least once a month. The lowest percentage of children experiencing online peer violence at least once a month is found in Croatia, France, and Italy (two percent), while the highest is in Poland and Malta (13 and 11 percent).

In our country, a quarter (24 percent) of children have seen pleasures messages at least once a month, compared to Poland, where this figure is the highest (48 percent), and Germany, where it is the lowest (4 percent). In Croatia, such cases were recorded among 11 percent of children (2024, May 18). Retrieved from <https://www.unicef.org/serbia/koriscenje-interneta-i-digitalne-tehnologije-pregled-nalaza>.

On the Serbian government's website <https://pametnoibezbedno.gov.rs/>, some of the most well-known internet challenges circulating among children are listed. Some of these can be dangerous, even deadly, such as licking a toilet bowl during the coronavirus pandemic or running in traffic between cars and trucks. Teenagers record these dangerous scenes for fun and post the material on social media to gain as many likes as possible among their peers.

There are many similar examples among young people around the world. Last year, the Italian prosecutor's office launched an investigation following the death of a ten-year-old girl from Palermo, who reportedly played the "choking game" before her death which is also known as "the blackout challenge". This challenge had been very popular on the video-sharing platform TikTok for some time. A few years ago, Chinese doctors publicly warned people not to buy light bulb-shaped candies to participate in a dangerous online challenge. Social media users massively bought these sugary light bulbs and posted pictures and videos of themselves attempting to fit the entire candy into their mouths (2024, June 2). Retrieved from <https://www.bbc.com/serbian/lat/srbija-60265947>.

According to the EU Kids Online research, pupils spend in average of over 3 hours a day online, while older pupils are spending up to 4.5 hours. On weekends, two-thirds of them spend between 4 and 7 hours on the internet. The main purposes for using the internet are entertainment and communication with others. About three-quarters of children and young people (74%) have a profile on a social media platform or a gaming site. Beside this, 41% of children aged 9-10 and 72% of children aged 11-12 have profiles, despite the minimum age requirement set by social networks typically being 13 years. Approximately one-third of surveyed pupils have issues related to the time spent online, leading to conflicts with family or friends. Just under half unsuccessfully try to reduce their online time, neglecting social interactions and school responsibilities, feeling bad when they cannot be online, while nearly one-fifth ignore basic biological needs (such as the need for food and sleep) (2024, May 18). Retrieved from <https://www.unicef.org/serbia/koriscenje-interneta-i-digitalne-tehnologije-pregled-nalaza>. These data are indeed concerning and highlight the significant impact that online media and social networks can have on children.

Media sometimes depict violence as a way to solve problems or conflicts. Children may accept this type of behavior as normal and acceptable. As a result, there is a danger that children will address their problems through physical conflicts, including school violence.

It is strange that, despite our society's great concern for reducing violence, it neglects the messages about the extremely harmful impact of media. Part of the problem is the fact that media content is aimed at generating

profit, and companies managing media claim they are merely providing content that users want. Thus, the connection between media and physical violence remains in a vicious cycle, from which there appears to be no immediate way out or solution to the problem.

3 RESEARCH METHODOLOGY

3.1 Research problem

At primary school "Olga Petrov Radišić" in Vršac, physical violence manifests in various forms, but there is a lack of precise data on the frequency of its occurrence. To create an accurate picture of physical violence in the first cycle of education at this school, the author of the study will obtain results regarding the number of cases of different forms of physical violence, which mostly occur due to primary school teachers not keeping records of such incidents. They sometimes fail to report incidents for various reasons. It often happens that teachers feel powerless to address the problem or do not even know how to resolve it, which is why they do not report it. Without accurate data on the frequency and forms of physical violence, it is difficult to determine which measures are the most effective for prevention and appropriate resolution. Additionally, the presence of physical violence diminishes the school's reputation and makes it less safe for pupils. The lack of data on physical violence can create the impression that violence in schools is acceptable or that the school is not taking measures to combat it.

3.2 Research hypothesis

At the beginning of this research, a hypothesis was established: The most common forms of physical violence among lower-grade pupils at primary school "Olga Petrov Radišić" in Vršac are hitting, pinching, and pushing. In order to check this hypothesis, it is necessary to conduct research using reporting sheets that will show the frequency and forms of physical violence among lower-grade pupils. Based on the research results, it will be determined whether the hypothesis is correct, and if necessary, the school will take appropriate measures to prevent and combat this type of violence within the school.

3.3 Description of the conducted results and obtaining results

The combined results for all four classes are presented in Figure 1, which illustrates the comparisons of different forms of physical violence by grade. This will provide insight into the frequency of violence that occurs depending on the pupils' age.

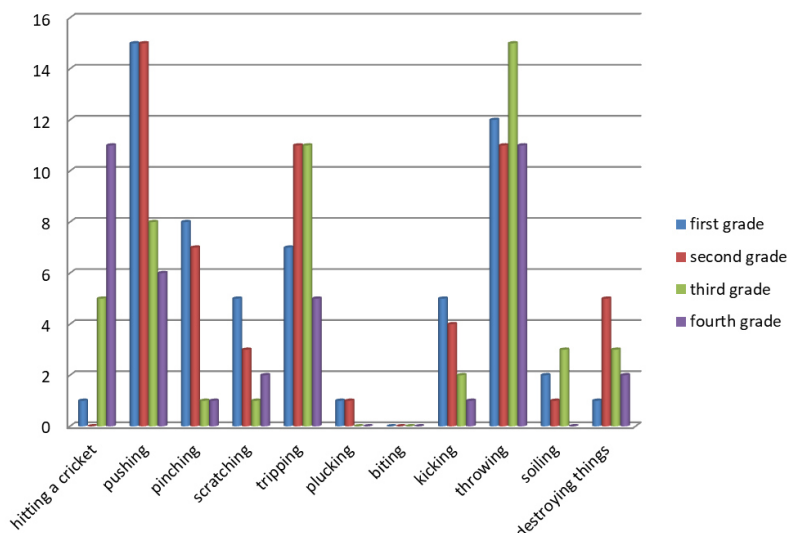


Figure 1. Comparison of the results of all forms of physical violence by classes

Based on Figure 1, it can be concluded that physical violence is present in the school, but on average, it is more frequent in the first and second grades than in the third and fourth grades. An interesting fact is that there were no cases of biting in any grade, and only two cases of hair pulling were recorded. As seen, the most common forms of violence in the first and second grades were pushing, throwing, and pinching, while throwing was the most common in the third grade, and hitting was the predominant form of violence in the fourth grade. Additionally, there are a negligible number of cases of hitting, hair pulling, and soiling in the first and second grades. Furthermore, the graph shows a significant difference in the number of cases of punching and kicking, being more intense in the first and second grades, while sharply decreasing in the third and fourth grades. This indicates that children in the first and second grades often use physical force to assert

their place in the group. Upon reviewing the Figure 1, it is noticeable that throwing as a form of violence is approximately the same across all four grades. We can conclude that there is a division regarding the amount of physical violence in the first and second grades compared to the third and fourth grades, which likely results from the maturation of pupils' personalities over time. Pupils in the lower grades are still developing and may be more immature and impulsive, while pupils in the higher grades have developed better self-control skills and can resolve conflicts in a non-violent manner (Bilić, Buljan & Hrpka, 2012.).

Figure 2 provides insight into the total number of cases of different forms of physical violence in the first cycle of education at primary school "Olga Petrov Radišić" in Vršac.

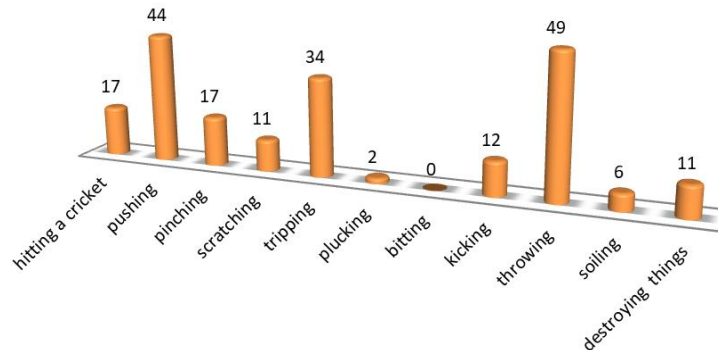


Figure 2. Total number of cases of different forms of physical violence in the first cycle of education

By summing the individual forms of violence, we arrive at a total number of 203 cases, which represents a very large number when considering the overall situation. Analyzing the Figure 2, we can see that the most common forms of violence among pupils in the first cycle of education are throwing (49 cases), pushing (44 cases), and tripping (34 cases). Other forms of violence occur to a significantly lesser extent. Positive aspects are that cases of soiling and hair pulling are rare and also there were no incidents of biting.

The most frequent form of physical violence was throwing, occurring 49 times. This form of physical violence is the easiest to execute, as it does not require direct physical contact between two pupils, making it the most frequently recorded case. This behavior can also serve as a way to attract attention or to obtain something that children desire. Additionally, children at this age may imitate the behavior of their peers. If they see other children throwing, they may be more inclined to replicate that behavior. Moreover, a child who is upset excited, or feels isolated might throw something at another child as a way to express their emotions or to attract attention. These claims can also be confirmed by Figure 3, which shows the total number of cases of violence by grade.

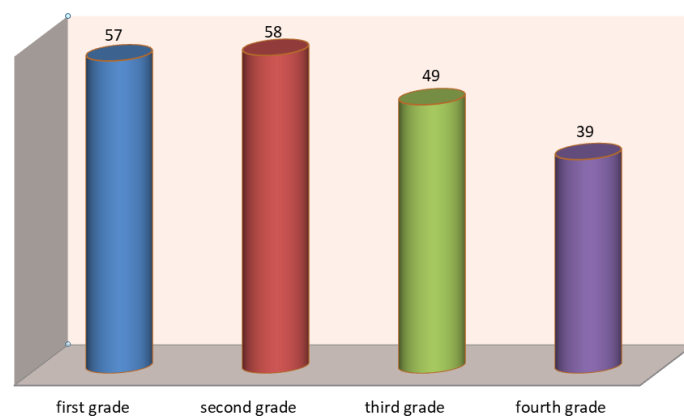


Figure 3. Total number of cases of different form of physical violence by grade

It can be seen from Figure 3 that the highest number of cases of violence is occurred in the first and second grades, and that the number gradually decreases in the third and fourth grades.

To better understand the prevalence of physical violence by grade, the results of the research will be presented as percentages in Figure 4.

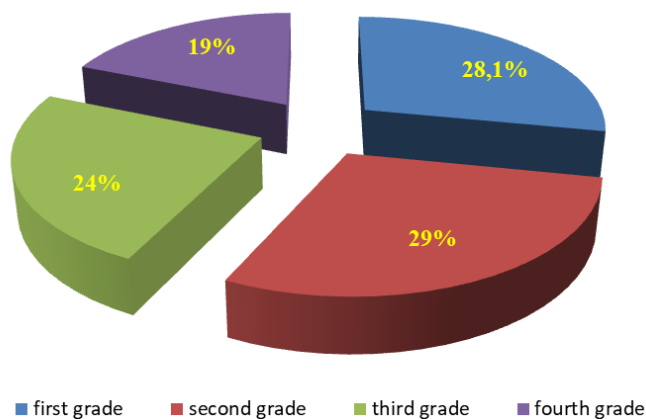


Figure 4. Total number of cases of violence in percentages by classes

Based on the results which are shown in Figure 4, it can be concluded that the frequency of physical violence decreases with the growth and maturation of pupils. After peaking in the second grade, where 58 cases were recorded, that percentage of physical violence declines in the third and fourth grades. Comparing the first and fourth grades, physical violence has decreased by 9.1%, which can be explained by the fact that pupils in the third and fourth grades have developed self-control and conflict resolution skills without resorting to violence, as well as their awareness of the dangers of physical violence and the consequences it can have (Jasenka, 2005.).

The research results, which indicate variations in the intensity and forms of violence depending on the age of the pupils, can be viewed through the fact that first and second-grade pupils lack sufficient emotional maturity and regulation of feelings. On the other hand, more severe forms of violence observed among third and fourth-grade pupils may be linked to their efforts to establish their status within the group, as well as the influence of external factors such as social media and television.

The obtained results can help schools to shape their preventive workshops and activities. For example, workshops for first and second-grade pupils can be focused on developing empathy and social skills, while third and fourth-grade pupils should be encouraged to report incidents of violence.

The issue of physical violence in schools represents a broader social problem. Different forms of physical violence that arise may be linked to violence occurring within the family, the surrounding environment, or the internet. Therefore, this problem must be approached from multiple perspectives, involving the school, family and local community in its solution. In addition, the authors suggest that it is necessary to establish better guidelines and laws to ensure clear support for schools in preventing violence. This would include increasing the number of extracurricular staff dedicated to activities aimed at reducing all forms of physical violence in schools, as well as continuous professional development for teachers and all school employees related to recognizing and responding to incidents of violence.

It is important to emphasize that the research was conducted in only one school, so the results might differ if the study were applied to a broader region. Additionally, the research was limited to one trimester, which means that the study does not provide an analysis of changes in different forms of physical violence over a longer period. Furthermore, the study presents a quantitative analysis, but it does not reveal the underlying reasons behind the occurrence of violence.

This research can be improved by tracking pupils over a longer period, for example, several years, to better and more deeply understand behavioral changes in patterns of violence during their development. Additionally, research could be conducted in multiple countries to examine whether different cultures and educational systems influence the occurrence of physical violence in schools.

4 CONCLUSION

The issue of unacceptable behavior among pupils, especially of physical violence, is the subject of numerous studies. This social problem is very complex, which is most evident in the difficulties encountered when collecting accurate data on various forms of physical violence, enabling schools to implement preventive and intervention activities. Keeping records and reporting cases of violence in elementary schools is done by only

a small number. When it comes to regular documentation, it often represents an additional burden for staff, leading many schools to either not keep records or to do so irregularly and carelessly.

Although the Regulation (Ministarstvo prosvete, nauke i tehnološkog razvoja Republike Srbije, 2023.), which is talking about the implementation of the protection program by the protection team, requires the submission of reports to the primary school director twice a year, this is only done in 28% of sampled schools. In most schools, reports are submitted once a year (Pokrajinski ombudsman, 2011.). By using records filled out by elementary school teachers and processing this data, information about the extent and types of physical violence in the school has been revealed, which will help to be developed effective methods for preventing and mitigating physical violence in the first cycle of education.

The research hypothesis aimed to determine whether hitting, pinching, and pushing are the most common forms of physical violence among younger pupils at the primary school "Olga Petrov Radišić" in Vršac. The results indicate that the hypothesis has been refuted, because the highest number of recorded cases were throwing, pushing, and tripping. Based on these results, the school must implement more effective measures through its educational and developmental work to reduce the high number of cases of physical violence. Activities aimed at pupils, elementary school teachers, and parents must be planned and carried out as soon as possible, with the primary goal of preventing and reducing certain forms of undesirable behavior among first-cycle education pupils.

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Experiences in the Creation and use of Electronic Teaching Materials

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Abstract. Experiences related to use of electronic teaching materials in vocational subjects are considered twofolds. The first part describes experiences in using electronic teaching materials in the teaching of vocational subjects, from the point of view of the teacher who applied it and observed student achievements. In the second part, the experiences and attitudes of students collected through a survey are presented with the aim of evaluating their attitude about what is most useful way and how teaching should look like in the future.

Keywords and phrases: Electronical teaching materials, video lessons, moodle platform.

1 INTRODUCTION

The development of education requires constant adaptation to the changes taking place in science, technology, and society. Technologies that are close to students must be used by a teacher who wants to increase the effect of working with students.

During 28 years of teaching practice in a secondary vocational school, many ways of working with students have been explored in an attempt to increase students' interest in acquiring knowledge in the specific areas of teaching. It has also been attempted to establish better communication with students, using communication mediums that are used by them every day.

At the very beginning, teaching was classic, face-to-face, and students were expected to listen, write down notes, and use textbooks and exercises. Since teacher training wasn't a part of engineering studies, teacher training is not undergone by engineers who become teachers until the professional exam, and even then, they are only acquainted with some ways of moderating classes, but not all of them have decided to apply them.

The biggest changes in the approach to teaching happened when the secondary vocational education reform program initiated by the Ministry of Education, headed by the then Minister Mr. Knežević, was joined by the school. On that occasion, several years of training were undergone by the teacher, which included seminars related to the moderation of group, team, and project papers, and training to improve competencies important for teachers, the creation of teaching materials, etc. After that, the approach to teaching and working with students began to change. Participation in seminars, webinars, and conferences, and learning how to use information technologies in classes, how to better present the material, better connect with students, improve their mutual communication and cooperation, encourage teamwork, use social networks in teaching, moderate project research work, and create teaching materials were all part of the change. During the coronavirus pandemic, teaching was conducted exclusively online, and that's when video lessons were recorded and independent assignments for work from home were introduced into the teaching program. That is how everything described in this paper was created.

At the end of the previous school year, a survey on the usefulness of electronic teaching materials among the students was conducted, so in the second part of this paper, the results of the survey will be presented.

2 USAGE OF ELECTRONIC TEACHING MATERIALS IN THE TEACHING OF VOCATIONAL SUBJECTS

Modern informational technologies have made it possible for many texts, images, short films, simulations, and emulations to be shared, thus enabling learning in different ways. However, good and quality content is not chosen by students, what is presented is not understood, and they are not trained to recognize the essence, so they generally get lost in the vast number of available materials. As a result, the effect of online learning is the opposite of expectations. Over the years, different approaches have been taken, such as selecting what is interesting, correct, and allows for a clear and easy understanding of the material. It is used to improve teaching and is incorporated into teaching materials by being adapted to the teacher's teaching method. In addition, tools are available on the Internet that can help engage students and assist them in completing tasks. These tools include simulation software, applets, e-classrooms, and a variety of animations. Simulation software is particularly useful for electrical engineering, as it allows electrical systems to be assembled, tested under different operating conditions, measurements to be taken, and measurement results to be displayed and analyzed.

The creation and use of electronic teaching materials is a demanding and long-term process, so it is naturally expected that the materials once made can be used for a longer period. This is where problems arise:

1. Old applications can no longer run on new computers.
2. Simulation software becomes obsolete and disappears, so the recorded materials are no longer relevant.
3. Plans and programs in schools are changing, so there is no longer a subject for which we have teaching materials or covered teaching content has been removed.
4. Websites that we refer to in classes cease to exist.
5. Websites with electronic classrooms, materials, tests cease to exist.

Because of all the above, the strength and will to innovate are lost by teachers, leading them to rely on standard ways of working.

Next, experiences related to electronic teaching materials and ideas for using technology in student work will be described.

2.1 Use of social networks for short message communication

Facebook, Discord, and the forum on the Moodle platform were utilized for this type of work with students, with Discord currently recognized as the easiest platform for communication. It is ensured that each student's work is visible to others, and the task requires a certain number of questions related to the teaching area or lesson to be asked, answered, and shared among students. Lessons need to be read or watched, and notes must be taken during the process. A few years ago, this type of work was actively participated in by students, but after the pandemic, a decrease in motivation has been observed, with students appearing fatigued from online classes. Through such forums, a deeper understanding of the lesson is encouraged, important points are highlighted, questions requiring clear answers are composed, and the work of others is followed. Cross-curricular competencies such as lifelong learning, communication, working with data and information, digital competence, cooperation, and participation in a democratic society are developed. As a result, a database of questions and answers is generated, which can be used for studying, preparing for written tests, or deepening knowledge, with collections of questions and tasks created during the process that can be reused for years. Greater student engagement can be achieved through additional motivation, such as rewards in the form of summative assessments or points for formative assessments. The success and quality of the material produced are dependent on the abilities of the students and their communication within the forum. This approach is deemed suitable for classes without weaker students and is applicable for processing theoretical content, preparing materials for review, and preparing for tests or exams. However, it has been observed that an increasing number of students struggle to identify key points, focus on secondary details, formulate clear and unambiguous questions, and effectively answer their own questions.

2.2 Blog creation

A blog, as a type of website, is characterized by the ability to host posts, texts, images, short videos, tables, graphs, and links to other materials. The content can be searched using various criteria, communication with the author via messages is enabled, and access to the content can be repeated multiple times. It is regarded as a stable Internet resource, lasting as long as the domain on which the material is hosted remains active. Tracking which students have visited the blog and viewed the material is difficult, making it unsuitable for evaluating student work. Lessons, specific areas, or entire subjects can be included on a blog, giving it the appearance of a textbook. The blog about electronics and microcomputers can be accessed at <https://marijanabogdanovic.wordpress.com/>. Through the use of blogs, students' competencies in lifelong learning, working with data and information, and digital literacy are developed. However, blogs are not particularly popular with students.

2.3 Video lessons

A video lesson is defined as a recorded lecture, and experience has shown that the lecturer's presence is not essential, with better results achieved when only the desktop and voice are recorded. It does not matter whether a school blackboard, handwritten notes on paper, an electronic board, or a computer screen is recorded while actions are demonstrated, steps explained, results interpreted, or graphs drawn. The duration of a video lesson is recommended to be no longer than 30 minutes due to students' limited patience and concentration. The creation of video lessons requires significant time, as the presentation sequence must be planned, examples and tasks prepared, the desktop designed, and the application of tools practiced. Once preparation is complete, recording becomes relatively easy, although multiple takes are often required due to presentation mistakes, unclear speech, or insufficient fluency. Students' competencies in lifelong learning, digital literacy, aesthetic skills, and working with data and information are developed through video lessons. A large number of views registered on a YouTube channel (<https://www.youtube.com/@marijanabogdanovic6830>) suggests that such materials are frequently watched, with 27 lectures on electronics, basics of electrical engineering, and microcontrollers recorded. Students find the ability to re-watch and revisit specific parts of the video beneficial, and these materials are often used after lectures to reinforce learning and supplement notes. While students generally enjoy video lessons, their attention as viewers is not always consistent. Drawbacks include the passivity they may encourage and the difficulty in monitoring and evaluating student engagement, as it is challenging to determine which students have viewed the material. To address this, notes, questions, or additional tasks should be added to video lessons to enable activity evaluation. Although video lessons have proven useful, it is not feasible to prepare recordings for every lesson.

2.4 Presentations

Presentations are summarized versions of lectures, designed to support the flow of the lecture according to the expected course and dynamics. Divisions, key terms, tables, graphs, pictures, diagrams, and video clips are displayed through them. They are regarded as excellent support for teachers when a projector and a suitable projection area are available, although this is not the case in every classroom or school. Around a hundred presentations have been created by the author, either independently or with assistance from students. Student presentations have been prepared as part of their lecture preparation, for the presentation of papers, or to showcase the results of project work. Although they are not considered effective learning materials due to their lack of detailed information, they are appreciated by students for providing a summary of the material that can be memorized. Presentations are always uploaded to the platform to assist students in their studies, but the extent of their usage by students remains unknown. Through the process of creating presentations, students' competencies in working with data and information, as well as aesthetic competencies, are developed.

2.5 Documents containing text, images, graphs

The electronic version of the textbook is represented by them. They are considered useful in cases where no textbook aligns with the prescribed content. Documents are designed to contain text, formulas, graphs, tables, various explanations, block diagrams, electrical diagrams, sketches, instructions, problems, and problem solutions. They should be used by students for studying and exam preparation. Their content needs to be concise, transparent, supported by images, and with the essence highlighted. However, they are not widely appreciated, and understanding of their content is declining among students. Their value as teaching materials

is recognized when student participation in their creation is involved, or when they include concise preparation for a knowledge test. Similar to a text forum, participation by all interested students is allowed, while individual contributions are monitored and graded, which is highly valued by students. They are often produced as the result of individual or group student efforts, such as papers or project work, thereby facilitating assessment. Once completed, questions, work instructions, and links to materials can be added. Reusability is one of their strengths, as they can aid in the creation of presentations and be uploaded onto e-learning platforms. Over time, if the subject persists, they may evolve into scripts or textbooks. When created by teachers, they provide support in the absence of other materials. When developed as papers or projects by students, numerous competencies are fostered, including lifelong learning, working with data and information, digital literacy, aesthetic awareness, collaboration, problem-solving, communication, responsible participation in a democratic society, as well as entrepreneurship and entrepreneurial competence.

2.6 Use of e-learning platforms

E-learning platforms were widely used during the pandemic, with all the above-mentioned features being combined. The setup of an entire course on the platform or the creation of a learning program for a specific area or lesson is time-consuming. Tasks and questions are effectively set, and teaching content in various forms is provided. Video conferencing capabilities are offered, while discussions, tests, monitoring activities, and grading are facilitated. A significant amount of work is required to prepare and set up the materials, and considerable time is needed to monitor the participants' activities. Superficiality in learning is enabled and even encouraged, particularly among students who study solely for grades. During the pandemic, they were utilized as the only teaching model. In situations where students are not at school, continuity of the educational process is ensured, whether due to illness or other reasons. However, practical work is not accommodated, and teaching in laboratories and workshops cannot be replaced. Competencies such as digital literacy, working with data and information, and lifelong learning are developed by students. Every year, the Moodle platform is used for learning, with teaching materials, useful resources, questions, and tasks for preparing written knowledge tests, forums, and links being posted. The creation of a programmed learning course is not utilized, as classroom and laboratory activities are conducted step by step. Questions and tasks for written knowledge tests are assigned, and students are encouraged to work diligently, find answers, complete tasks, and share their work with peers. It is observed that the platform is being visited less frequently by students, who show reluctance to engage in work both at school and at home.

3 EXPERIENCES AND ATTITUDES OF STUDENTS

At the end of the previous school year, a survey about electronic teaching and electronic materials was created by me. It covered all 5 classes in which I taught, so about 120 students from the second, third, and fourth grades of the educational profiles computer electrical technician and mechatronics technician were included in the survey. Of these, 107 correctly completed surveys were received, 5 were unusable, and the rest of the students were not in class and did not participate in the research. With the survey, I wanted to find out how the materials posted on the school's learning platform were used by the students, what they liked, what they didn't like, and their opinion on the usefulness of those materials. Seven questions were of the closed type, where students had to choose something from the offered statements, and five questions were of the open type where their opinion was asked. The results are interesting, as the students' maturity in understanding information, the need for it, and the role of the school in their professional development were demonstrated. At the same time, the answers show complete awareness of their own condition, motivation for work, and personal interest in learning.

Of those surveyed, it was stated by 104 students that they used the school's learning platform, while 3 students stated that the platform was not used by them at all. When asked what they considered the most useful of the materials posted on the platform, the following answers were received: 72 students thought that setting tasks and questions for practice and preparation of a written knowledge test was the most useful, 31 students chose video lessons, 28 students chose text materials, 11 students considered presentations from lectures useful, only 4 students chose the student works that were added as a source of content, while only 3 students chose a blog.

To the question of what is achieved by using video lessons, the following answers were received: 55 students thought that the material was made easier to understand, 52 students thought it was good that the lesson could be gone through more than once, 25 students thought they had clearer explanations, and 19 students thought

that making notes was easier. In this question, they had the option to write something else, and only one student wrote that the video lesson allowed the lesson to be watched step by step.

The next question was about what is achieved by using text lessons. The distribution of the answers is as follows: 66 students thought it was easier to take notes, 31 thought it was good that the lesson could be gone through more than once, 24 thought it was easier to understand, and 13 said they had clearer explanations.

The fifth question was related to the effect of using presentations as learning material. The following answers were given: 46 students thought they made it easier to understand, 36 thought they made note-taking easier, 25 said they had clearer explanations, and 23 thought it was good that presentations allowed the lesson to be gone through more than once.

Therefore, it can be concluded that the students show that they are looking for something easier, that it is not enough for them to listen to the lecture in class, and that they are looking for the opportunity to go through the lesson again, to look at some parts more than once, and in that way take notes more easily. It is most useful for them to receive a database of questions and tasks, so they know in advance what to expect on the exam.

In the continuation of the survey, 3 questions were asked related to the fact that practice questions and tasks were posted on the platform from which I selected what would be evaluated during the written knowledge test. One question was designed to provide information on whether the students put effort into those questions or simply took the answers from others and learned them by heart. Five offered answers were given, and 45% of students claimed that they did something by themselves and took something from others, 30% said they looked for all the answers independently, 20% exclusively used someone else's answers, 3% of students stated they did not use the questions when studying for a written test, and only 2% of students stated they did not prepare for the test.

Two open-ended questions were asked by me to find out why it is considered a good practice and why it is not. Over 80% of students wrote their opinions on why it is good to receive questions and tasks in advance to prepare for the written knowledge test. The following are their opinions:

1. It is believed by 50% of students that studying is easier, better grades are achieved, important things are highlighted, and understanding is improved.
2. It is believed by about 20% of students that learning what is important is allowed, so time is not wasted on secondary things and guidelines for work are provided, ensuring no surprises.
3. For 6% of students, knowing the questions gives more time for studying, leading to better results.
4. In addition to this, the following answers were provided: knowing the questions reduces stress, less time is spent so other subjects can be studied, the precision of knowledge is increased, and it is always available for study from home. The most interesting answer, which shows how teenagers think, is: "If you are not lazy to answer the questions yourself, then you learn better. "

When asked why it is not good to know the questions and assignments in advance, only 20% of the students responded. Their choice was justified as follows:

1. Effort is reduced since what is important does not have to be searched for by students on their own.
2. Less is learned – only what is covered by the questions is studied, and the rest will not even be looked at.
3. Rote learning occurs, and no essential learning takes place; real knowledge is not formed.
4. The possibility of cheating on the test exists.
5. Rote learning occurs, allowing students to achieve better grades than they deserve.
6. Since everything has been done for them, a lot of time is thought to be available, and answers are forgotten and not studied.

In the final part of the survey, questions related to students' attitudes towards electronic learning were asked. The question of whether interactive lessons, programmed learning, and electronic tests on the platform would be preferred was met with an evenly split response. Positive opinions were justified by saying that: it is easier to study and take tests on the platform, the degree of mastery of the material can be checked, it helps in better understanding, everything is in one place, it can be done whenever and as many times as needed, it helps if a student is absent from class because it can be made up for more easily, it would be more interesting, it could be evaluated when forming a grade, and, most interestingly, "we should go into the future and use the computer as much as possible." Those who do not want parallel work explained it as follows: they do not want to do

double work, they waste time, they spend too much time on the Internet, they do not like it, communication with the teacher is important to them, they already have everything they need at school, classes in the school are excellent, and the biggest drawback of programmed learning and electronic tests is seen in the opportunities for copying and cheating.

The tenth question asked about the influence of electronic teaching materials on the motivation to study and work, offering three options with a request for justification: motivation increases, motivation decreases, or there is no influence on motivation. Half of the students believe that electronic teaching and teaching materials have no influence on motivation. Only 6 students believe that this type of teaching reduces motivation, explaining that it is easy to wander from the lesson to other internet content, which reduces the desire to learn. The rest of the students believe that the use of electronic teaching materials, regardless of the form, increases motivation to work. Their explanations included: it is easier and more interesting, they like everything that is on the computer and electronic, the scope of the material is reduced, the most important things are extracted and emphasized, everything is in one place and always available, and they are aware that it enables them to get a better grade, seeing that the teacher is interested in increasing learning and initiating cooperation.

The last two questions related to the possibility of e-learning completely replacing attendance at school. Only 30% of students think that this would be good, explaining it as follows: passengers spend a lot of time on transport, so such teaching would leave them with more free time, the whole generation is turning to computers and the Internet, they are good at it, and it is more and more their world. However, they emphasized that only theoretical classes could be organized this way, and that this is good in emergency situations. The majority of students, 70%, believe that schools should not be exclusively online. Their position was explained with the following statements:

1. It is easier to understand when the teacher explains in person, as the explanations are more detailed, questions can be asked, and a lot is learned in class while writing and talking with the teacher.
2. Not all students are disciplined to work from home, and many would not complete everything expected in online classes.
3. Attention is lost when looking at the screen for a long time.
4. The possibility of cheating on electronic tests has been increased, so less effort is put into studying, knowledge is reduced, and grades are often not realistic.
5. Writing with a pencil must not be forgotten.
6. Socialization – being at school and communication with other students and teachers – is considered necessary.
7. Remote education does not allow laboratory exercises and practice, so training for work is not provided.

4 CONCLUSION

The conclusion can be divided into two groups. The impact of electronic teaching materials on students, and on teachers, should be analyzed separately.

Based on the experience of the author, the teacher of vocational subjects in a secondary vocational school, the following can be singled out:

1. Electronic materials are generally concise, with important content emphasized, and this is considered useful for students who can no longer extract the essence from a lot of data, cannot understand a lesson from a textbook, or even a longer text.
2. Electronic teaching materials are seen as useful only as a support for regular teaching because the interaction between teacher and student, which keeps vigilance and attention during the processing of teaching content, cannot be replaced.
3. Electronic learning can only be used for theoretical teaching, while laboratory exercises and practical work must be conducted at school or possibly at a company from the domain.
4. A lot of content and tools are available to the teacher to design and create lessons according to their own needs and the needs of students, but such preparation of the lesson requires much more time, and motivation is increasingly reduced.

Based on the results of the survey, the following conclusions can be drawn:

1. Students are increasingly oriented towards the digital world and are proficient in it, so any form of work with the use of a computer is attractive to them.
2. Students are aware of the disadvantages of learning from virtual content, but it is chosen because it is easier for them and because they are accustomed to using a computer.
3. Students cannot remember everything during the lessons, and it is useful for them to have electronic materials that are concise, always available, and serve as a guide in the selection of learning content.
4. Students believe that electronic teaching cannot replace teaching at school, but it is considered useful as a support.
5. Students want to be trained for work and consider work in laboratories and practical work is important.
6. Attention is lost easily, so it is considered better to be in school.
7. Company and communication with friends and teachers are desired.

In the end, two statements from students that left the strongest impression will be mentioned:

- “The teaching and way of working as it is now is excellent, we have everything we need, we just need the will!”
- “Nothing can replace school, it can only help!”

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Using AI for Academic Benefits. Case Study with Students of SEEU in Tetovo

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Abstract If you had written down a question, in seconds the artificial intelligence platform ChatGPT would have collected it and written the material/content for you and students have started using this to write academic essays, term papers, and even degree theses. So, now the question is what to do about it.

Before looking at the solutions, it was decided to do done a small study with the students of my courses at Southeast European University in Tetovo. It was conducted research with 100 interviewees from all faculties at the University and were asked regarding the use of artificial intelligence in their studies and learning. Around 70 percent of them have admitted that they use artificial intelligence platforms, where they have obtained better grades. So, now the question is what to be done about it when we all know that the use of artificial intelligence without a strategy exposes citizens to risk. However, first were collected some data from students to see for what purposes in academia they use artificial intelligence. It will be presented some significant responses from students where they admit either to have used it or to be using it now during their studies. Then, based on that and after interviewing some experts from the computer science faculty we come up with some recommendations on how we can prevent students to misuse AI or minimize its use at least while doing the paperwork, like essay writing, articles or other written assignments.

Keywords and phrases: AI, academic benefits, paperwork, written assignments

1. INTRODUCTION

This work with the students and teachers is the best example of contemporary students' usage of AI at our University. It was demonstrated and illustrated how students benefit from AI and how they manage it. This case study raises important issues, not the least of which is whether or not we as a society or university can benefit more from AI rather than to be damaged from it. It may be useful for students and teachers to have some kind of picture of the use of AI so we know how to handle it. One good way to deal with something new is to expose first the students to this new digital trend through cases such as these collected in this article.

2. RESEARCH METHODOLOGY

“To travel illuminatingly is more important than to arrive...The route must take in all the most interesting points and yet maintain an overall sense of direction”

(David Pirie, 1953)

The purpose of this study was the provision of an overview of the usage of AI by our students at SEEU and its influence in the process of learning and assignments accomplishments. The specific objective was the identification of the ways students use AI and their perceptions regarding it.

In parallel, the analysis assesses the impact of AI on students learning in various faculties of our university and in the improvement of the students general learning capacity. Furthermore, the study should also endeavor to establish to what extent these informal discussions can contribute to promoting a useful AI usage among students. Students were interviewed on this question and their responses were written down. Actually, the

discussion was held in person and their general views and impressions were all put together to be analyzed and later to be interpreted and presented in the study.

Generally, in this study we use a mixed methodology, exclusively established quantitative and qualitative methods. The sample are teachers and students at SEEU. A semi structured interview was conducted with them and the data was collected from each of the study groups: students and teachers. The reason for using this type of interview was that, based on the qualitative results from those important themes have been derived in advance, a loose structure allows the interviewer to keep the interviewee focused on major questions of interest rather than, potentially, side-tracking onto issues that are not of direct concern for the study. It also leaves way for adding extra questions that may arise during the interviewing phase. The semi structured interview was designed based on indicative questions arising from early analysis of the results.

According to the Longman Dictionary of Applied Linguistics, an interview is “a conversation between an investigator and an individual or a group of individuals in order to gather information” (2002:271) is stated that there are many types of interviews: depth interviews, focused interviews guided interviews, structured interview and so on.

As for the data collection, the students were all from the Language Center and the data was analyzed using combined methods since the study is a combination of quantitative and qualitative method. The quantitative data was analyzed using Statistical package of Social Science (SPSS version 17) Following Dorney’s (2003) suggestion each student was given a number. As Singleton & Lengyel, (1995) states, content analysis involves the following steps: 1. To define the problem. 2. decide where the source of the material will be 3. Identify the categories or features that will be the focus of your research. So, all these steps were taken into account when the data was analyzed too. Similarly, Berg (2007), suggests that in content analysis the researcher should begin by looking for naturally occurring similarities and differences among things or classes; “... you look for similarities and dissimilarities-patterns-in the data”, but systematically.

3. COMPUTERS AND LANGUAGE LEARNING

Dornely & Schmidt (2001), cited in Ellis (2008), claim that the best intervention in language learning would be to improve the quality of teaching. They argue that making teachers responsible for their student’s success and motivation is the means to this improvement. As teachers, therefore, we should give our best to improve our teaching to keep pace with teachers across the rest of the world. At this point, however, it seems that increased recognition of the value of technology in supporting language learning is an essential strategy for awakening ourselves as teachers to the need to improve our teaching. As learning settings become increasingly internationalized, teachers and students are gaining access to new opportunities for language learning. With the assistance of technology, students are gaining access to innovative learning experiences and opportunities to assess their learning outcomes through real-time feedback. As Nelson & Oliver (2009) have observed, access to a variety of learning environments is like travelling to different places just to experience and see various cultures or meet various ways of living (p108).

In an American study (Cromwell, 1998) with 543 students and their teachers, teachers reported that students with laptop access and taught via internet were highly motivated and excited by the technology-supported learning. As one teacher reported, (computers have) created greater interest in research, writing and projects, Computers or AI lead to a sense of discovery every day, keeping students more focused and on a task”.

4. STUDENTS’ PERCEPTIONS AND ATTITUDES TOWARDS AI

In general, most students like we said earlier admit that they have either used AI or are using it while studying. To the question, which was anonymously asked: Do you use artificial intelligence for academic benefits, they answered “yes” around 70 percent. Around 46 % answered “no”. But I think that even these students use it, but they just do not want to admit it or they are afraid that they can be found and penalized for it.

1. Do you use artificial intelligence for academic benefits, and describe how?

64 students	yes/64%
36 students	No/46%

With the aim of creating a clear picture of this issue at SEEU, as we mentioned above, we conducted this conversation in the form of an interview with the students of our groups. Around 100 students from four groups were involved in the study and they all willingly participated in the interview.

The students were asked quite regularly about artificial intelligence and the question was straightforward, do you use artificial intelligence for academic benefits and how. In response to the question, they were free to express their opinion by answering “yes” or “no” and elaborate it a little. Indeed, most of the students answered the question based on their personal experience in the past and present. They answered the questions as follows and further elaborated their attitude.

Those we polled who said “no” mostly felt negative about AI. Students with “no” answer felt that looking things up at AI for whatever reasons is not learning but cheating. Here it is what they further elaborated with their negative response. Their responses are summarized and put in groups based on their general reasons:

Students of group/reason 1:

We don't and have not used AI because we think we will become lazier and more uncreative, everything will be handed to us on a platter, we will use only what was just handed over on a tray.

Students of group/reason 2:

What makes us human will be lost and if the soul of the person is going to be lost, then everything will be emotionless and people will lose the empathy.

Students of group/reason 3:

My generation that we are 19 or 20 years old may not rely so much on that artificial intelligence but the young generation seem that they are getting lazier and lazier and they would submit 100 percent to that intelligence.

Students of group/reason 4:

In reality we think we will become more stupid and lazier because there will be someone who will do our work for us, and everything will be through a computer, and the person will not try as hard as he should.

And the students who responded that they have used AI for academic gain or benefits, who were positive about it, said the following:

Students of group/reason 1:

If you are using mobile phones and other digital devices the artificial intelligence is already built into it but people do not realize that they are already working with artificial intelligence. So, we better accept and not resist, better to educate people how to use it.

Students of group/reason 2:

For me personally I think is sketchy but I think we need to get used to it because it's evolving through time. I think it's getting more popular among young people. I think it's really funny to use it because you don't know what to expect from it.

Students of group/reason 3:

"Each of us has a special style of writing and if we can explain that style with a few attributes, we can convey that to the robot and he can write texts as if we had written them and the professor won't even suspect it."

After these findings, where a great percentage of students explicitly expressed that they use AI for academic purposes and benefits, the question raised now is what to do about it. In our annual training sessions that we hold every beginning of academic years, were held many discussions and many things were said by teachers and academics in this regard.

5. TEACHERS' PERCEPTIONS AND ATTITUDES TOWARD AI

Most teachers admitted that they knew that ChatGPT existed and already reviewed a written work in English, Albanian or Macedonian written by Chat GPT. They were surprised, but some of them were also convinced

that they knew the writing style of their students well, so they would easily recognize that they did not write the text themselves.

So, the professors and the staff of the Faculty of Computer Sciences and Information Technologies (CST), who we contacted for this matter claimed that it is almost impossible to detect if something is plagiarized, if it is written by this artificial intelligence. And even if such a thing could be done today, it will be impossible in the future.

Most of the staff thought stated that "It's very difficult to check because until now students had the internet at their disposal, they could take things from Wikipedia, from tutorials and here you can search the internet to see if something has been downloaded but ChatGPT rewrites, retells, and even if you give it the same question four times, it will create a different text for you, and that text passes the plagiarism detection tools,"

6.USING AI FOR ACADEMIC BENEFITS

However, they still believe that we can benefit from artificial intelligence much more than harm us. "That's like asking me what damage a digitron could do fifty years ago when it first came into use. Of course, then mental abilities for calculations were valued, in order for the brain to work better. "We have lost some abilities with the digitron, but we no longer spend time on calculations, but on more advanced things," said the professor.

According to most of them, the tools will become more powerful and this is a harbinger of the time to come. Well, education and the whole society should adapt to the process.

Perhaps the question should be, how can we use that tool, that is, teach and direct students how to use it, to work more than they have been able to work so far. If they had to write code from scratch or a seminar from scratch, ChatGPT can give them a springboard and they can do something more complex or analyze a topic more deeply," added some other professors from CST.

They pointed out that young people must have developed critical thinking, because even this artificial intelligence is not always right and often convincingly improvises. Thus, someone who does not know will think that what he is reading is a fact. They believe that professors can also benefit from this tool and with the help of artificial intelligence they could have better materials, scripts, textbooks and presentations to better convey their knowledge to students.

CONCLUSION

Since as stated before, this study is exploratory, it is not easy to make generalisation. As Barcelos (2000) states, "it is up to the teacher to accept or not to accept the results (p118). The study contains quantitative data based on a relatively small sample and therefore it is opened to claims of bias on the basis that it may have unintentionally excluded less confident students or teachers. However, in general, the use of artificial intelligence (AI) in the learning process brings several benefits and challenges that can affect the way we learn. Here are some conclusions regarding this issue:

- Personalization of Learning: IA can provide personalized content for each student based on their needs and knowledge level. This makes the learning process more efficient and suitable for each individual.
- Access to Extensive Information Resources: Through AI, students have instant access to a large amount of information and educational resources, including articles, videos, and e-books.
- 24/7 Assistance and Support: AI systems can provide assistance and answers to students' questions at any time, helping them learn even outside of traditional school hours.

Here are some conclusions regarding its challenges and Potential Risks:

- Lack of Human Interaction, excessive use of AI can reduce the social and interpersonal interaction between students and teachers, which is an important aspect of developing social and emotional skills.
- Technology Dependence: Students can become technology dependent and lose the ability to solve problems autonomously without the help of AI.
- Inequality in Access: Not all students have the same access to advanced technology, which can increase existing inequalities in education.

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Self-Evaluation of Primary Schools in the Application of Information and Communication Technology

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Abstract. This paper presents research on the issue of self-evaluation in primary schools regarding the use of ICT. The focus is on investigating the current state in one school to assess existing conditions and identify key problems that needs to be addressed in the future. The research consists of examining a sample through surveys and evaluating the extent of ICT implementation in teaching. An anonymous survey was used, allowing the application of descriptive statistics to gather the opinions of school leaders, teachers, and higher-grade pupils and compiling the results into a report that provides an accurate representation of the current situation concerning the use of digital technology in the learning process.

Keywords and phrases: self-evaluation, information and communication technology, teachers, pupils, professional development.

1 INTRODUCTION

In contemporary society, the rapid advancement of information and communication technologies inevitably affects various segments of life, including education. Primary schools, as the foundation of an educational society, face challenges in adapting to new trends and a key factor in improving the quality of teaching is the successful integration of information and communication technology in classrooms. In order to achieve continuous improvement in the educational process, primary schools largely recognize the importance of self-evaluation as a tool for assessing their own work and achieving better results. Therefore, the evaluation of one's own work becomes an indispensable component in enhancing the quality of the educational process in primary schools.

Through self-evaluation, primary schools gain the opportunity to thoroughly analyze the effectiveness of their methods, as well as to monitor the impact of ICT on achieving educational goals. This process becomes even more significant when it is viewed in the context of integrating information and communication technologies into teaching. The use of ICT in the classroom presents new challenges for teachers, pupils, and school management, but it also offers new opportunities for improving the teaching process.

This study encompassed research conducted in a primary school with the aim of self-evaluating the application of ICT in teaching during the second cycle of education, considering the fact that modern technology is increasingly being recognized by teachers as an indispensable tool in the classroom. The attitudes and opinions of teachers, pupils, and school management regarding the use of information and communication and multimedia technologies in teaching were examined. To gather opinions and perspectives on the use of ICT in teaching, specially designed surveys were prepared, which were completed by all three groups of respondents, with the statements in the surveys tailored to each group. In this way, we

aim to contribute to obtaining a realistic picture of the application of ICT in the educational process during the second cycle of education at the Primary school "Olga PetrovRadišić" in Vršac.

2 THEORETICAL BACKGROUND

2.1 *Self-evaluation of teachers' work*

The issue of evaluating teachers' work has been present in education since its early beginnings. Although teacher evaluation existed in the past, it was not always as systematic as it is today.

The evaluation of teachers' work serves two key purposes: one is to promote the professional development of teachers, while the other aims is to assess their skills and competencies. Through the process of self-evaluation, teachers gain insight into the effectiveness of the activities they have implemented (Vulović&Milosavljević, 2007).

For the successful implementation of the self-evaluation process, the willingness of teachers is essential, as well as a genuine desire to reflect on their work. The process of self-evaluation in the educational process highlights the significance of two functions. The first function involves achieving goals through the use of appropriate tools, while the second entails opening a dialogue about priorities, objectives, and quality criteria for teachers' work (Živković, 2015).

In the focus of school self-evaluation, the following are most commonly found:

- "all activities implemented within the school's domain (cooperation with parents, excursions, teaching, extracurricular activities);
- the curriculum;
- the activities of participants in the educational process (teachers, pupils, educational staff, teaching staff);
- textbooks and accompanying materials." (Maričić, 2016)

In her research, author Stamatović emphasizes the importance of self-evaluation within schools as a useful and necessary tool for improving teaching practices. The results of her study show that as many as 95.7% of teachers indicated that the self-evaluation process is conducted in their schools. Most teachers participate in the school self-evaluation process occasionally (60.6%), while the majority engage in self-evaluation of their own work periodically (65.6%). The research also indicates that teachers who pursue further professional development and attend training sessions more frequently tend to check their own work more often. This suggests that development and training change teachers' mindsets and strengthen the need for ongoing self-reflection. Regarding self-evaluation methods, a significant number of teachers use personal journals and notes, and among the results presented by Stamatović, feedback from pupils (18.5%) and from colleagues (14.2%) is also significant (Stamatović, 2012).

In addition to the previously mentioned research presenting the findings of author Stamatović, Maričić's study from 2016 reveals different conclusions. The results of Maričić's research are in contrast to those presented by Stamatović. In her doctoral dissertation on the topic "Self-Evaluation as a Factor of Quality in Pedagogical Work in Schools," Maričić conducted a study that included 303 teachers. This study focused on their self-evaluation process. It highlighted that there is a lack of adequate implementation of self-evaluation in schools. A very small number of schools regularly conduct the self-evaluation process, and most teachers are not involved in this process. Furthermore, teachers are not fully familiar with the school's standards. The research findings revealed that teachers did not fully understand the role and significance of self-evaluation, but rather perceived it as an additional burden (Maričić, 2016).

3 RESEARCH METHODOLOGY

3.1 *The research problem*

At the primary school "Olga PetrovRadišić" in Vršac, there is a significant amount of ICT equipment. However, the main problem is how the school can monitor its application and progress over time,

particularly throughout the school year. The need for development and improvement of the teaching process must originate from the teachers who are expected to use this equipment in their work. In this way, the quality of the school's work can be enhanced, as well as the professional and personal development of each teacher. This highlights the importance of addressing this topic.

3.2 The research task

The research utilized an anonymous survey that will allow to determine the attitudes and opinions of teachers, pupils in the second cycle of education, and school administrators regarding the use of ICT in teaching. Subsequently, the results will be compiled into a report that will provide an accurate representation of the current situation regarding the application of digital technology in the learning process.

3.3 The research hypothesis

In the research conducted by the author of this paper, a survey was used to obtain a picture of the school's condition regarding the use of ICT in teaching through the application of descriptive statistics. At the beginning of the research, the following hypothesis was set: "Effective self-evaluation will contribute to obtain a realistic picture of the application of ICT in the teaching process in the second cycle of education and upbringing at the primary school „Olga PetrovRadišić” in Vršac."

3.4 The sample description

The main sample of this research consists of 80% of pupils from the higher grades, teachers, and school administrators who work at primary school "Olga PetrovRadišić" in Vršac. This means that the study involved 149 pupils, 22 teachers, and 4 school administrators, which is shown in Figure 1.

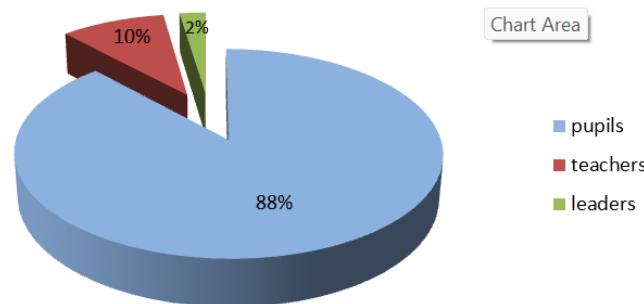


Figure 1. Percentage structure of respondents

3.5 Description of the conducted research and obtaining results

The first were analysed the attitudes of pupils regarding the use of ICT in teaching. By organizing the obtained responses and calculating the arithmetic mean for each statement (2024, June 12, Retrieved from <https://www.scribd.com/document/552251106/SELFIE-Prirucnik-Za-Skolske-Koordinatorere>), we arrived at the results presented in Figure 2, which show the pupils' responses to the given statements.

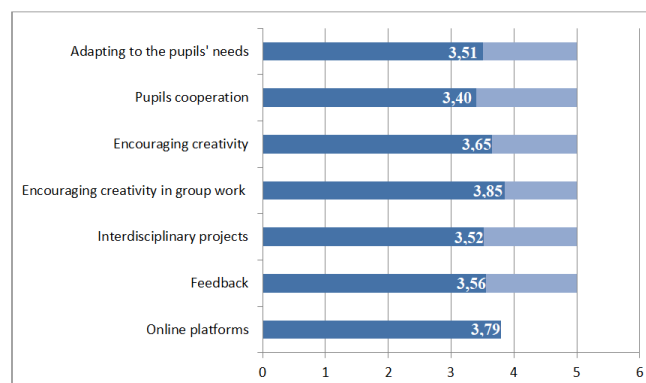


Figure 2. Average responses of pupils for each statement

The results obtained from the survey concerning pupils are presented in figure 2. As it can be seen, the varying ratings in the statements indicate an inconsistency in the approach to technology across different aspects of teaching. Digital technologies are most frequently used in situations where group work takes place and in learning through online platforms. On the other hand, it is surprising that pupils do not collaborate sufficiently when technology is utilized in teaching, meaning their mutual cooperation is not encouraged to the extent it should be. This is evidenced by the average score of 3.40. This rating is lower comparing to the scores for encouraging creativity, adapting to pupils' needs, working on interdisciplinary projects, and receiving feedback. This suggests that there is space for improvement to further encourage pupil participation. Overall, when considering all the statements, pupils are quite dissatisfied with the way digital technology is used in teaching, as the average score is only 3.61 out of a maximum of 5.

Figure 3 presents the results of the survey answered by teachers, specifically the average score obtained for each statement.

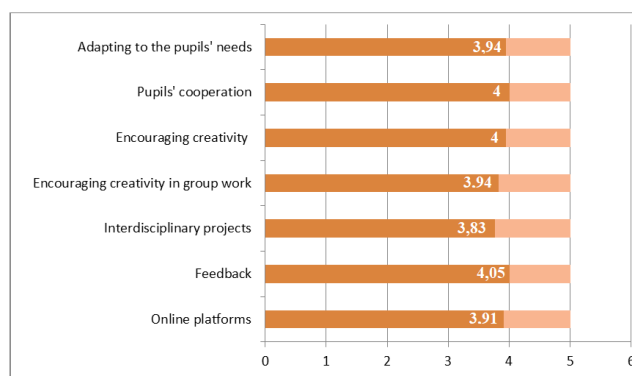


Figure 3. Average responses of teachers for each statement

This figure 3 shows that teachers, in general, rated themselves higher compared to the pupils' ratings. This may indicate that teachers have a positive opinion regarding the application of ICT in the teaching process. The highest-rated statement was about providing feedback to pupils through digital technologies, which received a score of 4.05. This rating can also be attributed to the COVID-19 pandemic, during which teachers at primary school "Olga PetrovRadišić" in Vršac worked online using Google Classroom, where they provided feedback to pupils along with other activities. This experience allowed teachers to establish a routine in their work, leading them to continue using some form of digital feedback. Additionally, teachers believe that they have a strong emphasis on using digital technology to encourage creativity and cooperation among pupils, which is confirmed by a score of 4. However, the results are slightly weaker when it comes to adapting digital technology to individual pupil needs, encouraging pupils for group work, and applying online platforms in teaching. This can be supported by the fact that there are various tools and digital textbooks available today that greatly assist teachers in these activities. Regarding the connection of different subjects, teachers believe there is some integration of various subjects through digital technologies, but it is not utilized sufficiently, and this statement received the lowest rating with an average score of 3.83. Overall, considering the figure 3 and the ratings of all statements, teachers assessed their view of ICT application in teaching with an average score of 3.95.

The next figure shows the evaluation of teachers by school administrators, specifically the average score obtained for each of the provided statements.

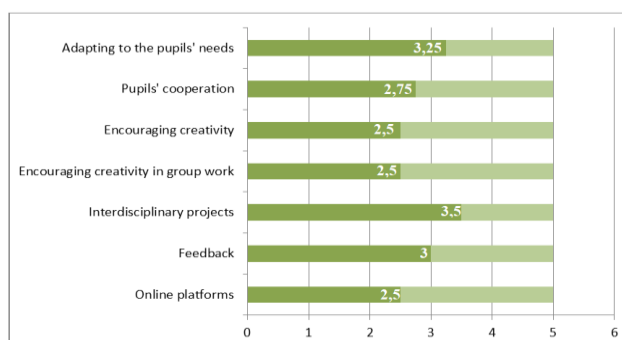


Figure 4. Average responses of leaders for each statement

From figure 4, we can observe that the obtained ratings are relatively low. Only two statements related to adapting to pupils' needs and the application of technology in interdisciplinary competencies exceed a score of 3. According to the school administrators, this indicates that teachers have adequately adjusted their use of technologies to meet individual pupil needs and are using them appropriately to connect interdisciplinary content. On the other hand, there are three statements, or areas of work, that received a low rating of 2.5. This shows that school administrators believe that teachers do not sufficiently encourage creativity, group work, and do not pay enough attention to online platforms when they work with pupils. Overall, the average score for all statements in the section where administrators express their opinions is 2.86.

Except this section, which presents the results of groups by statements from the survey, it is necessary to display the average score for each statement that resulted from the evaluations by pupils, teachers, and administrators. This will provide a realistic picture of the application of digital technologies at "Olga PetrovRadišić" and this will be shown in figure 5.

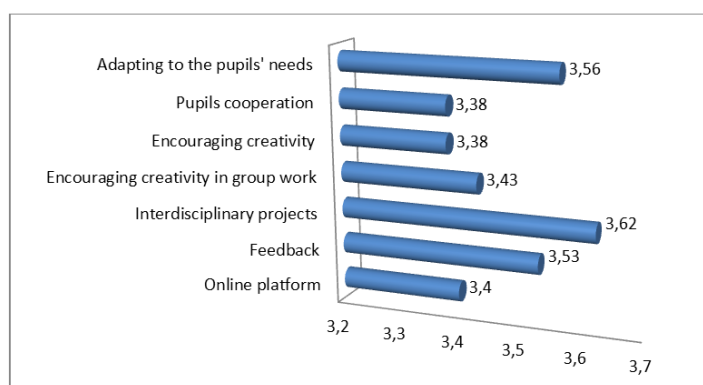


Figure 5. Average grade for each section

It can be seen that no area exceeded a score of 4. It is also noticeable that digital technologies are most frequently applied in connecting multiple subjects and their content. The next areas where ICT is applied is in providing feedback on pupil progress and adapting to the pupils' needs. These are areas where teachers had to navigate well during the COVID-19 pandemic, using Google Classroom and Viber to inform pupils about their progress. The ratings indicate that this practice has partially continued. All other areas received average scores below 3.50, which suggests that there is significant space to apply digital tools in teaching in the future.

Below is the figure 6 which show the average score for all statements overall, reflecting the views of all three groups of respondents on the application of digital technologies in teaching.

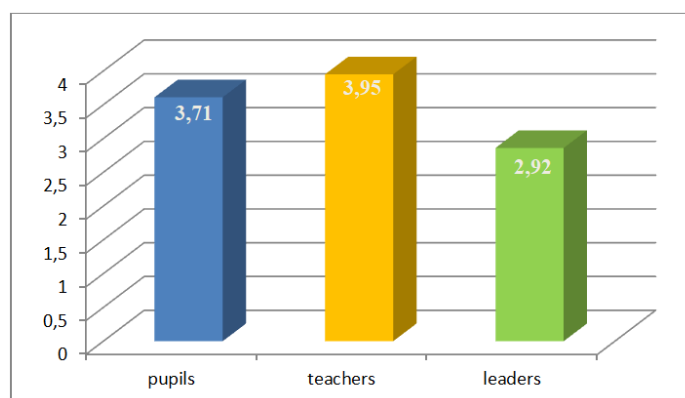


Figure 6. Comparison of results by user groups

The results presented in figure 6 indicate that the application of digital technologies in teaching at primary school "Olga PetrovRadišić" Vršac can be viewed in two parts. In the first part, the results show that pupils and teachers believe that digital technologies are used to a good measure in teaching. Teachers, in particular,

have a very positive attitude towards the application of ICT in education, while pupils were somewhat more moderate. On the other hand, the results from the administrators are low and do not align with the results from the other two groups of respondents, which stems from their dissatisfaction with the current application of ICT in teaching.

4 CONCLUSION

The research hypothesis aimed to determine the profile of the school regarding the application of ICT in the teaching process in the second cycle of education and upbringing at the primary school "Olga PetrovRadišić" in Vršac. The results indicated that the application of digital technologies is not sufficiently represented in teaching. This is highlighted by the average score obtained from all three groups of respondents, which is only 3.53. From this, it can be observed that the application of digital technologies is still an insufficiently implemented activity in the teaching process. What we do not know well, we will clearly not apply, and thus it is logical to expect that the process of self-evaluation of ICT application in teaching is perceived as a form of new administrative burden for teachers, without considering the essence of this process.

The low result can also be justified by the nature of humans, which is difficult to engage in what they do not know sufficiently well. Therefore, teachers do not apply ICT extensively in their classes with pupils. More experienced teachers tend to use traditional methods, believing that their experience is the best teacher. However, it is important to find ways to motivate teachers to change their attitudes, step out of their comfort zones, and attempt to introduce changes in their work. There are always resistances to change, but it is crucial to confront them and find adequate ways to overcome them (2024, may 27). Retrieved from <https://unesdoc.unesco.org/ark:/48223/pf0000382765>. For change to happen, it is necessary to raise the level of motivation among all participants in education (2024, june 3). Retrieved from <https://iste.ascd.org/transformational-learning-principles>. Positive success is achieved when there is a willingness for change and a motivation for improvement within the collective.

Research on the self-evaluation of elementary schools regarding the application of ICT can significantly contribute to understand the current situation in our educational system. The research would enable the identification of the current state of how ICT is utilized in elementary schools, including available resources, technical equipment, and necessary training for teachers. Additionally, through this type of self-evaluation, schools can assess how the implementation of ICT affects the educational process, including pupils engagement, teaching quality, and learning outcomes. If the research were conducted in multiple schools, it would allow for comparative analysis that could identify regional differences and best practices in the application of ICT across our country.

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Integrating Supply Chain Education into STEM Programs

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Abstract. This paper explores the integration of supply chain education into STEM programs to enhance interdisciplinary skills and better prepare graduates for the evolving demands of the modern workforce. As industries increasingly require professionals with both technical expertise and knowledge of supply chain management, there is a growing need to combine these fields within academic curricula. The paper identifies three main elements essential to this integration: curriculum development and design, institutional support and resources, and industry and community engagement. Each element is supported by sub-elements that provide practical approaches, such as creating interdisciplinary courses, promoting faculty development, and forming partnerships with industry. The study also outlines strategies for governments, enterprises, and educational institutions to support this integration through funding, policy frameworks, collaborative initiatives, and investment in digital tools. The findings suggest that integrating supply chain education into STEM programs can enhance the employability and versatility of graduates, while also contributing to more resilient and innovative industries. The proposed theoretical model emphasizes a holistic approach that relies on cooperation among various stakeholders to successfully align education with the needs of the global economy.

Keywords and phrases: Education, Supply Chain Management, STEM Integration, Interdisciplinary Learning, Curriculum Development

1 INTRODUCTION

Supply chain management (SCM) has become increasingly important in today's STEM (Science, Technology, Engineering, and Mathematics) careers, reflecting its growing relevance in a technologically advanced and interconnected world. While traditionally associated with business disciplines, supply chain principles are now recognized as essential in STEM fields [1]. Modern supply chains rely heavily on technological innovation, engineering solutions, and data analytics to optimize operations, minimize costs, and ensure efficiency [2]. This intersection makes it valuable for professionals in STEM careers to be knowledgeable in supply chain concepts. For instance, engineers must optimize manufacturing processes and logistics, while data scientists analyze patterns and trends to make informed decisions that support supply chain activities.

Integrating supply chain education into STEM curricula provides numerous benefits, such as developing a broader skill set among students [3]. While STEM programs traditionally focus on building deep technical expertise, modern industries increasingly demand professionals who can bridge technical knowledge with business acumen. Introducing supply chain concepts helps fill this gap by providing a broader perspective on how technical skills can be applied in real-world business contexts. Furthermore, supply chain education fosters critical thinking, adaptability, and problem-solving abilities [4]. These competencies are vital for navigating uncertainty, optimizing resources, and managing risks in STEM roles, enhancing students' competitiveness and value in the job market.

However, several challenges arise in integrating supply chain education into STEM programs. A significant barrier is the lack of faculty expertise in supply chain topics within traditional STEM departments. Additionally, aligning supply chain education with the specific objectives of different STEM disciplines can be complex, as curricula often prioritize core technical skills. Limited resources and institutional constraints further complicate this integration, requiring substantial investments in new courses, faculty training, and digital tools [5].

Strategies for overcoming these challenges include developing interdisciplinary courses, fostering partnerships with industry experts, and using digital tools to provide hands-on experiences. Schools can offer flexible learning pathways, such as specialized tracks or minors, to allow students to gain expertise in supply chain management without detracting from their primary studies [6]. Partnerships with companies can provide internships, mentorship, and real-world projects that align education with industry needs, enhancing both student learning and employability.

Integrating supply chain education into STEM programs offers a strategic approach to preparing students for a future where interdisciplinary knowledge is crucial. With careful planning and collaboration, academic institutions can enhance the relevance of STEM education while meeting the needs of an evolving workforce.

2 THE ROLE AND BENEFITS OF INTEGRATING SUPPLY CHAIN MANAGEMENT IN STEM CURRICULA

Supply chain management (SCM) is becoming increasingly important across various STEM (Science, Technology, Engineering, and Mathematics) fields, highlighting its relevance in a world that is both technologically advanced and interconnected. Although traditionally viewed as a business function, SCM principles are vital in STEM professions due to their focus on optimizing operations, managing resources, and navigating complex logistical challenges [7]. For instance, engineers must not only design and manage efficient production lines but also consider procurement, inventory management, and logistics to ensure cost-effectiveness. Similarly, data scientists play a crucial role in analyzing large datasets to predict trends, optimize supply chain processes, and make data-driven decisions, which are critical in today's global economy.

Integrating SCM into STEM curricula offers multiple benefits that can enhance the skill set of graduates. STEM programs have historically emphasized technical proficiency, but modern industries increasingly seek professionals who combine technical expertise with a strong understanding of business operations. Supply chain education introduces competencies such as project management, data analysis, risk assessment, and strategic planning, providing a broader, more comprehensive perspective on how STEM skills apply in real-world contexts [8]. These interdisciplinary capabilities not only enhance problem-solving abilities but also foster adaptability, enabling graduates to manage uncertainties and resource constraints more effectively. This combination of technical and business skills makes students more versatile and competitive in the job market, particularly in fields where supply chain efficiency is crucial, such as technology, engineering, and manufacturing.

However, integrating SCM into STEM programs poses several challenges. A significant barrier is the lack of faculty expertise in supply chain topics within STEM departments. Many STEM educators may not have sufficient background in SCM, making it difficult to design and teach interdisciplinary courses effectively. Additionally, aligning SCM education with existing STEM curricula can be complex due to the need to balance technical content with supply chain principles [9]. STEM programs often prioritize core competencies in specialized areas, which can make it challenging to incorporate new topics without overburdening students or diluting the focus on essential skills. Limited institutional resources and resistance from departments accustomed to traditional curricula further complicate these efforts.

To address these challenges, innovative strategies are required, such as developing interdisciplinary courses that blend STEM and SCM content, allowing students to see practical applications of their technical skills. Schools can offer specialized tracks, minors, or electives focused on supply chain management, providing flexibility for students to tailor their education to align with their career goals. Collaborations with industry can also play a crucial role by offering guest lectures, internships, and project-based learning opportunities, enabling students to gain hands-on experience and insights from professionals.

By strategically integrating supply chain education into STEM curricula, institutions can prepare graduates for a dynamic job market where interdisciplinary knowledge and skills are increasingly essential.

3 CHALLENGES AND STRATEGIES FOR INTEGRATING SUPPLY CHAIN EDUCATION INTO STEM PROGRAMS

Integrating supply chain education into STEM programs presents several challenges that must be carefully addressed to achieve successful implementation. A primary obstacle is the lack of faculty expertise in supply chain management within traditional STEM departments. Many STEM educators lack experience with

business-related subjects, such as supply chain management, making it difficult to design and teach courses that effectively combine both technical and supply chain content. This gap can result in resistance from faculty members who may view supply chain topics as outside the scope of their traditional focus areas [10]. Additionally, there are complexities in aligning supply chain education with the specific goals and requirements of different STEM disciplines. For example, engineering programs prioritize technical skills like materials science and thermodynamics, which may leave little room for incorporating new supply chain topics without overloading the curriculum.

Resource constraints pose another significant challenge. Introducing new courses or modules often requires substantial investment in resources, including funding for faculty training, developing new courses, and acquiring digital tools like simulation software. Many institutions may lack the financial capacity or infrastructure to support such initiatives. Administrative hurdles, such as obtaining curriculum approvals, can further slow the integration process, while time constraints in already packed STEM programs make it difficult to introduce new content without overburdening students.

Addressing these challenges requires a multifaceted strategy that involves developing interdisciplinary courses, fostering institutional collaboration, and leveraging industry partnerships. Creating interdisciplinary courses that blend STEM and supply chain management topics can provide students with a holistic view of how their technical skills apply in real-world business contexts [11]. Joint courses co-taught by STEM and supply chain faculty can offer diverse perspectives and encourage students to appreciate the interconnectedness of these fields. Additionally, providing specialized tracks, minors, or electives within STEM programs focused on supply chain management offers flexibility, enabling students to gain relevant knowledge without sacrificing their core technical education.

Industry partnerships are crucial for providing practical learning opportunities. Collaborations with companies can offer guest lectures, mentorship, internships, and real-world projects that allow students to apply their knowledge to real supply chain challenges. Such partnerships help bridge the gap between theoretical knowledge and practical application, ensuring that the curriculum remains relevant to industry needs. Establishing industry advisory boards can provide ongoing guidance on curriculum development, ensuring alignment with current market demands and trends [12].

Institutions can further enhance integration efforts by investing in digital tools and simulation software that provide hands-on learning experiences. These technologies allow students to engage with supply chain scenarios in virtual environments, fostering critical thinking and decision-making skills without requiring extensive physical resources. Additionally, creating a supportive institutional culture that values interdisciplinary education is essential. Offering professional development for faculty, recognizing collaborative teaching efforts, and incentivizing innovation in curriculum design can help overcome resistance and build support for supply chain integration within STEM programs.

Successfully integrating supply chain education into STEM curricula requires a strategic approach that combines curriculum innovation, resource investment, and collaboration between academic institutions, industry partners, and faculty.

4 THEORETICAL MODEL



Figure 1. Model for successful integration of supply chain management into STEM programs

The sub-elements of each main element showed in Figure 1. Model for successful integration of supply chain management into STEM programs in the model work together to create a cohesive framework for integrating supply chain management into STEM programs. Curriculum development and design depend heavily on interdisciplinary course creation, which provides a foundation for blending supply chain management with STEM subjects. Competency-based learning objectives ensure that students gain the skills needed in both fields, reinforcing the relevance of the integrated curriculum. Flexible learning pathways, such as specialized tracks or minors, allow students to tailor their education, while digital tools and simulations offer practical, hands-on experiences that enhance their understanding of complex supply chain processes. Continuous curriculum evaluation and feedback ensure that the program remains up-to-date and aligned with industry needs, encouraging iterative improvements.

Institutional support and resources act as the enabler of this integration process. Faculty development and training are essential for equipping educators with the knowledge to deliver interdisciplinary content effectively. Funding and resource allocation are critical for providing the financial support needed to develop new courses, invest in technology, and maintain infrastructure. Interdepartmental collaboration facilitates the sharing of expertise and resources, creating a multidisciplinary environment conducive to integrated education. Infrastructure and technology investments, such as software and laboratories, provide the tools necessary for hands-on learning and research, further supporting the integration of supply chain management into STEM programs.

Industry and community engagement serve as the integrator, connecting academic learning with practical applications. Partnerships with industry experts bring real-world perspectives into the classroom, enhancing the curriculum with insights from current supply chain practices. Internship and co-op opportunities offer students valuable hands-on experience, allowing them to apply their knowledge in real-world settings and

develop skills that are directly relevant to the job market. Industry advisory boards provide guidance on curriculum development, ensuring that it aligns with current industry trends and demands. Career development and networking events help students build connections with potential employers, understand career paths, and develop the competencies needed for success.

Successfully integrated supply chain management into STEM programs is the ultimate goal, achieved through the interplay of the three other main elements. Enhanced employability and career outcomes are a direct result of well-designed curricula, strong institutional support, and industry engagement. Positive feedback from industry partners and employers reflects the effectiveness of the integrated education model, while the development of innovative projects and research demonstrates the program's impact on fostering creative problem-solving and innovation. Sustained institutional commitment and expansion indicate that the integrated approach is viable and scalable, ensuring its continued success and growth.

5 GUIDELINES AND RECOMMENDATION

Based on this paper we can provide following guidelines and recommendations for implementing supply chain management into STEM programs. Here are following guidelines and recommendations :

- Governments should allocate funding and grants specifically for interdisciplinary education initiatives. This financial support can help academic institutions develop new courses, provide training for faculty, and invest in necessary digital tools and resources.
- Education policymakers should develop frameworks and guidelines to promote the inclusion of supply chain education in STEM curricula. These frameworks can encourage schools and universities to create interdisciplinary programs that meet both technical and business education standards.
- Enterprises can form partnerships with educational institutions to provide guest lectures, internships, and mentorship opportunities. These collaborations allow students to gain practical experience and learn directly from industry experts, enhancing their readiness for the workforce.
- Businesses should support ongoing professional development for STEM faculty by offering access to industry seminars, workshops, and real-world projects. This involvement ensures that educators are up-to-date with the latest trends and practices in supply chain management, which they can then integrate into their teaching.
- Students and professionals should pursue certifications or additional training in supply chain management to enhance their interdisciplinary skill set. Taking online courses, attending workshops, and engaging in lifelong learning opportunities can make them more versatile and competitive in the job market.
- Academic institutions should create a culture that values interdisciplinary education by recognizing and rewarding faculty who engage in collaborative teaching and curriculum development. Offering grants, incentives, and professional recognition can encourage more educators to participate in and support these efforts.

6 CONCLUSION

The sub-elements of each main element work together to integrate supply chain management into STEM programs effectively. Curriculum development relies on creating interdisciplinary courses that blend supply chain and STEM content, broadening students' perspectives. Competency-based learning objectives help students develop skills relevant to both fields, while flexible learning pathways, like specialized tracks or minors, allow for tailored education. Digital tools and simulations enhance hands-on learning, and continuous evaluation ensures alignment with industry needs.

Institutional support and resources serve as the enabler for this integration. Faculty development is essential for equipping educators with the knowledge to teach interdisciplinary content, while adequate funding and resource allocation provide the necessary financial backing. Interdepartmental collaboration fosters a multidisciplinary environment by sharing knowledge and resources. Investments in infrastructure and technology, such as simulation software and laboratories, support effective teaching and research in integrated programs.

Industry and community engagement act as the integrator, connecting academic learning with practical applications. Partnerships with industry experts bring current supply chain practices into the classroom, enriching the curriculum. Internship and co-op opportunities provide students with practical experience and help develop in-demand skills. Industry advisory boards guide curriculum development to align with market needs, while career events connect students with potential employers.

The successful integration of supply chain management into STEM programs leads to several positive outcomes. Improved employability and career prospects for graduates, along with positive feedback from industry partners, demonstrate the program's effectiveness in preparing students for the workforce. The development of innovative projects and research reflects the program's role in fostering creative problem-solving and innovation. Sustained institutional commitment and expansion indicate that this integrated approach is both viable and scalable, meeting the evolving needs of education and industry.

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E-learning Platforms for Studying Cloud Technologies

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Abstract. This paper presents the usage of e-learning platforms for studying cloud technologies. Several possibilities for implementing e-learning are discussed here. The first possibility is to implement a special learning platform dedicated to cloud technologies using some of the known learning management systems. Another possibility for learning cloud technologies is by using special learning platforms which are provided by the cloud service providers. An overview of some learning platforms is given here.

Keywords and phrases: E-learning, Learning Management Systems, Cloud Computing, Cloud Technologies, Cloud Service Providers.

1 INTRODUCTION

Electronic learning or e-learning is the delivery of learning materials in digital form and their access via the Internet. The resources or the learning objects should be digitalized in a suitable format. In context of the resources, special attention should be paid to the content and the way of presenting the material to the end users. It is good to use a resource format that is widely used, so that the resources can be opened and viewed without problems. The main purpose of e-learning is to enable access to resources from anywhere and anytime. This was the biggest obstacle in traditional ways of learning, where we are often limited in terms of the resources or the time to access them.

Many educational institutions use e-learning to provide a continuous learning process for the students. The benefits are mutual because the students can constantly learn while the professors would have prepared students especially for those subjects where prior knowledge is required. The need for e-learning was especially highlighted during the period of the Covid-19 pandemic when most of the universities in the world switched to distance learning (Zdravev, Boev, & Dzidrov, 2020, p. 115). There were universities that were ready for this change in the educational process, but some had to adapt to the new situation and introduce e-learning. In this way, the professors could share the learning resources, while students had constant access to them from anywhere. Those universities that had not implemented e-learning platforms also faced the moment of technology adoption. If the professors have not used an e-learning system before, in that case, time was needed for appropriate training. This also applies to students who had to accept this new way of acquiring knowledge by using digital resources. However, even for those universities that had implemented e-learning platforms, training was again needed to refresh knowledge about the possibilities offered by the platforms and the correct delivery of learning materials. In addition to this, the creation of appropriate learning resources is also extremely important. There are many different types of resources that can be used for learning such as presentations, books, videos, simulations, images, audios and so on. Professors must decide which resources are the most suitable for conveying the material to students. Here, of course, their creativity comes to the fore, but also their commitment to the creation of digital resources that would be helpful for students.

In addition to educational institutions, many companies also use e-learning to improve the skills of their employees. Instead of employees attending face-to-face training, the courses can be organized through e-

learning and video conferencing platforms. The benefits of this are great for both employees and companies. Employees do not have to leave their workplace and attend classical courses. The companies, on the other hand, would have employees who will not be absent too much from their jobs and will still invest in improving their skills and competences (Alsharhan, Salloum, & Shaalan, 2021, p. 928). They must contribute to the development and improvement of their employees to remain competitive in the field in which they operate. Companies should respect the concept of lifelong learning of their employees, thus investing in the human capital they have (Beqiri, & Mazreku, 2020, p. 94). E-learning platforms can encourage the applicability of this concept in a real environment.

In (Cloke, 2024), we can see some e-learning statistics. It is predicted that by 2030 the e-learning market will grow exponentially reaching over 545 billion. Trends show growth in each new year. In the education sector e-learning is the quickest growing market since 2000 with a 900% growth rate. It is worth mentioning that mobile learning with 23% annual growth is the fastest growing trend in the e-learning field, which only confirms the importance of using mobile devices in the learning process. 90% of students prefer e-learning over traditional classroom learning. This is primarily due to the flexibility and affordability that this form of learning provides. E-learning is used by 90% of companies that conduct some form of training nowadays. For comparison, in 1994 only 4% of companies used some kind of e-learning. More than 40% of Fortune 400 companies use e-learning regularly for their activities. As many as 94% of employees stated that they would like to work in a company that invests in training and development. All these statistics only confirm the importance of e-learning in education and corporate environment.

Cloud technologies are significantly used nowadays. Many organizations and institutions use cloud services offered by cloud service providers. Most of them have also migrated their applications to the cloud (Zdravev, Velinov, & Spasov, 2021, p. 100) (Filatov, 2019). Some of the benefits of cloud technologies for organizations are scalability, flexibility, cost savings, automatic updates, disaster recovery and continuous security. That is the reason why cloud technologies are quite current and used nowadays. Subjects related to cloud technologies are part of university curricula. Some of the companies that use cloud technologies also provide training for their employees. For easier mastering of the material, greater flexibility and acquisition of skills, educational institutions and companies can use some of the e-learning platforms offered by cloud service providers or their own platforms.

The existing research papers are mostly concerned with the application of cloud technologies in the process of creation of e-learning platforms, but not with the creation of specific e-learning platforms for studying cloud technologies. In this regard, in this paper we present several e-learning platforms for this purpose. The rest of the paper is structured as follows. Section 2 presents the concept of Learning Management Systems (LMS) and some well-known LMS. Section 3 is for the application of e-learning in studying cloud technologies. Section 4 presents some learning platforms specially designed for acquisition cloud skills and knowledge. The last Section 5 is a conclusion of our work.

2 LEARNING MANAGEMENT SYSTEMS

Learning Management System (LMS) is a software primarily used for creation, management, and distribution of educational content. These systems are the basis for the development of electronic learning. There are multiple Learning Management Systems (LMS) in use nowadays (Ouadoud, Nouha, & Tarik, 2021, p.60). Some of them are open source and can be used for own purposes, while others are not open for use by the general public and are paid. Open-source platforms usually have a community that is quite active in terms of discovering and fixing bugs, informing about new versions, sharing experiences, etc. This is significant for developers and users of these platforms in case of facing problems or timely information regarding the technology. It is worth mentioning here that many plugins have been developed for the open-source platforms. This is due to the openness of the code and the activity of the community. By using the platforms and according to the needs, innovative ideas for additional features often appear among the users that were not included in the basic version. The plugins significantly help in enriching the functionalities of the e-learning platforms. Some of the paid platforms have a trial period in which they can be used freely, for example 1 year, but after the trial period for their use, the users must pay. In the basic versions, some of the e-learning platforms do not offer all the functionalities. These are usually more advanced functionalities, and we must pay for their usage.

Some of the most used LMS today are Moodle, Canvas, Sakai, Blackboard, ATutor, MyGuru2, Claroline,

Connect Edu, SumTotal and so on. According to (Bouchrika, 2021) the three most used LMS in the USA are: Canvas with 30.77% market share, Blackboard with the same percent of market share and Moodle with 25.27%. In (Benta, Bologa, & Dzitac, 2014, p. 1170) we can see one case study for the application of e-learning platform in higher education. It is presented an example of usage of the Moodle e-learning system, as a basic tool for student motivation and in solving independent or collaborative tasks. Ouadoud et al. (2016) present a comparative analysis of the following free LMS tools: ATutor, Claroline, Moodle and Sakai. Elbasuony et al. (2018) explore the knowledge, attitude and usage of Blackboard learning system. According to this study the students have excellent knowledge and attitude for e-learning and the Blackboard platform. Garcia et al. (2021) describe the adoption of Canvas tool for e-learning and the acceptance of LMS as a web-based platform. The students perceived this tool as an important platform for improving their learning, especially because of the functionalities that are easy to understand, easy access to courses and assistance with given tasks.

Typically, in an e-learning system there are multiple roles that can be assigned to users. Each role has its own defined permissions regarding access to resources or the platform. Common roles are administrator, professor, and student. The administrator is responsible for maintaining the e-learning platform, assigning permissions to the users and for technical support. The professor creates digital content or learning resources for the courses he teaches. He is also in charge of their logical ordering in terms of the content of the course in the e-learning platform. The students enroll in the courses and have access to all learning materials.

The general architecture of an e-learning system can be seen in Figure 1. The users, through devices such as laptops, tablets or mobile devices have access to the presentation layer. The core functionalities of the system are in the e-learning platform layer. This layer communicates with the database layer to store user records and manage settings.

Some of the features of e-learning platforms are:

- Ability to create courses for appropriate subjects
- Creation of tests and electronic testing
- Management of digital learning resources
- Modules for collaboration between the professor and the students such as messaging components, forums, videoconferencing tools, etc.
- Monitoring and evaluation of students' progress according to their activity on the platform
- Modules for assigning tasks and evaluation of solutions submitted by the students
- Provision of special tools for performing simulations, editors, online compilers, etc.

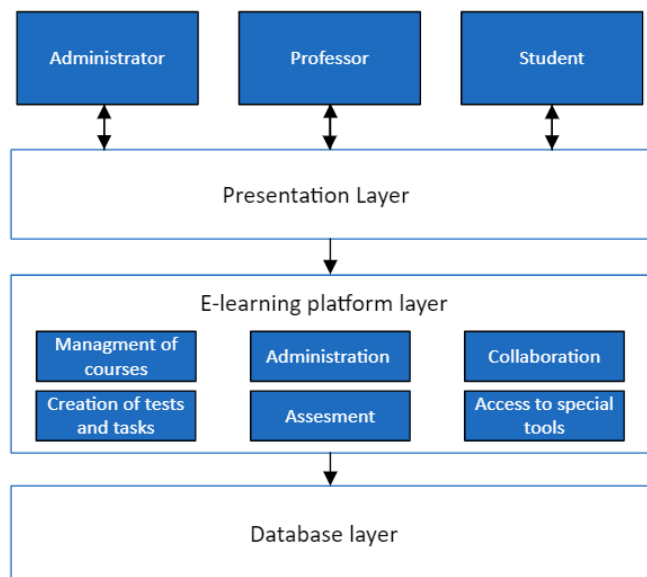


Figure 1. E-learning system architecture

All functionalities provided by e-learning platforms contribute to creating an integrated environment for students in which they can learn, share, ask and create. In addition to the students, there are also benefits for the professors who, through the platform, provide a special place where they can upload the materials, communicate with the students, review assignments, and keep up with the progress of the students.

3 APPLICATION OF E-LEARNING FOR CLOUD TECHNOLOGIES

Cloud technologies have been applied in many fields of society nowadays. Considering the novelties they offer, their application in education is significant from the point of view of studying but also in the context of their usage in the implementation process of educational software (Velinov et al., 2023, p.67). Additionally, they can be used to provide IT infrastructure such as access to processing, storage, or networking resources. Ferri et al. (2020) describe the usage and adoption of cloud computing in high tech startups. They also provide

a case study in which they explore some of the features of cloud such as reduced costs, greater opportunities, scalability and so on. Sultan (2014) presents some of the challenges and opportunities of the usage of cloud computing for healthcare provision. An exploratory case study for adoption of cloud computing in public sector is given in (Zhao et al., 2013, p.42). This study also presents some guidelines for evaluation of cloud services in decision making process of the governments.

Considering the wide application, the study of cloud technologies is important. In education, cloud technologies are mostly studied and used in higher education. They are studied less in primary and secondary education (Velinov et al., 2023, p.68). Considering the applicability, more attention should be paid to these technologies in both primary and secondary education. In this way, the students would be prepared with knowledge about these technologies, and this would benefit them in higher education but also in their application in different use cases. Curricula in higher education should also include more subjects related to cloud technologies or their application in some of the related subjects. In context of this, the students will be able to acquire cloud computing skills.

E-learning can have a significant impact in acquiring knowledge about cloud technologies. As it provides access to learning resources at any time and from any place, this can help the interested individuals. This is especially true for people who are employed and who cannot attend regular training to acquire knowledge and skills in cloud technologies. In this regard, standard learning management systems can be used to create courses dedicated to the cloud. The digital learning content will be published in the courses and the users will be able to login and learn with a progress that they can dictate to themselves. This provides great assistance and flexibility in mastering the course content.

4 LEARNING PLATFORMS FOR CLOUD TECHNOLOGIES

Due to bringing cloud technologies closer to users, cloud service providers often present special platforms for learning cloud technologies. In context of this, Amazon Web Services (AWS) has made AWS Academy LMS available to educational institutions (Figure 2).

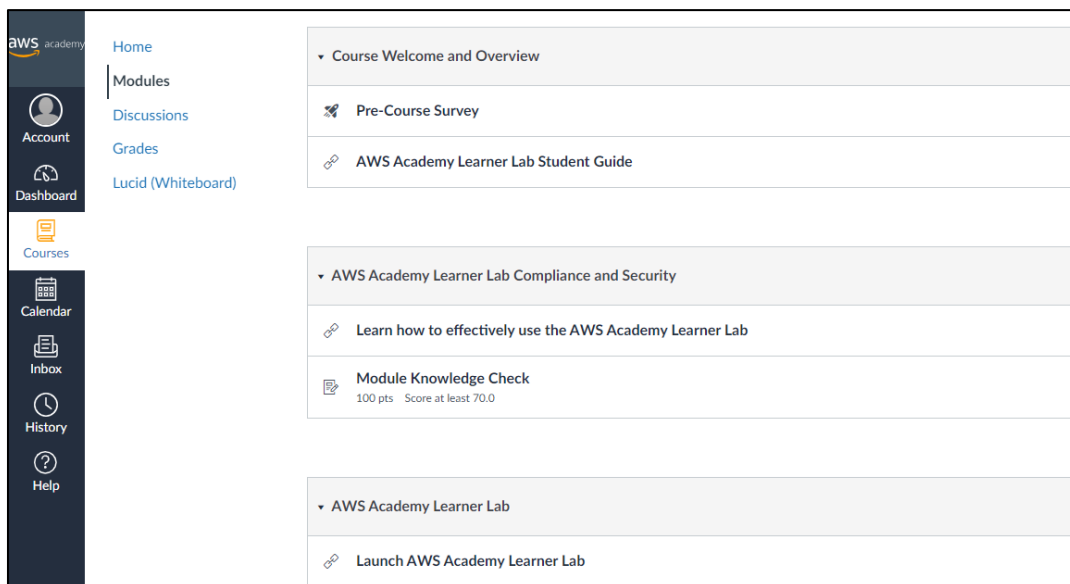


Figure 2. AWS Academy LMS

This learning platform allows creation of courses from multiple categories that are related to basics of cloud computing, data engineering, cloud security, microservices, machine learning, natural language processing and so on. What is particularly interesting and provided by this platform is the creation of courses from the AWS Academy Learner Lab category through which access to AWS services is provided. The students have a certain free budget for using the services for 1 year. All this significantly contributes to practical work with cloud technologies and is helpful for professors and educational institutions.

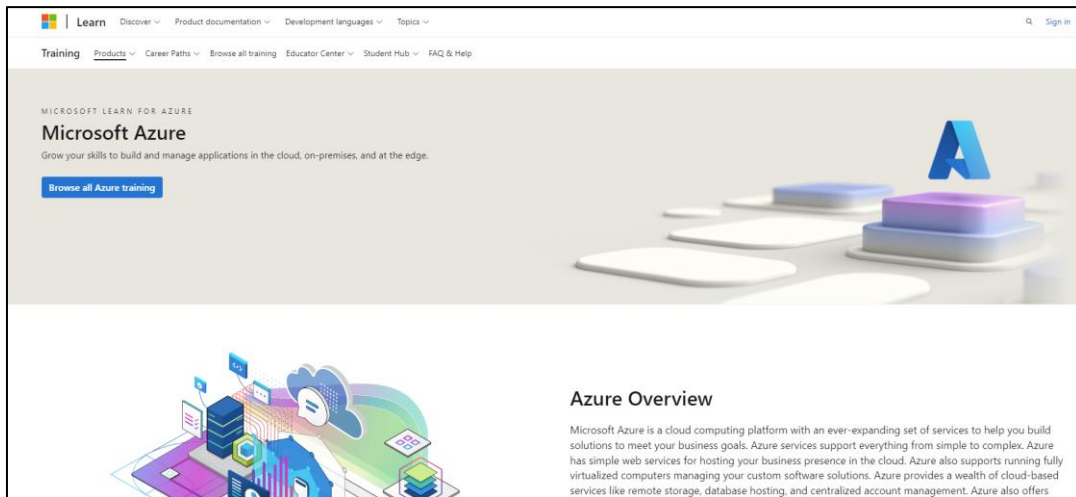


Figure 3. Microsoft Learn Platform

Microsoft has the Microsoft Learn Platform for learning cloud technologies offered through Microsoft Azure cloud service provider (Figure 3). This platform has guiding training paths at its own pace. In terms of the learning process this platform also provides great flexibility. Microsoft Learn has several learning paths related to fundamentals of Microsoft Azure, Azure architecture and services, Azure management and governance, Cloud Adoption Framework, Microsoft Azure Well-Architected Framework and so on. The platform also offers the possibility of certification and instructor-led training. There is also an option for Microsoft Virtual Training Days which provides free training in multiple languages on different topics. Another functionality that is offered by Microsoft is Azure for Students. With it, the students can register and get a free budget to use Azure cloud services by logging in with their university or school email. There is also an option to create Azure free account which gives students free credits to use Azure services for 1 year.

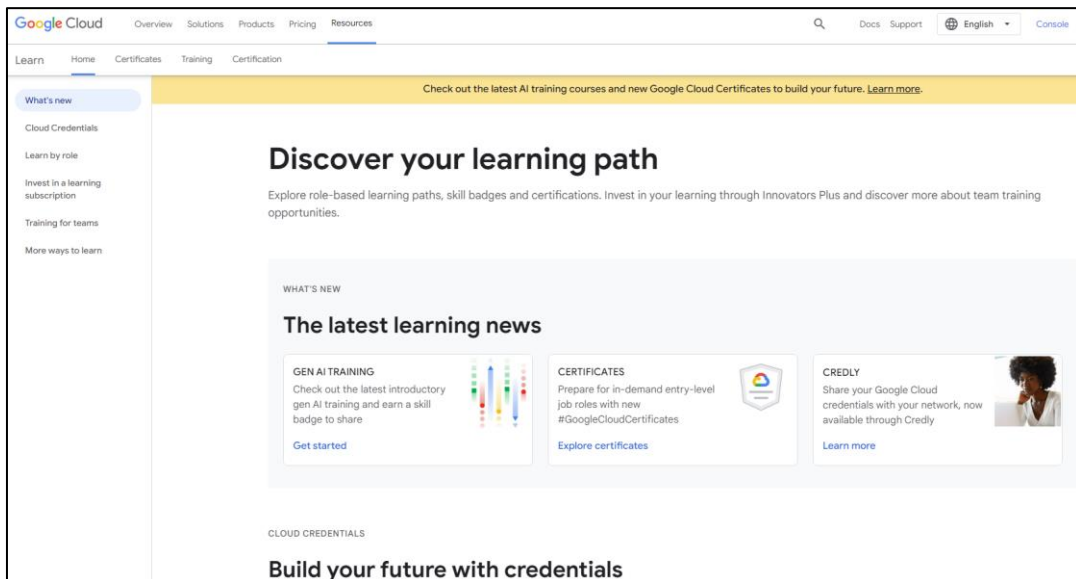


Figure 4. Google Cloud Learn Platform

For learning of Google Cloud Platform services, we can use the Google Cloud Learn Platform (Figure 4). It provides a lot of features for the users such as learning paths, training, certification, learning by role, training for teams, online events, blogs and so on. This platform can be used by both beginners and advanced users who want to acquire new skills. Another option for students is Google Cloud for Students program, which offers free credits for usage of Google Cloud services, resources, and digital learning content.

5 CONCLUSION

Cloud technologies are being used significantly nowadays. They are used in different areas which confirm their application. In this regard, there is a need to create e-learning platforms that are dedicated exclusively to learning cloud technologies. This is the reason why in this paper we present some e-learning platforms for cloud. Some of the most used LMS can be used for creation of cloud-dedicated e-learning platforms. Cloud providers also offer learning platforms that can assist users in acquiring knowledge and practical skills related to cloud technologies. The e-learning platforms can be beneficial for students who can access the learning materials at any time and from anywhere. The access to cloud services through e-learning platforms can significantly help students enrich their practical skills and expand their knowledge of cloud technologies.

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Implementation of Artificial Intelligence in Teaching and Learning

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Abstract. Artificial intelligence brings significant changes to the educational system, enabling personalized learning, efficient analysis and task automation. This paper presents current implementations of Artificial Intelligence in education, the technologies enabling this application and the experiments conducted in educational environments. The focus is on adaptive systems, virtual tutors and learning analytics, which contribute to improving the educational process. Additionally, the paper analyzes ethical issues, such as student privacy and algorithmic bias, as well as future challenges in artificial intelligence implementation. Through the analysis of various studies and experiments, the paper highlights the potential of Artificial Intelligence in enhancing the educational process and achieving better student outcomes, emphasizing the need to balance technological support with fostering student independence. This review provides a foundation for further research and application of artificial intelligence in education, aiming to create more accessible and efficient educational environments.

Keywords and phrases: artificial intelligence, education, personalized learning, learning analytics.

1 INTRODUCTION

Artificial intelligence (AI) is becoming an essential part of many sectors, and education is not an exception. The application of AI in education enables personalized approaches to learning, optimization of teaching materials and improvement of the teaching process efficiency (Luckin et al., 2016). In the current educational system, where individual student needs are often overlooked, AI offers opportunities to tailor content based on student progress and learning styles (Holmes et al., 2019).

In addition to personalization, AI also contributes to the automation of administrative and evaluative tasks. This reduces the burden on teachers, allowing them to focus more on the creative aspects of teaching, such as interacting with students and adapting teaching methods (Woolf, 2010). The application of learning analytics enables teachers to monitor student progress and identify areas where students struggle. Based on the collected data, AI systems can predict learning issues before they become serious, allowing for earlier intervention (Baker & Inventado, 2014).

However, there are challenges in implementing AI in education, including ethical concerns such as student privacy and algorithmic bias. Furthermore, further research is needed to adapt AI systems to various educational environments and cultures (Aoun, 2017).

The paper can be summarized as follows. The introduction is followed by the literature overview. The third section describes various AI technologies in education. The fourth section presents the experiments and results. Section five is the conclusion.

2 RELATED WORK

This section will provide a brief overview of the related works. Karamazova Gelova et al. (2023) analyzed the difficulties that new students at technical faculties face when they are learning about complex numbers, despite their previous education in high school. Through statistical analysis, specific challenges and gaps in understanding this abstract mathematical concept were identified. As a solution, the use of GeoGebra software for visualization and learning facilitation is proposed, which can significantly improve the understanding and problem-solving related to complex numbers. The paper emphasizes the need for innovative approaches in education to enhance students achievements in mathematics. Brtka et al. (2023) explore the impact of artificial intelligence on online education, highlighting its ability to personalize learning, automate teacher tasks and enhance student engagement. Authors predict significant benefits from the application of AI in educational environments, such as customized assessments and increased interaction. Additionally, the paper compares evaluations of knowledge retention and interaction between AI systems and human instructors. Finally, the technical and ethical challenges accompanying the implementation of AI in educational processes are emphasized. Huang et al. (2021) evaluated the application of artificial intelligence in education, highlighting its positive impact on the quality of teaching and learning. Authors demonstrated how artificial intelligence can enhance methods such as adaptive learning, assessment and virtual classroom management, thereby increasing student engagement and creativity. Additionally, the paper addresses the challenges that artificial intelligence may face in the educational sector in the future, emphasizing the importance of reforming the educational system through the introduction of innovative technologies. This review provides insights into the potential of artificial intelligence to transform educational practices. Iqbal et al. (2014) assessed the role of artificial intelligence in education, underscoring its benefits in advancing personalized learning and the effectiveness of educational practices. The paper addressed the challenges that artificial intelligence faces during implementation, including ethical dilemmas and the need for teacher training. Furthermore, the importance of developing effective approaches for introducing artificial intelligence into educational systems is emphasized. Through this analysis, the work provides insights into the opportunities and limitations that artificial intelligence brings to the transformation of education. Krstić et al. (2022) explored the impact of artificial intelligence on the educational process, highlighting its applications such as personalized support for students and the automation of tasks like grading. The paper emphasized the advantages of artificial intelligence, including increased efficiency and flexibility to educational needs. Additionally, there is a growing interest in artificial intelligence in education, with predictions of a significant rise in the use of this technology in the coming years, especially in light of the challenges brought by the COVID-19 pandemic. This paper contributes to the understanding of how artificial intelligence can transform traditional educational practices. Kamruzzaman et al. (2023) investigated how the introduction of artificial intelligence and the Internet of Things (IoT) can transform education, particularly through personalized and interactive learning experiences. The results showed that artificial intelligence can analyze data about students to tailor content and provide real-time feedback. The IoT enables the monitoring of student engagement, which further enhances the learning process. Authors highlighted the importance of ethically using these technologies to ensure equal access to education for all students.

3 THE TECHNOLOGIES OF ARTIFICIAL INTELLIGENCE IN EDUCATION

The technologies of artificial intelligence applied in education encompass various software platforms, data analysis algorithms and interactive learning support systems (Fig.1). Key technologies include intelligent tutoring systems, learning analytics systems and adaptive learning platforms.

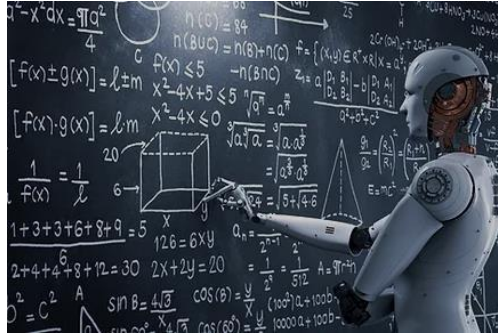


Figure 1. Artificial intelligence in education

Intelligent tutoring systems provide personalized support throughout the learning process to the students. They analyze each students learning style and adjust the pace and content of lessons according to their needs. For example, a system like Assessment and Learning in Knowledge Spaces uses advanced algorithms to assess students knowledge and tailors the material to ensure optimal progress (Luckin et al., 2016). Learning analytics enables the collection and analysis of data about students, which can be valuable for making decisions about their educational pathways. The data is used to predict student success, identify weaknesses and recommend additional learning resources (Ferguson, 2012).

Adaptive learning systems, such as Knewton, use data to tailor learning experiences for each individual. These systems analyze student behavior, knowledge levels, and interests to provide personalized courses (Siemens, 2013).

One of the formulas used in adaptive systems is Bayes' theorem:

$$P(K|A) = \frac{P(A|K) \cdot P(K)}{P(A)} \quad (1)$$

where $P(K|A)$ is the probability that a student possesses the knowledge K , given the answer A , where $P(A|K)$ is the probability that the student gives answer A , assuming he has knowledge K . $P(K)$ denotes the prior probability that the student possesses knowledge K , and $P(A)$ refers to the probability of answer A (Lambert, 2018).

The Fig. 2 shows the different applications of AI in education in five main areas. These areas include: Intelligent Tutoring Systems, Curriculum Planning, Learning Analytics, Content Recommendation, Chatbots and Virtual Assistants.

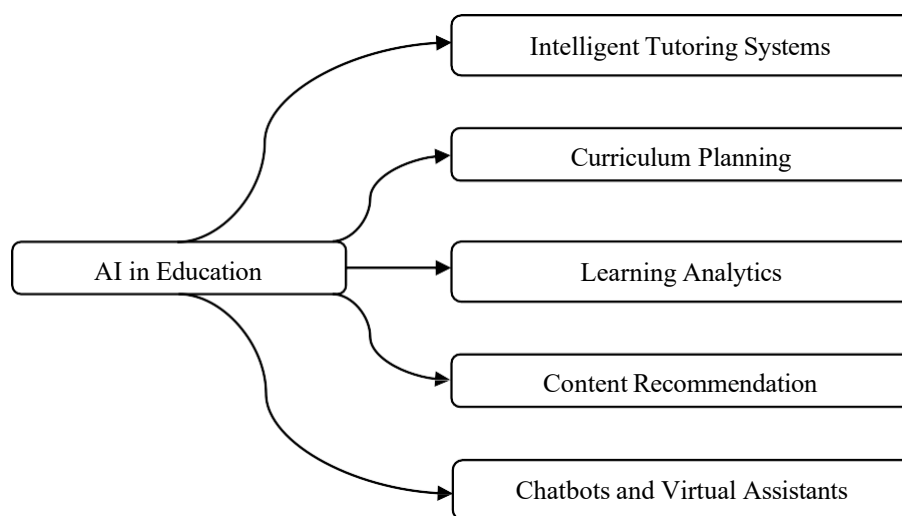


Figure 2. Different applications of AI in education

4 EXPERIMENTS AND RESULTS

In practice, the use of AI in education yields varying results depending on the educational context and the level of technology implementation. In many cases, personalized AI-based systems achieve significantly better outcomes among students compared to traditional learning methods. In a study conducted at universities, students who used adaptive learning platforms achieved better exam results and demonstrated a higher level of motivation for learning (Luckin et al., 2016).

The implementation of AI in education has proven to be a factor that increases student engagement in various subjects. For example, AI-based platforms have been widely adopted in language learning, where systems like Duolingo and Babbel provide customized lessons based on students' results and progress. Studies show that students who use these platforms learn the language faster compared to those who follow traditional methods (Holmes et al., 2019). These systems utilize machine learning algorithms to analyze mistakes in real time and adjust future lessons accordingly, optimizing the learning process for each individual student.

One of the experiments conducted in high schools showed that students using adaptive platforms, such as the Assessment and Learning in Knowledge Spaces system, achieved 20% better results on final tests compared to the control group, which used traditional learning methods. This system adapts content to the needs of students and provides real-time feedback, thereby improving the learning process. Additionally, systems like Assessment and Learning in Knowledge Spaces offer constant assessment, providing both students and teachers with insight into progress. This type of continuous evaluation motivates students to remain engaged in their studies, as they are constantly aware of their progress and the areas where they need to improve (Holmes et al., 2019).

In the field of vocational education, AI technologies have also been used to improve learning outcomes. In one case, an AI-based simulation was implemented in a technical training program for engineers. The simulation replicated real scenarios, allowing students to apply theoretical knowledge in a practical environment. Students who used the simulation demonstrated significantly better problem-solving skills compared to those who attended traditional lecture-based training programs. This experiment showcased the potential of AI not only to enhance academic learning, but also to prepare students for practical challenges in various industries (Luckin et al., 2016).

On the other hand, some studies show that students have expressed concern about the reduction in communication with teachers. There is a fear that the excessive use of technology could diminish the human aspect of education, making it less engaging and personalized. This dilemma between the benefits and potential limitations remains a key challenge for the broader implementation of AI in educational systems. However, hybrid education models, where AI is used to supplement traditional teaching methods rather than replace them, have shown promise in addressing these concerns. A study conducted in blended learning environments revealed that students prefer using AI for organizational tasks and specific feedback, while still relying on teachers for guidance and moral support (Woolf, 2010).

In a study based on data collected through the analysis of educational processes, it was found that AI-based learning analytics systems can predict potential problems before they escalate, allowing for timely teacher intervention. This contributes to a reduction in failure rates among students and increased support for specific needs. Educational process analyses also provide valuable insights into student engagement and success patterns, which can be used to enhance teaching methods. In a large experiment, AI-based analytics systems were able to predict school dropout rates with over 85% accuracy, enabling teachers to intervene promptly and provide targeted support for at-risk students. This approach resulted in significant improvements in student retention (Holmes et al., 2019).

AI is increasingly being used to assess student work, especially in situations where manual grading is time-consuming. AI-powered automated grading systems have demonstrated accuracy comparable to that of teachers while providing students with detailed feedback more quickly. This has proven particularly useful in subjects like essay writing, where AI systems can analyze grammar, coherence, and argument structure, helping students improve their writing skills over time (Luckin et al., 2016). Although concerns about the fairness and transparency of AI-based grading systems persist, these tools have the potential to enhance the efficiency of educational assessments, especially in large educational institutions with limited resources.

Although the implementation of AI in education continues to yield positive results, its application must be carefully managed to ensure that technology complements rather than replaces traditional educational methods. The balance between AI-driven personalization and human interaction is crucial for the holistic development of students, and further research and experiments are necessary to fully harness the potential of AI in education.

5 CONCLUSION

This paper explores the implementation of AI in teaching and learning, emphasizing its role in transforming the educational system. The application of AI facilitates changes in learning, efficient data analysis, and task automation, leading to improvements in educational processes. Experiments have shown, that adaptive systems and virtual tutors can significantly enhance student engagement and learning outcomes. However, challenges such as ethical dilemmas and the need for adaptation to various educational environments remain important factors to consider for the future implementation of AI in education.

FUTURE WORKS

In future studies, new approaches and AI technologies in education should be explored, focusing on ethical aspects such as student privacy protection and system accessibility. It is also important to develop methods for implementing AI in various educational environments and cultures to ensure equal access to educational resources. Investigating the impact of AI on the role of teachers and the classroom atmosphere is crucial for understanding how to best utilize these technologies to enhance the educational process.

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Architecture and Development Methodologies Systems: A Machine Learning-Based Approach

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Abstract. This paper explores the architecture and development methodologies of modern recommender systems with a special focus on machine learning-based approaches. Advances in technology and the role of machine learning in advancing personalized recommendation systems are explored. The paper also analyses the importance of personalization and improving user experience through efficient recommendation algorithms. In addition, challenges in data collection are explored, including the cold start problem and ethical aspects. Special emphasis is placed on collaborative filtering and content-based filtering, studying the advantages, disadvantages and hybrid approaches that combine these techniques. The paper emphasizes the importance of monitoring system performance and iterative improvement to maintain the quality of recommendations over time. It is concluded that a comprehensive approach, adaptability of the system and balancing between different techniques is key to developing effective recommendation systems that meet the evolving needs of users.

Keywords and phrases: machine learning; development of modern systems; data collection; data analysis.

1 INTRODUCTION

The recommendation system is a sophisticated information system whose main goal is personalized offering of entities, such as products, services or content, to users based on their individual preferences, behavioral history and demographic characteristics (Ganesh, A. et al. 2022, Dau A., Salim N. 2020). This system relies on complex machine learning algorithms to analyze and interpret large datasets, identifying hidden patterns and connections between user actions. At its core, a recommendation system functions as an intelligent intermediary between users and diverse entities, providing personalized recommendations that improve user experience and drive engagement (Thomas, B. et al. 2021, Khanal, S. et al. 2020). Key elements of the system include collection and analysis data, application of algorithms for predicting preferences, as well as continuous updating of the model to adapt to evolving user needs. Station recommendation system indispensable instrument in the modern digital environment, providing personalized and relevant recommendations that make it easier for users to decide among the many available options.

1.1 The importance of personalized recommendations

The importance of personalized recommendations in the modern digital environment is essential, providing a range of benefits to both users and providers of services or products (Ameisen, E, 2024). Personalized recommendations are adapted to the individual preferences and needs of the user, which results improved user experience. Users experience the platform or service as customized, which increases their satisfaction and loyalty. In the digital age, where options are often overflowing, personalized recommendations help users make informed decisions faster decisions. The time required for searching and filtering information is reduced, and users are exposed to relevant content. By providing recommendations that are directly relevant to users, the level of engagement increases. Users are more likely to interact with the platform or service which demonstrates an understanding of their needs (Ameisen, E. 2024, Neupane, D. et al. 2020). In the field

of digital marketing, personalized recommendations allow targeting specific groups of users. This increases the effectiveness of advertising, because ads are shown to the most likely interested.

Users are more inclined to stay on a platform or use a particular service if they the system regularly surprises with relevant recommendations. This contributes to long-term loyalty user (Hussien, F. T. A., et al. 2021). A recommendation system can track changes in user preferences over time, adjusting recommendations to reflect new interests or user needs. U sectors of online commerce, personalized recommendations can directly contribute to increased sales through product suggestions that are highly relevant to the user. It enables service providers more precise targeting of resources, because personalized recommendations allow you to focus on that which is really important for every user (Kiran R. et al. 2020). Overall, personalized recommendations play a key role in transforming the digital experience, making it richer, more efficient and tailored to the individual user needs.

The aim of this research is to analyze the architecture and development methodologies of modern recommender systems, with a particular focus on the application of machine learning. Specifically, the goal is to explore how different recommendation techniques (collaborative filtering, content – based filtering and hybrid approaches) can contribute to the personalization of recommendations and improvement of the user experience, while addressing data collection challenges such as the “cold start” problem and ethical aspects of data processing. The paper emphasizes the importance of iterative system enhancement to maintain the quality of recommendations over time, by optimizing the balance between different approaches to archive high accuracy and relevance of recommendation.

2 RELATED RESEARCH

An overview of approaches to recommender system development includes various methodologies and techniques that are used in the construction of these systems (Afsar, M. et al. 2022, Bhanuse, R., et al. 2021). The development of a recommendation system is a complex process that requires careful data analysis, implementation of appropriate machine learning algorithms and continuously adapting to changes in user preferences.

Collaborative filtering filter- This approach is based on similarity between users(Afsar, M. et al. 2022, Segaran, T. 2024). Model predictions are constructed using information about the behavior of similar users in order to identified target user preferences. There are two basic types of collaborative filters filtering - user-based filter and product-based filter.

Content-based filter- This approach analyzes the characteristics of the product or content in order to made recommendations (Afsar, M. et al. 2022, Zhang, Q. et al. 2021). The system identifies similarities between products based on their features or user preferences, and then recommends products that are similar to those has already been used or rated positively by the user.

Hybrid approaches- Combine collaborative filtering and content-based filtering to took advantage of both approaches(Ganesh, A. H., et al. 2022, Afsar, M. M. et al. 2022). These hybrid models provide better performance in situations where one approach alone may not be sufficient.

Deep learning - The application of deep learningneural networks for developing recommendation systems is becoming increasingly popular (Afsar M, et al.,). These models can efficiently learn complex patterns from large data sets, providing highly personalized recommendations.

Time-Dependent Models- Involve tracking changes in user preferences over time times(Ganesh, A. H et al. 2022, Afsar, M. M et al. 2022, Bhanuse, R., et al. 2021). These models take into account temporal factors in order to adapt recommendations according to the evolution of user interests. Geolocation aspects - Integration of geolocation data can add a dimension of context to recommendations. The systems take into account the user's location and provide personalized suggestions based on local preferences or available resources.

Online Learning- Uses continuous data collection and real-world model training time in order to keep the system up-to-date and adapt to dynamic changes in the user preferences (Afsar, M. M et al. 2022, Wang, S., et al. 2021). The approach to recommender system development depends on the specifics of the application and nature data. A combination of different approaches can provide the most effective results in creation personalized and relevant recommendations for users.

States the following, algorithms for collaborative recommendation filtering are typical personalized recommendation approaches widely used in many online-commerce recommendation systems. It's a method that depended on three rules: people have similar favorites and attention, their favorites and attention are stable, and their choices can be inferred by marking their historical searches. Thus, a collaborative algorithm is constructed on the user's action to find direct neighbors for each and predict his interests according to his neighbor's interests or preferences. Example: Amazon has implemented collaborative filtering to recommend products to customers (Segaran, T. 2024).

The review of the author's work (Zhang Q, et al. 2021) is a systematic review literature in the field of different recommendation systems. Applications, techniques are discussed here recommendations and machine learning algorithms. This paper describes how RSs can provide personalized recommendations to online users so they can reduce time and effort in choosing items or services according to their wishes. The RS study found that the recommendation system is an effective tool for suggesting service recommendations to users. Social media like Facebook, Google, Amazon and Twitter have proven that well designed RS can provide accurate information to a large number of users. The collaborative filtering algorithm based on collaboration is the most commonly used technique on Amazon.com. This technique can independently measure the number of users and the number of items. When we use collaborative filtering based on items, we make a comparison between purchased and rated user items with related items. Then similar items are added to the recommendation list. According to the study, it was observed that the main problems in item-based RSs are the influence of context awareness, the loss of transparency of neighbors is rare (Zhang Q et al. 2021).

In this paper (Bhanuse R, et al. 2021) it is presented a hybrid recommendation system that combines the desirable features of collaborative filtering as well as content-based filtering, for the task of recommending online learning systems to user content/curriculum. Our recommendation easily includes changing user profiles (how students go through course content) and also generalize different content sources (courses that taught by different departments) and types. They applied the system to a real data set that includes 111 students organized in interdisciplinary groups. Our results show the clear advantages of our hybrid recommendation system has, showing more than a 30percentage point improvement over conventional techniques filtering. The first step in our hybrid recommendation system is to run and collect predictions from both collaborative filtering and content-based filtering schemes. Of course, the predictions of both approaches vary. Let's say we get two sets of predictions A and B, from collaborative filtering and content-based filtering respectively.

- a. First we calculate $S=A \cup B$ (we set up the union operation over both referrals).
- b. For each recommended item, we examine the content vector to check whether the clusters are incontent vectormatch user preferences (again using cosine similarity) obtain a set P.
- c. For each item in the set S, we also check the consistency of the collaborative filtering results with general model of access patterns of other users. We only accept an item if it is a probability approaches greater than a threshold (usually 0.7). This results in the set K.
- d. They return the union of two sets $(P \cup K)$ as a result of their hybrid recommendation system (Bhanuse R, et al. 2021).

In this paper (Wang, S., et al. 2021) it is presented a new, hybrid recommendation system tailored for e-learning platforms. It is concluded that traditional content filtering and collaborative filtering approaches are not well suited to the e-learning platform (low hit rate). However, our hybrid approach achieves higher hit rates (and lower reciprocal hit-ranks), indicating the advantages of using both user preferences and content filtering and combining the best of both worlds for better performance. More than 30% improvement over state-of-the-art content and collaborative filtering approaches, which enable online learning practitioners to more precisely design recommendation systems for their platform.

3 DATA COLLECTION AND ANALYSIS

3.1 Importance of relevant data

In the context of recommender system development, the importance of relevant data cannot be overemphasized, since data are the basic building blocks that enable models to provide accurate and useful recommendations to users (Hussien, F. T. A., et al. 2021, Khanal, S. S. et al. 2020, Cakir M., et al. 2020). Key aspects that highlight the importance of relevant data in this context include: The quality of the data directly affects the accuracy of the recommendation system. If the data is accurate, voluminous and relevant, the models will be better able to identify patterns and provide reliable recommendations users (Neupane. D. et al. 2020). Relevant data enables recommendation systems to create personalized recommendations that reflect the user's actual preferences and interests. What they are the more comprehensive the data, the more effective the personalization.

“Cold start” is a challenge in recommender systems when they have limited information about a new user or product (Kiran, R. et al. 2020, Segaran, T. 2024, Khanal, S. S. et al. 2020). Relevant data helps in overcoming this challenge, providing enough information to properly understand the new one entity. Quality data helps reduce the impact of noise and inaccuracy in models (Neupane, D., et al. 2020, Zhang, Q., et al. 2021). Well-processed data provides a clean basis for training the model, thus the resistance of the system to unwanted effects increases. When users get referrals, especially in the context of content-based filters, it is important that the recommendations are understandable. Relevant data allows for better modeling of models that provide clear and meaningful recommendations. Contemporary recommendation systems face dynamic changes in user preferences and offerings products or services. Constantly updated relevant data allows systems to track and reflect those changes in real time (Thomas, B. et al. 2021, Ameisen, E. 2024). Machine learning algorithms depend on quality training data. Relevant data allows algorithms to better generalize from a pattern in the data, leading to improved performance in various scenarios. Processing and using relevant data in accordance with ethical guidelines helps build user trust in the system. Transparency in the use of data additionally supports an ethical approach to system development for recommendation. Overall, the importance of relevant data in recommender system development stems from the fact that this data serves as the basis for creating intelligent models that can adequately understand, anticipate and adapt to individual user needs (Bhanuse. R. et al. 2021).

3.2 Data types for model training

Properly selected and carefully prepared data is crucial for the efficient operation of the recommendation system. The variety of data provides models with a good basis for learning and generalization (Ameisen, E. 2024, Kiran, R. et al. 2020, Afsar, M. M. et al. 2022, Khanal, S. S. et al. 2020). Different kinds of data are used to train the model, ensuring breadth of information and coverage. Some of key types of data in training a recommendation system model include: Information about user activities, including searches, products viewed, ratings, purchases and more interactions. This data about user behavior provides insight into their preferences and interests. Demographic data includes information about users such as age, gender, geographic origin and other socio-demographic characteristics (Segaran, T. 2024, Wang, S., et al. 2021). These data supplement understanding the user's context. Attributes of products, content or entities that are recommended. These data help with content-based filtering and may include descriptions, categories, keywords, or other characteristics. Information about the time when users performed certain activities. Analysis of weather data allows models to identify seasonal patterns, trends and changes in preferences over time (Segaran, T. 2024, Zhang, Q. et al. 2021). User or product location data may provide additional context in recommendations. For example, they can be used to customize recommendations in according to local preferences or offers. Information about the user's connection to others on the platform or social networks. Social data may include friendships, mutuals interests or interactions with other users. User ratings or product reviews provide direct feedback on satisfaction or dissatisfaction. This data is often used in collaborative filtering filters. Information coming from external sources, such as weather conditions, news, social trends or economic situation. The integration of this data can improve the system's ability to adapt to changes in the environment (Hussien, F. T. A., et al. 2021, Wang, S., et al. 2021). Transaction Information users, especially relevant for e-commerce platforms. This data includes information about purchases, prices and price preferences. Information that is constantly updated and refers to the user's current activities. Real-

time data enables systems to track changes in user behavior in real time (Cakir M., et al. 2020). The combination of these different types of data contributes to the creation of a rich and comprehensive set data for training the recommender system model. This variety allows the models to provide personalized and relevant recommendations that reflect the complexity of user preferences and context.

4 DATA SHARING AND PERFORMANCE EVALUATION

4.1 Splitting into a training set and a test set

Separating the data into a training set and a test set is a key development practice recommendation systems based on machine learning (Zhang, Q. et al. 2021, Khanal, S. S. et al. 2020, Cakir M., et al. 2020). This step enables the evaluation performance of the model, providing a reliable estimate of its ability to generalize to the unseen data. Key aspects of this process include (Wang, S. et al. 2021, Cakir M., et al. 2020): The primary objective of separating the data into a set for training and testing set is to enable the model to learn certain patterns from the training data and then check your effectiveness on data that you didn't see during training. This helps in evaluate the generalization of the model (Neupane, D., et al. 2020, Kiran, R. 2020). The data is usually divided into training and testing sets in a certain ratio, for example, 80% data for training and 20% for testing.

This ratio can vary in depending on the size of the data set and the specificity of the problem. Random selection of data when separation helps eliminate any potential biases or ordering in the data (Bhanuse R, et al. 2021).

This is important to ensure representativeness of the training set and the test set (Bhanuse, R., Mal, S., et al. 2021), (Cakir M., et al. 2020). If you face the problem of imbalance in data classes, it is important to preserve that imbalance in the in the training set and in the test set. This helps the model learn and evaluate effectively real world performance. Special attention can be paid to stratification during separation data, especially if you have multiple classes or categories. Stratification ensures that the proportions class conserved in both sets. For added reliability, validation techniques can be used (Neupane, D. et al. 2020, Zhang, Q., et al. 2021, Wang, S., et al. 2021).

This involves multiple iterations of splitting the data into different training and testing sets in order to received a more comprehensive evaluation of the model. After training, the model is evaluated on a test set in order to obtain an objective assessment of its ability to generalized (Bhanuse R, Mal S, 2021). These performances help identify the effectiveness of the model in solving real problems. It is important to avoid leakage information from the test set to the training set, which could result in overoptimization model. The test data should represent the actual conditions that the model may encounter. Separating the data into training and testing sets is a key step in validation performance of recommendation system models (Thomas, B., et al. 2021, Ameisen, E. 2024). This process helps build reliable and efficient models that are capable of providing accurate recommendations in real-world conditions.

4.2 Metrics for system evaluation

Evaluating a recommender system involves using different metrics to evaluate it accuracy, relevance and model performance (Ameisen, E. 2024, Kiran, R., et al. 2020, Wang, S., et al. 2021), (Cakir M., Oguducu S., Tugay R. 2020). Accuracy is measured as the ratio of correct recommendations entities (eg., products) in relation to the total number of recommended entities. The precision formula is (Khanal, S. S., et al. 2020, Cakir M., et al. 2020):

$$prec. = \frac{\text{number of trail recommendations}}{\text{total number of recommended entites}} \quad (1)$$

Recall measures the system's ability to identify all relevant entities among all real one's relevant entities. The recall formula is:

$$recall = \frac{\text{number of trail recommendations}}{\text{total number actually of recomm.entites}} \quad (2)$$

The F1-score is a harmonious middle ground between precision and responsiveness and provides a balanced approach model evaluation. The formula for F1-score is:

$$F1 = 2x \frac{precision \times recall}{precision+recall} \quad (3)$$

MAP measures the average accuracy of recommendations for different user queries (Wang, S., et al. 2021, Khanal, S. S., et al. 2020, Cakir M., et al. 2020). Higher values indicate better performance. NDCG evaluates the relevance of recommendations taking into account the ranking. Tall NDCG values indicate relevant recommendations that are in high positions. AUC-ROC measures the system's ability to distinguish between positive and negative instances. Greater value AUC-ROC indicates better performance in distinguishing relevant from irrelevant entities. MRR measures the average inverse rank of the first correct entity (Cakir M., et al. 2020, Hodovychenko M., et al. 2023). This metric favors models that place relevant entities in more positive positions.

Spearman rank correlation: This metric measures the degree of ranking between actual and predicted scores rating. A high value indicates a good match between the system and actual rankings user preference (Segaran, T. 2024, Zhang, Q., et al. 2021).

Intra-list Similarity: This metric measures the similarity between entities within recommended lists. Tall value indicates diverse recommendations within the list. Diversity and serendipity: These metrics evaluate the variety of recommendations and the system's ability to present users with unexpected but relevant entities (Ganesh, A. H. et al. 2022, Neupane, D., et al. 2020, Kiran, R., et al. 2020). The choice of appropriate metrics depends on the specifics of the problem, the goals of the system for recommendation and nature of data. A combination of different metrics provides a comprehensive insight into system performance from different perspectives. It is important to consider the context of application in order to selected metrics that best reflect relevance and meet user criteria (Afsar, M. M. et al. 2022, Zhang, Q. et al. 2021).

4.3 Performance monitoring and improvement

Monitoring and improving the performance of a recommendation system are key steps in keeping it effective and user-oriented system over time (Segaran, T. 2024, Bhanuse, R., et al. 2021, Cakir M., et al. 2020, Dau A., et al. 2020). Actively collecting feedback from users is a valuable source of information about user satisfaction and their needs.

Using surveys, ratings, or comments can help identify areas for improvement. Monitoring performance metrics, such as accuracy, responsiveness, and F1-score, helps assess accuracy system. Regular analysis of these metrics allows weak points to be identified and targeted resources to improve those aspects. Implementing A/B testing allows comparison performance of different versions of the system (Segaran, T. 2024, Zhang, Q., et al. 2021).

This may include changes to recommendation algorithms, user experience interface or other factors to determine the best fit to users. Tracking user retention helps measure how satisfied users are system and how often they return (Hodovychenko M., et al. 2023, Khanal, S. S., et al. 2020). High retention indicates a positive user experience, while decreasing retention may indicate the need to improve the system (Afsar, M. M., et al. 2022, Segaran, T. 2024).

Click-Through Analysis: Tracking how users react to recommendations, including clicks on recommended entities, can provide insight into how engaging and useful the recommendations are.

The system's ability to adapt to changes in user behavior over time is key to maintain the relevance of recommendations (Wang, S., et al. 2021, Cakir M., et al. 2020, Dau A., et al. 2020). Monitoring the evolution of user preferences helps in model adjustment. Periodic updates of machine learning algorithms make it possible exploiting new techniques and approaches that can improve the accuracy and relevance of recommendations. Integrating new functionalities or adapting existing ones can improve user experience experience.

Monitoring how users react to these changes enables iterative improvement system (Ganesh, A. H. et al. 2022, Thomas, B., et al. 2021, Ameisen, E. 2024). Active communication with users and including their feedback in the improvement process can be crucial. An open dialogue with users helps in understanding theirs needs and expectations. If the system is used on different platforms (web, mobile application, social networks), monitoring the performance on each of them helps to customize the interface and recommendation to the specifics of each platform (Zhang, Q., et al. 2021, Wang, S., et al. 2021).

Through continuous monitoring, analysis and iterative improvement, the recommendation system maintains a high level of user satisfaction and ability providing relevant recommendations in a dynamic environment (Bhanuse, R., et al. 2021, Cakir M., et al. 2020).

5 MACHINE LEARNING ALGORITHMS IN RECOMMENDATION SYSTEMS

5.1 Collaborative filtering filter

Collaborative filtering is a technique often used in recommendation systems to user interests are predicted based on similarities between them and other users (Thomas, B., et al. 2021, Neupane, D., et al. 2020, Bhanuse, R., et al. 2021, Cakir M., et al. 2020). This one the approach relies on the idea that users who have similar tastes or behaviors will have similar one's product or content preferences.

In a collaborative filtering filter, they don't analyze the explicit characteristics of the product or user, but the focus is placed on patterns of behavior community of users (Khanal, S. S., et al. 2020, Cakir M., et al. 2020). There are two basic types of collaborative filtering filters: user-based (based on users) and item-based (based on products).

User-Based Collaborative Filtering (UCF): In user-based filtering, recommendations are made based on the similarity between the target user and other users (Afsar, M. M., et al. 2022, Zhang, Q., et al. 2021).

If two users have similar preferences in the past, it is assumed that they will have similar preferences in the future. E.g, if user A and user B often choose the same products or rate products similarly, the system will recommend products that user B likes and that user A has not seen yet (Kiran, R., et al. 2020, Zhang, Q., et al. 2021, Bhanuse, R., et al. 2021).

Item-Based Collaborative Filtering (ICF): In item-based filtering, the focus is on similarities between products. If the user shows interest in certain products, the system will recommend other products that are similar to those that the user has already rated or purchased (Hussien, F. T. A., et al. 2021, Zhang, Q., et al. 2021). This one the method is often used when the number of users is large and the number of products is smaller. One of the key one's advantages of collaborative filtering is that it does not require explicit knowledge of products or to users (Hodovychenko M., et al. 2023, Khanal, S. S., et al. 2020).

In addition, it can work effectively in situations where there are hidden or unknown factors influencing user preferences (Khanal, S. S., et al. 2020, Cakir M., et al. 2020, Dau A., et al. 2020). However, collaborative filtering can also face with challenges, such as the cold start problem, where it is difficult to recommend products new users or new products that have no rating history.

In practice, the recommendation system often combines different approaches, including collaborative one's filtering, in order to achieve better results and overcome the limitations of each individual approach (Wang, S., et al. 2021, Dau A., et al. 2020).

5.2 Content based filter

Content-based filtering is another key approach in recommender system development (Thomas, B., et al. 2021, Khanal, S. S., et al. 2020). This method focuses on analyzing the characteristics and features of the products or content themselves, rather than on the similarities between them user. The idea is to tailor recommendations to users based on their previous preferences, taking into account the relevant product characteristics (Hodovychenko M., et al. 2023, Khanal, S. S., et al. 2020).

Content-based filter analyzes product characteristics to create a profile of each product. These features can include keywords, genres, authors, or other relevant attributes. Content is often vectorized in order to represent it numerically (Khanal, S. S., et al. 2020, Dau A., et al. 2020). For example, textual content can be converted to vectors using techniques like TF-IDF (Term Frequency-Inverse Document Frequency) or word embedding (word embeddings). Based on the user's previous interactions with the content, the system creates a profile user. This profile reflects user preferences, taking into account product features which they rated or consumed (Thomas, B., et al. 2021, Ameisen, E. 2024, Khanal, S. S., et al. 2020). The relevance of content for a specific user is measured by comparison user profiles with product profiles.

Content that is similar to the user profile is considered more relevant and more recommended. Based on the similarity analysis between user profiles and profiles products, the system provides personalized recommendations (Ameisen, E. 2024, Dau A., et al. 2020). These recommendations reflect specific interests and preferences of each individual user. A content based filter has an advantage in cold start situations where there are new products or users (Thomas, B., et al. 2021, Kiran, R., et al. 2020, Bhanuse, R., et al. 2021).

By analyzing the characteristics of new content, a relevant recommendation can be provided even when there is none previous grades (Bhanuse, R., et al. 2021, Wang, S., et al. 2021). A content-based filter often provides transparency in the referral process because recommendations are created based on clear product characteristics and user preferences (Thomas, B., et al. 2021, Neupane, D., et al. 2020, Kiran, R., et al. 2020). Filter content-based has advantages in situations where the user profile is well defined or when there is a good description of the product features.

However, it can face challenges in situations where a wider variety of recommendations is needed or when it is difficult to create precise user profiles. A combination of different approaches often leads to more efficient recommendation systems (Ameisen, E. 2024, Neupane, D., et al. 2020, Afsar, M. M., et al. 2022).

5.3 Hybrid approaches

Hybrid approaches in recommender systems combine several different techniques and methods in order to improved accuracy, reliability and personalization of recommendations (Khanal, S. S., et al. 2020), (Cakir M., et al. 2020, Dau A., et al. 2020). This combination makes it possible overcoming the shortcomings of individual methods and providing a more comprehensive approach to the recommendation task. These approaches use different recommendation techniques and combine them into a single functionality.

On the for example, it is possible to combine collaborative filtering and content-based filtering so that take advantage of both techniques to improve accuracy. These approaches take into account time

factor when recommending. They are used to adapt recommendations in accordance with changes in user behavior over time (Khanal, S. S., et al. 2020, Cakir M., et al. 2020).

For example, the following algorithms can be combined seasonal trends with those that analyze long-term user preferences. This approach uses a combination of product features and user preferences, including additional information such as demographic data or contextual information.

Hybrid feature modeling provides a richer picture of user preferences. Weighting factors are used to assign them different importance by different methods (Afsar, M. M., et al. 2022, Segaran, T. 2024, Cakir M., et al. 2020). For example, it is possible to set weights on the basis reliability of each individual method or depending on the context of the user. In cascade approaches, different methods are used sequentially. For example, one method may be applied first and then the results of that method are used as input to another method.

This allows for more complex and contextual customized recommendations (Cakir M., et al. 2020, Dau A., et al. 2020). In multi-level systems, different methods apply to different levels system. For example, it is possible to use one method at the level of data sets and another at the level user, thus providing more dimensions of personalization.

Hybrid approaches with rendering

(Ensemble Methods)- These approaches combine multiple models or algorithms to achieve better results performance (Segaran, T. 2024, Zhang, Q., et al. 2021).

Popular techniques in this context include bagging, boosting and stacking. Using hybrid approaches in recommender systems enables better customization different scenarios and requirements (Segaran, T. 2024, Zhang, Q., et al. 2021). These approaches can be flexible and adaptive, thus providing users personalized recommendations that take into account different aspects of their preferences and behavior. Hybrid approaches often represent an effective solution in practice, where they are combined different data sources and techniques to achieve high accuracy of recommendations.

6 A PROPOSAL FOR THE ARCHITECTURE OF A RECOMMENDATION SYSTEM

The previous assessment of RS (recommendation system) clearly identified that it is a hybrid solution most suitable based on its ability to overcome the problems inherent in CB (collaborative filtering based) and CF (methods when applied in isolation) (Hussien, F. T. A., et al. 2021, Dau A., et al. 2020).

By using both methods they benefit advantages of each, thus mitigating the problems of cold start and data scarcity. Architecture of the hybrid solution is described in Figure 1.

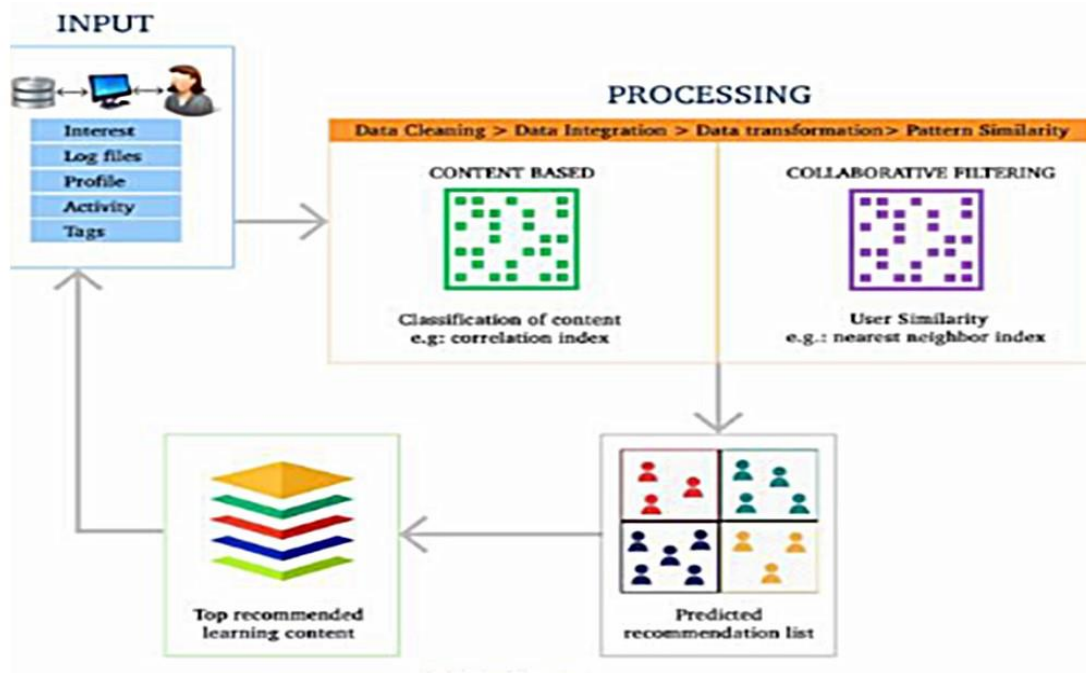


Figure 1. Hybrid Recommender System Architecture System (Hussien, F, 2021).

A hybrid recommender system combines different approaches to provide better recommendations to users. Architecture of the hybrid recommender system (Figure 1).

- In this system, the characteristics of the items themselves and user preferences are analyzed in order to provided recommendations. This system includes analysis of item characteristics.
- Uses behavioral information and user data to identify similarities between users and provide recommendations based on their common interests.
- Different components of the system work together, taking into account the output of one component as the entrance of another.
- This system allows users to customize recommendations according to their needs, in order to make the system more personal and relevant for each user.
- The system's ability to automatically adapt to changes in user behavior or new data is one of the advantages.
- The system uses a combination of metrics that reflect accuracy, precision, responsiveness, and others relevant system performance.
- The system has mechanisms for collecting feedback from users in order to continuously improved.
- The ability of the system to adapt to changes in the data set in real time. When implementing a hybrid recommendation system, it is important to carefully balance these factors in order to achieve the optimal balance between precision, personalization and efficiency.

Referrals are a long-standing problem in many fields, such as e-commerce and social networks (Cakir M., et al. 2020). Most current research focuses on traditional methods such as content-based filtering or collaborative filtering, while relatively little research is devoted to hybrid recommender systems.

Due to recent advances in deep learning, which has achieved success in areas such as computer vision and natural language processing, deep learning has also attracted much attention in recommender systems. There

are several studies that use user ID and item embedding to implement collaborative filtering with deep neural networks.

However, such studies do not use other categorical or continuous characteristics as inputs (Cakir M., et al. 2020). Propose a novel deep neural network architecture that uses not only ID embedding, but also additional information such as job advertisement and candidate characteristics for a job recommendation system, which is a reciprocal recommendation system. Experimental results on a recruitment site dataset show that the proposed method improves recommendation results compared to deep learning models using only ID embedding Figure 2.

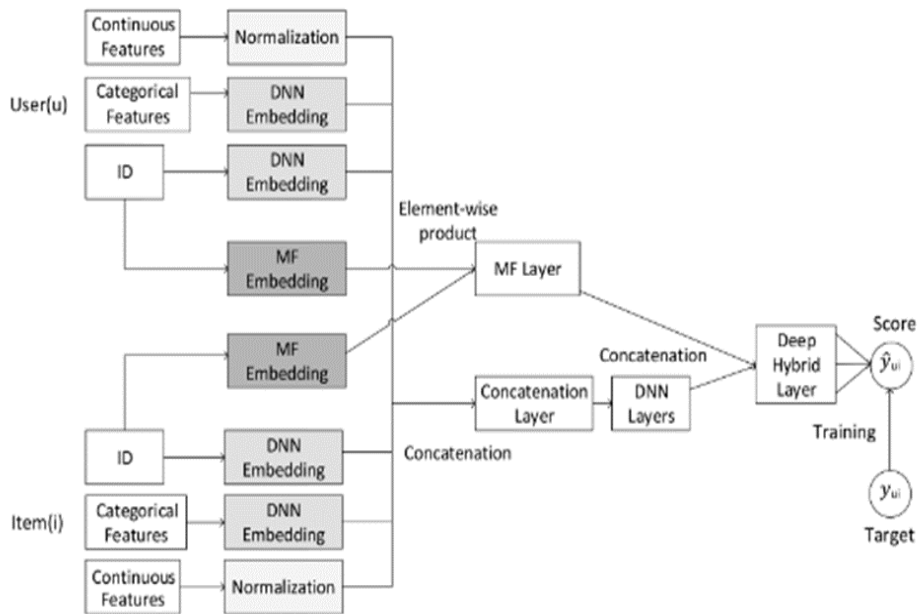


Figure 2. Deep Hybrid Model (Cakir M., et al. 2020).

A hybrid recommendation system based on deep learning is proposed (Cakir M., et al. 2020, Dau A., et al. 2020). It uses the interaction between users and items for collaborative filtering (CF) and auxiliary information from both users and items for content-based filtering (CBF). Deep Hybrid combines matrix factorization (MF) and deep neural networks (DNN) through a joint common layer to predict a top-n list of items. All interactions are treated as positive, and negative instances are randomly selected since there is no explicit feedback.

Additionally, the Kariernet dataset was used to evaluate performance in experiments, providing mutual recommendations (Cakir M., et al. 2020). It identifies the best candidates for a job posting and ranks the most suitable jobs for a candidate. The results show that evaluation metrics HR and NDCG for item recommendation are higher than for user recommendation because while the number of job postings is more limited for a candidate, the set of candidates for a job posting is broader.

As future work, we will explore processing textual information from users and items since there is a significant amount of information in the text (Bhanuse, R., et al. 2021, Cakir M., et al. 2020). For example, detailed explanations of candidates' experiences and qualifications and job posting descriptions will expand our latent feature space as we perform the joint recommendation task. Also, we randomly select items to rank for users and find the top-n list of these items in this study, but it may recommend irrelevant items to users due to the random selection in real applications. Therefore, the goal is to implement a candidate generation task before generating the top-n list.

Data collection:

- User Data: Information about user interactions, preferences, demographics and behavior patterns.
- Item Data: Details about the items we recommend, such as product descriptions, genres, ratings and other features.

- Contextual Data: Additional information that may influence recommendations, such as the time of day, the user's location, or the device they are using.
- Storage and Preprocessing of Data: Data is stored in large data warehouses using solutions such as Hadoop, Apache Spark or cloud solutions.
- Data is cleaned and transformed into a format suitable for analysis and modeling.

Engineering Features:

- Relevant features are created from raw data to improve model performance. This may include natural language processing (NLP) for text data, creating embeds for articles, etc.

Collaborative Filtering:

- User-User Collaborative Filtering: Recommendations are based on similarities between users.
- Item-Item Collaborative Filtering: Recommendations are based on similarities between items.

Content Based Filtering:

- User Profiling: A user profile is created based on their interactions and preferences.
- Item Similarity: Recommended items similar to those the user has already shown interest in, based on the item's characteristics.

Hybrid Combination:

Combining Methods:

- A blend of collaborative and content-based filtering to take advantage of both approaches.
- Model Stacking: Using ensemble learning techniques to combine different models to achieve better performance.

Scoring and Ranking Recommendation:

- Recommendations are generated by scoring items and ranking them based on relevance to the user.

Display Recommendation:

- Recommendations are displayed to users via an API endpoint or through the application's user interface figure 3.

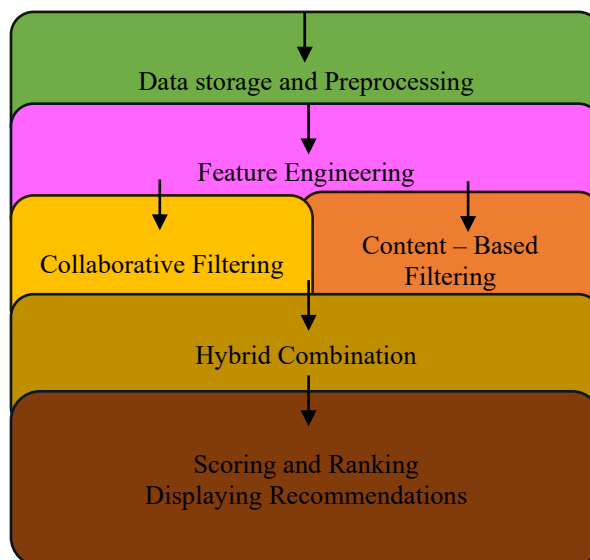


Figure 3. Hybrid Recommender system architecture.

7 CONCLUSION

The systemic development of recommended systems in recent decades has been strongly driven by progress in the field of machine learning. Recommendation algorithms have become increasingly sophisticated,

enabling systems to provide personalized recommendations with high accuracy. Personalized recommendations have become key in improving the user experience on different platforms.

Systems for recommendations provide users with content and products that are relevant to their individual preferences, thereby increasing user engagement and satisfaction. Collection and processing data plays a key role in the efficient functioning of the recommendation system.

Challenges such as the cold start problem, data bias, and ethical aspects of data collection require careful analysis and implementation of appropriate solutions. Both approaches, collaborative filtering and content-based filtering, have their own advantages and challenges. A combination of these approaches, as well as of hybrid methods, is often used to achieve better performance and overcome shortcomings individual methods.

Monitoring the performance of the recommendation system is critical to maintenance quality of referrals over time. Continuous collection of feedback, analysis Performance metrics, and iterative improvement of algorithms contribute to system efficiency. A comprehensive approach to recommender system development involves careful balancing between different techniques and methods. System adaptability is key, especially in the context of variables user preferences, new products and technology evolution.

In conclusion, the development of modern recommendation system is a dynamic process that relies on complex technologies and methods, with the aim of providing personalized and relevant recommendations to users. Promotion accuracy, transparency and adaptability of the recommendation system remains a key focus of research and implementation to meet the growing needs and expectations of users.

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Vector Applications in Mechanics: A Way to Bring Mathematics and Physics Together

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Abstract. This paper provides a quick review of vector algebra's applications in mechanics, along with practical, solved examples. Vector algebra defines vectors, their addition, scalar multiplication, the scalar and vector product of two vectors, and the mixed product of three vectors, as well as the fundamental features of these operations. Physics is a natural science that investigates nature in its most general sense. Mechanics, as an inherent aspect, investigates diverse modes of matter movement. A great number of physical quantities in mechanics are vector in nature, meaning they are determined by intensity, and direction therefore the symbiosis of mathematics and physics is unavoidable in formulating physical laws.

Keywords and phrases: vectors, mechanics, application.

1 INTRODUCTION

Vector quantities and their operations are the domain of vector algebra (Đorić, Lazović, & Boričić Joksimović 2023). Physical quantities that are entirely defined by numerical values matching the unit of measurement are referred to as scalar quantities or simply scalars. The collection of such measurements encompasses length, area, volume, temperature, mass, time, work, energy, and others. The second group comprises physical quantities that are not solely described by a numerical value (magnitude); rather, they also require two additional parameters: direction and orientation. Examples of such quantities are velocity, acceleration, and force. The graphical depiction of a vector quantity is oriented along. It quantifies and assigns a numerical value, such as intensity or modulus, to a vector. The correct orientation of the vector is determined by its direction, which is denoted by an arrow. In physics, vectors are denoted by Latin letters accompanied by a horizontal arrow above the letter; for instance, \vec{v} (velocity), \vec{a} (acceleration), \vec{F} (force), etc. In physics, the magnitude of a vector is typically represented using the same symbols without an arrow, such as v, a, F , etc (Grbić, Lončarević & Medić, 2017).

Mechanics is a branch of physics that examines the various types of matter's movement in space and time. It is categorized into kinematics and dynamics; kinematics examines the motion of bodies without addressing the reasons for that motion, whereas dynamics focuses on the analysis of body movement influenced by the forces that induce such motion. Statics is a specialized subset of dynamics that examines the circumstances of a body's equilibrium. In examining numerous mechanical issues when the dimensions of the body are relatively minor compared to the dimensions of the area in which it operates, a permissible and adequate approximation is the assumption of negligible body dimensions. A material point is defined as a location where the entire mass of an object is concentrated (Budinski Petković, 2008).

2 SOME VECTOR APPLICATIONS IN KINEMATICS

The body's motion symbolizes how its location changes across time and space. Discussion of position, and hence mobility as a change of position, is only feasible when contextualized in reference to the body to which they pertain. The other body is referred to as the reference body. In mechanics, a reference body is linked to a coordinate system known as a reference system. The Cartesian rectangular coordinate system is predominantly utilized in mechanics. The location of the point in this coordinate system is defined by three independent coordinates: x , y , and z . It can also be ascertained using the position vector (radius vector) \vec{r} , which originates from the coordinate system's reference point and terminates at the observed point (Fig. 1).

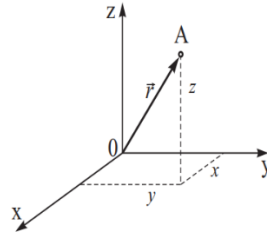


Figure 1. Radius vector (Budinski Petković, 2008)

The magnitude of the radius vector

$$\vec{r} = x\vec{i} + y\vec{j} + z\vec{k} \quad (1)$$

is established. This vector equation represents three scalars, which Cartesian coordinate system are expressed as

$$x = x(t), y = y(t), z = z(t). \quad (2)$$

A line that connects all places in space traversed by the material point during movement is referred to as a trajectory. A segment of the road, designated as a path, is defined by the trajectory of a material point prior to a specific time interval, denoted as s (Budinski Petković, 2008).

Task 1

A material point with a mass $m = 10$ g goes to a position at the time t specified by the radius vector

$$\vec{r} = 4(t\vec{i} + t^2\vec{j}) + \frac{1}{8}t^2\vec{j} + \frac{4}{\pi^2}\sin\frac{\pi}{2}t\vec{k}.$$

Calculate the distance of the material point from the coordinate origin at time $t = 2$ s.

Solution:

The distance of the material point from the coordinate origin can be articulated as

$$d = |\vec{r}_2 - \vec{r}_1| = |\vec{r}_{t=2s} - \vec{r}_{t=0s}|.$$

Under the constraint $\vec{r}_{t=0s}$ equals zero, the formula for the distance simplifies to

$$d = |\vec{r}_{t=0s}| = \sqrt{x^2 + y^2 + z^2} = \sqrt{(4 \cdot 2)^2 + (4 \cdot 2^2 + \frac{1}{8} \cdot 2^2)^2 + (\frac{4}{\pi^2} \sin(\frac{\pi}{2} \cdot 2))^2}.$$

Substituting numerical values yields $d = 18,34$ m.

At time t , let the observed particle be located at location A, defined by the position vector \vec{r} , and at time $t + \Delta t$, it is at position A', defined by the position vector \vec{r}' (Fig. 2). Let us represent the vector difference as $\Delta\vec{r}$.

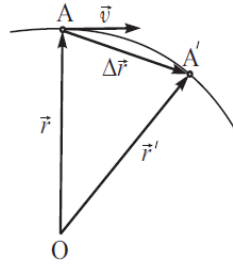


Figure 2. Velocity (Budinski Petković, 2008)

The velocity of the particle at point A is defined as the limiting value of the coefficient of growth of the position vector $\Delta\vec{r}$ and the corresponding time interval Δt when Δt tends to zero

$$\vec{v}(t) = \lim_{\Delta t \rightarrow 0} \frac{\Delta\vec{r}}{\Delta t} = \lim_{\Delta t \rightarrow 0} \frac{\vec{r}(t + \Delta t) - \vec{r}(t)}{\Delta t}. \quad (3)$$

The limiting value of the quotient $\frac{\Delta\vec{r}}{\Delta t}$ as Δt approaches 0 signifies the definition of the derivative of the vector function $\vec{r}(t)$ with respect to the independent variable. The instantaneous speed is defined as the first derivative of the position vector with respect to time

$$\vec{v}(t) = \frac{d\vec{r}}{dt}. \quad (4)$$

Velocity is a vector that aligns with the tangent to the trajectory at the observed point. The direction of the velocity vector is dictated by the movement of the material point, and in the limit when $|\overrightarrow{dr}| = ds$, the magnitude of velocity is expressed as

$$v = \frac{|d\vec{r}|}{dt} = \frac{ds}{dt}. \quad (5)$$

Decomposing the radius vector along coordinate axes in a rectangle system (1) and differentiating yields the following

$$v = \frac{dx}{dt}\vec{i} + \frac{dy}{dt}\vec{j} + \frac{dz}{dt}\vec{k} = v_x\vec{i} + v_y\vec{j} + v_z\vec{k}. \quad (6)$$

The SI unit of velocity is m/s.

During motion, the particle may follow various trajectories and possess distinct velocity vectors. Consider that the particle possesses speed \vec{v} , at time t , and at time $t + \Delta t$, it has speed \vec{v}' (Fig. 3).

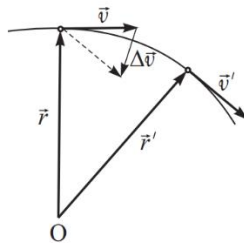


Figure 3. Acceleration vector (Budinski Petković, 2008)

The acceleration of a particle at certain point is defined as the limiting value of the rate of change in speed, denoted by $\Delta\vec{v}$, over the corresponding time interval Δt , as Δt approaches zero

$$\vec{a}(t) = \lim_{\Delta t \rightarrow 0} \frac{\Delta\vec{v}}{\Delta t} = \lim_{\Delta t \rightarrow 0} \frac{\vec{v}(t + \Delta t) - \vec{v}(t)}{\Delta t} = \frac{d\vec{v}}{dt} = \frac{d^2\vec{r}}{dt^2}. \quad (7)$$

Consequently, the acceleration vector of a material point at a given moment in time is equal to the first derivative of the velocity vector or the second derivative of the position vector with respect to time. The SI unit of acceleration is meters per second squared m/s^2 . According to (1) and (7), the acceleration vector of a material point is obtained using Cartesian coordinates

$$v = \frac{d^2x}{dt^2}\vec{i} + \frac{d^2y}{dt^2}\vec{j} + \frac{d^2z}{dt^2}\vec{k} = a_x\vec{i} + a_y\vec{j} + a_z\vec{k}. \quad (8)$$

Task 2

The radius vector of the object varies with time according to the equation

$$\vec{r}(t) = At^2\vec{i} + Bt\vec{j} + C\vec{k},$$

Where $A = 2 \text{ m/s}^2$, $B = 3 \text{ m/s}$, and $C = 2 \text{ m}$. Determine the velocity and acceleration vectors of the object, and the magnitude of velocity after a duration of $t = 2 \text{ s}$ from the commencement.

Solution:

Commencing from the definitions of speed (4) and acceleration (7), one derives

$$\vec{v} = 2At\vec{i} + B\vec{j}; \quad \vec{a} = 2A\vec{i}$$

Magnitude of object's velocity is

$$v = \sqrt{v_x^2 + v_y^2 + v_z^2} = \sqrt{(2At)^2 + B^2}.$$

Substituting numerical values yields $v = 20,22 \text{ m/s}$.

3 SOME VECTOR APPLICATIONS IN DINAMICS

In contrast to kinematics, which analyzes the motion of bodies without addressing the underlying reasons, dynamics investigates both the movements and their causes. The fundamental inquiry in dynamics is to the relationship between forces and motion. Experience indicates that each alteration in the motion of an object is attributable to a specific form of interaction between the involved bodies and other entities. A physical quantity that denotes the measure of mutual effects between bodies, specifically their interaction, is termed a force. Force is a vectorial physical quantity. Forces can be categorized as contact forces, which occur by direct engagement between bodies, and non-contact forces, which operate over a distance through physical methods.

The notion of body mass is essentially linked to the concept of force, regardless of the circumstances. Masses can be recognized even when the effects of forces on various bodies are analyzed. When, for instance, a wooden ball and an iron ball exert equal force on a smooth surface, both having identical shape and volume, it is noticed that the iron ball will move with a velocity comparable to that of the wooden ball, indicating that it resists changes in motion more than the wooden ball. To achieve uniform velocity for these balls, it is necessary to exert greater force on the iron balls. Different bodies exhibit varying degrees of resistance to alterations in their motions. This bodily characteristic is referred to as inertness. Mass is a quantifiable assessment of a body's inertia. The product of mass and velocity of an object is referred to as momentum, denoted as $\vec{p} = m\vec{v}$. Momentum, in contrast to mass, which is a scalar, is a vectorial physical quantity.

Newton's laws constitute the foundation of classical dynamics, as the entirety of classical dynamics is predicated on these three laws. The concept of force and its characteristics are determined by these laws. It is important to acknowledge that these principles apply to the motion of bodies with relatively large masses in comparison to atomic mass and at velocities far lower than the speed of light. Newtonian mechanics is, as measurements and experiments have shown, merely a limiting instance of relativistic and quantum mechanics.

The first law states that an object remains at rest or in uniform linear motion unless acted upon by an external force that induces a change. Mathematically expressed, for $\vec{F} = 0$, it follows that $\vec{v} = \text{const}$; that is, $m\vec{v} = \text{const}$.

Newton's second law of motion states that the variation of momentum, $d\vec{p}$, over time, is proportional to the force, \vec{F} , exerted on the body and is directed along the line of that force

$$\frac{d\vec{p}}{dt} = \vec{F}. \quad (9)$$

If the mass of a body remains stationary over time, it can combust. The equation

$$m \frac{d\vec{v}}{dt} = \vec{F}$$

signifies that

$$m\vec{a} = \vec{F} \quad (10)$$

indicating that the product of mass and the acceleration of the material points is equal to the applied force. The magnitude of this force and acceleration are directly proportional, and both the direction of acceleration and the force align accordingly.

The third Newton's law states that the activities of two bodies are always equal in magnitude and opposite in direction. This principle is known as the principle of action and response, which signifies the origin of force. It can be expressed mathematically as

$$\vec{F}_A = -\vec{F}_R. \quad (11)$$

According to Newton's laws, which underpin classical mechanics, changes in the motion of a body occur solely when a force acts upon it; specifically, if the net force resulting from all influences on the body is non-zero, a change in motion will ensue in accordance with the direction of the applied force.

Task 3

A mass $m_1 = 400$ g is positioned on a horizontal table. It is linked to another mass via a thread that is threaded across the reel, with $m_2 = 200$ g suspended freely (Fig. 4). Determine the tension force of the thread, disregarding the friction between the object and the table. (Satarić, Budinski Petković, Lončarević, Mihailović, & Ilić, 2016).

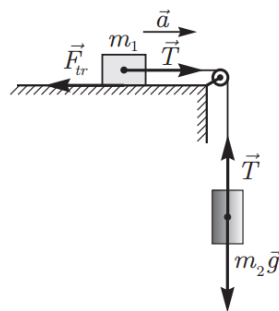


Figure 4. Visual depiction of the issue (Satarić, Budinski Petković, Lončarević, Mihailović, & Ilić, 2016)

Solution:

According to second Newton's law, for the first and second bodies, the equations are:

$$m_1 a = T$$

$$m_2 a = m_2 g - T.$$

Thus, it follows that

$$m_2 a = m_2 g - m_1 a,$$

that is

$$a = \frac{m_2}{m_1 + m_2} g.$$

The thread tension force, denoted as T , is derived from above equations and as follows

$$T = \frac{m_1 m_2}{m_1 + m_2} g = 1,308 \text{ N.}$$

One can inquire why the weight of the initial body was not considered in addressing this problem. The solution is straightforward. Other bodies exert forces in the direction perpendicular to the base upon which the body is positioned. As the initial body shifts on the table, it is evident that its weight lacks a component in the direction of movement a , and in accordance with Newton's second law, the alteration of motion occurs in the direction of the applied forces.

4 CONCLUSION

The synergy between physics and vector algebra is fundamental in describing and analyzing a wide variety of physical phenomena. Here are a few ways in which these two fields intersect: In classical mechanics, forces are represented as vectors, which have both magnitude and direction. Vector algebra allows physicists to compute the resultant forces acting on objects, helping to determine the motion of the objects according to Newton's laws of motion. This is crucial in fields such as dynamics, statics, and kinematics. Work done by a force is the dot product of the force vector and the displacement vector. Vector algebra provides the mathematical tools needed to compute work and energy in various physical systems. In rotational motion, quantities like torque and angular momentum are vectors. Vector algebra helps in calculating these quantities and understanding the relationship between them, such as the torque being the cross product of the force and the lever arm. In fluid dynamics, velocity and pressure fields are often described using vectors. Vector algebra is essential for analyzing how fluids flow, especially when calculating quantities like vorticity or circulation, which involve vector derivatives. In modern physics, particularly in the theory of relativity and quantum mechanics, vector spaces and operators are used extensively. Special relativity, for instance, uses four-vectors to describe spacetime events, and vector algebra is crucial for understanding concepts like energy-momentum relations. In electromagnetism, electric and magnetic fields are represented as vector fields. Maxwell's equations, which describe the behavior of these fields, heavily rely on vector algebra operations like the dot product and cross product. The vector nature of these fields is essential for understanding phenomena like electromagnetic waves, forces on charged particles, and circuit theory.

In summary, vector algebra provides the framework for modeling, analyzing, and solving physical problems that involve quantities with both magnitude and direction. This synergy allows for the precise mathematical treatment of physical systems across various branches of physics.

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Analysis of Students' Academic Achievement in the Field of Probability

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Abstract. At the Faculty of Technical Sciences, University of Novi Sad, the probability theory is studied as part of the compulsory undergraduate academic curriculum across numerous study programs. This paper presents a statistical analysis of data collected from Probability Theory colloquium results across three different study programs, aiming to compare students' success in mastering the Probability Theory course.

Keywords and phrases: mathematics, probability theory, statistical analysis, academic performance

1 INTRODUCTION

Mathematics is an essential part of engineering, providing a wide range of tools and techniques that help engineers design, analyze, and optimize complex systems. It equips engineers with a precise language for describing and quantifying physical phenomena, enabling them to make accurate predictions and measurements. Engineers apply mathematical concepts and methods to model engineering systems, whether designing a bridge or analyzing the aerodynamics of an airplane. Over time, the development of new mathematical concepts and techniques has enabled engineers to tackle more complex and sophisticated challenges, such as the creation of advanced materials and the design of autonomous vehicles.

A branch of mathematics that deals with the prediction and calculation of uncertainty, which is of significant importance in engineering sciences, is probability theory. Classical probability theory provides a formal foundation for quantifying risk and uncertainty in engineering problems that would otherwise be approached qualitatively, using engineering judgment. The role of probabilistic methods in engineering has been extensively investigated (Ang & Tang, 1984; Ang & Tang, 2007).

In recent research, imprecise probability has gained importance in engineering. Unlike classical probability, imprecise probability focuses on interval-valued probabilities. A key feature of imprecise probabilities is the identification of bounds on the probability of events of interest. The uncertainty of an event is characterized by two measures: a lower probability and an upper probability (Beer, Ferson, & Kreinovich, 2013; Oberguggenberger, King, & Schmelzer, 2009).

This paper examines Probability Theory as a part of the compulsory curriculum across three study programs at the Faculty of Technical Sciences, University of Novi Sad. The study aims to investigate whether differences in the mathematics curricula of these programs impact students' success in mastering Probability Theory. To achieve this, the number and scope of mathematics courses in each program were analyzed, followed by a statistical analysis of student performance in the Probability Theory colloquium across the three selected study programs.

The second section provides an overview of the mathematics curriculum in the following study programs: Engineering Management, Computing and Control Engineering, and Information Engineering.

The third section presents the data on students' scores from the Probability Theory colloquium across all three study programs, followed by a comparative analysis of their achievements.

2 OVERVIEW OF MATHEMATICAL CURRICULUM IN SELECTED STUDY PROGRAMS

The Faculty of Technical Sciences, University of Novi Sad, is one of the leading educational and research institutions in the region. It consists of 13 departments, and 27 study programs are accredited for bachelor's academic studies. Mathematics is included in 26 study programs to varying degrees, ranging from one to five courses per program. Probability theory is taught in 17 study programs.

This paper analyzes students' success in the Probability Theory colloquium across three study programs: Engineering Management, Computing and Control Engineering, and Information Engineering. The rationale for selecting these three study programs lies in the fact that the Probability Theory course in each program is preceded by different mathematics courses, with significantly varied content.

2.1 *Mathematics at Engineering Management*

In the Engineering Management study program at the Faculty of Technical Sciences in Novi Sad, three mathematics courses are taught in the following order: Mathematics 1, Mathematics 2, and Probability Theory and Statistics.

In the Mathematics 1 course, students study real functions of one variable, including limits, continuity, differentiation and its applications, indefinite and definite integrals of real functions of one variable with applications, first order ordinary differential equations, and second order differential equations with constant coefficients.

The Mathematics 2 course covers real functions of several variables, differential calculus and its applications, extrema and conditional extrema of multivariable functions. It also includes economic functions, optimization of economic functions, elasticity of economic functions, and topics related to simple and compound interest, as well as continuous interest.

The Probability Theory and Statistics course introduces students to probability theory, conditional probability and Bayes' formula, discrete and continuous random variables, transformations and various characteristics of random variables. Additionally, it covers the basics of mathematical statistics, estimation theory, statistical tests (both parametric and nonparametric hypotheses and significance tests), and sample correlation and regression.

2.2 *Mathematics in Computing and Control Engineering and Information Engineering*

In both the Computing and Control Engineering and Information Engineering study programs at the Faculty of Technical Sciences in Novi Sad, four mathematics courses are taught in the following order: Algebra, Mathematical Analysis 1, Mathematical Analysis 2, and Probability and Random Processes. Additionally, the Information Engineering program includes three more mathematics courses: Mathematical Logic, Fundamentals of Graph Theory and Combinatorics, and Practicum in Statistics.

In the Algebra course, students study logic, relations, functions, Boolean algebra, groups, rings, fields, polynomials, complex numbers, finite fields, vectors, analytic geometry, determinants, systems of linear equations, vector spaces, matrices, and linear transformations.

In the Mathematical Analysis 1 course, students cover real and complex numbers, metric spaces, sequences, real functions of one real variable, indefinite, definite, and improper integrals and their applications, real functions of several variables, and ordinary differential equations.

The Mathematical Analysis 2 course includes number series, functional series, double and curvilinear integrals, complex analysis, Fourier series and transform, and Laplace and inverse Laplace transforms with their applications.

In the Probability and Random Processes course, topics such as probability spaces, random variables, numerical characteristics of random variables, random processes, Markov chains and processes, birth and death processes, and queuing systems are studied.

In the Practicum in Statistics course, students study populations, samples, sampling techniques, descriptive statistics, point and interval estimation, parametric and nonparametric hypotheses, significance testing, statistical inference, and correlation and regression analysis.

The Mathematical Logic course covers the basics of the syntax of logical systems, classical logic, the syntax of predicate calculus, the Davis–Putnam–Logemann–Loveland (DPLL) procedure, and the computational interpretation of logic.

In the Fundamentals of Graph Theory and Combinatorics course, students study permutations, variations, and combinations, set theory, basic concepts of graph theory, graph isomorphism, and graph operations.

It is evident that the mathematics curriculum in these three study programs differs significantly, which naturally raises the question of whether this impacts students' success in mastering probability theory.

3 STATISTICAL ANALYSIS OF STUDENTS' ACHIEVEMENTS

3.1 Descriptive Analysis

The sample consisted of all students from the selected study programs who attended the Probability Theory colloquium during the winter semester of the 2023/24 academic year. The number of students registered for the colloquium, the number of students who attended, and the relative frequency (in percentage) for each study program are presented in Table 1.

Table 1. Probability Theory colloquium turnout

	<i>Eng. Men.</i>	<i>Com. and Control Eng.</i>	<i>Inf. Eng.</i>
<i>Registered</i>	264	313	102
<i>Attended</i>	148	252	71
<i>Relative frequency (%)</i>	56.1	80.5	69.6

Due to differences in scoring systems across the study programs, the scores were scaled to ensure uniformity. The maximum score on the colloquium is 100 points, and a passing score is 51 points. Grades are assigned as follows: 51–60 points correspond to grade 6, 61–70 to grade 7, 71–80 to grade 8, 81–90 to grade 9, and 91–100 to grade 10. Table 2 displays the number of students from each study program, grouped by their achieved scores on the Probability Theory colloquium according to the grading scale.

Table 2. Frequency distribution of achieved points across study programs

<i>Number of points</i>	<i>Eng. Men.</i>	<i>Com. and Control Eng.</i>	<i>Inf. Eng.</i>
0-50	53	104	38
51-60	8	60	16
61-70	29	48	11
71-80	20	25	5
81-90	16	7	1
91-100	22	8	0

The number of students who passed the Probability Theory colloquium, the number of students who failed the Probability Theory colloquium and the relative frequency of the number of students who passed the colloquium (in percentage) for each study program is given in Table 3.

Table 3. Pass/fail summary by study program

	<i>Eng. Men.</i>	<i>Com. and Control Eng.</i>	<i>Inf. Eng.</i>
<i>Passed</i>	95	148	33
<i>Failed</i>	53	104	38
<i>Relative frequency (%)</i>	64.2	58.8	46.5

The average number of points for the sample from the Engineering Management study program ($n=148$) is 58.43 ± 30.37 , with a median of 66.67. For the sample from the Computing and Control Engineering study program ($n=252$), the average number of points is 47.59 ± 24.89 , with a median of 53. Meanwhile, for the sample from the Information Engineering study program ($n=71$), the average is 39.85 ± 24.71 , with a median

of 45. The box plot in Fig. 1 illustrates the minimum, lower quartile, median, upper quartile, and maximum values for the three samples.

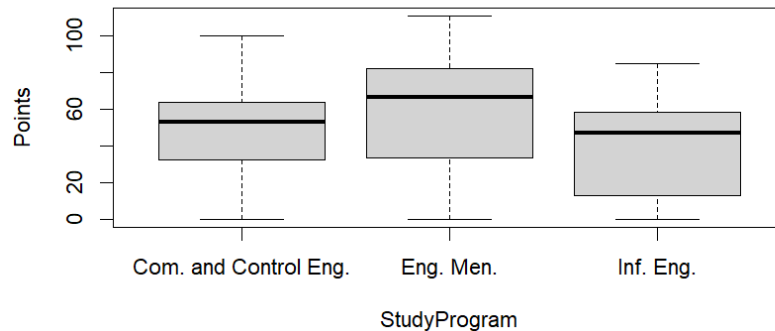


Figure 1. Box Plot

3.2. Comparative Analysis

In this subsection, the comparative statistical tests were performed in order to further analyze the observed differences in students' achievements. The statistical analyses were conducted using the R programming language (R Core Team, 2024) within the RStudio environment (RStudio Team, 2024).

Firstly, to examine the dependence between pass/fail ratio and the study program (see Table 3), the chi-square independence test was performed. The null hypothesis of the test is that categorical variables Study program and Passed/Failed are independent. The obtained chi-square statistics equals 6.21, with 2 degrees of freedom and accompanied p value of 0.045. Since the p value is 0.045, which is below the significance threshold of 0.05, we reject the null hypothesis and conclude that there is a statistically significant association between study programs and student performance, measured by the pass/fail ratio, on the Probability Theory colloquium. However, as the p value is above the more rigorous threshold of 0.01, the evidence is not strong enough to reject the null hypothesis at the 1% significance level.

Next, the one-way analysis of variance, i.e., ANOVA (Chiara & Hesterberg, 2019) was used to compare the mean values of achieved points across the selected study programs. The null hypothesis is that all the group population means are the same, i.e., $H_0: m_1 = m_2 = m_3$, where m_1, m_2, m_3 are the mean values of the number of obtained points in program studies Engineering Management, Computing and Control Engineering, and Information Engineering, respectively. Alternative hypothesis is $H_a: m_i \neq m_j$, for some $i \neq j$, i.e., at least two of the mean values m_1, m_2, m_3 are not equal, i.e., there is statistically significant difference between some study programs. The results of ANOVA are presented in Table 4.

Table 4. ANOVA summary

	<i>Df</i>	<i>Sum. Sq.</i>	<i>Mean Sq.</i>	<i>F value</i>	<i>Pr (>F)</i>
<i>Study Program</i>	2	19541	9770	13.6	0.00000176
<i>Residuals</i>	468	335415	717		
<i>Total</i>	470	534956			

The obtained p value is far below the commonly used significance level of 0.01, allowing us to reject the null hypothesis. This provides strong evidence that there are statistically significant differences in the mean number of points scored on the colloquium across the three student groups are unlikely to be due to chance.

The final step is to determine where the differences lie, specifically between which groups of students the statistically significant differences exist. To address this, the Tukey HSD (Tukey Honest Significant Differences) test was conducted. The null hypothesis states that the differences between the means of the groups are zero ($H_0: m_1 - m_2 = m_1 - m_3 = m_2 - m_3 = 0$), while the alternative hypothesis states that at least one pair of means is different ($H_a: m_i - m_j \neq 0$, for some $i \neq j$). The test generates a set of 95%

confidence intervals for the differences between the mean values of the study programs. The results are presented in Table 5 and illustrated in Fig. 2.

Table 5. Tukey HSD test results

	<i>Diff.</i>	<i>Lwr.</i>	<i>Upr.</i>	<i>p value</i>
<i>Eng. Men. vs Com. and Control Eng.</i>	11.063889	4.545276	17.5825018	0.0002254
<i>Inf. Eng. vs Com. and Control Eng.</i>	-7.516041	-15.973271	0.9411894	0.0930849
<i>Inf. Eng. vs Eng. Men.</i>	-18.579930	-27.666884	-9.4929751	0.0000062



Figure 2. Confidence intervals for Tukey test

Since the p value for the comparison between students from Information Engineering and Computing and Control Engineering is 0.09, which is greater than the significance level of 0.05, there is no statistically significant difference in the mean number of points obtained at the colloquium between these two groups. However, based on the results from Table 5, there is a statistically significant difference between the students from Engineering Management and Computing and Control Engineering, as well as between those from Information Engineering and Engineering Management, both at the 5% significance level. Fig. 2 illustrates the confidence intervals for the differences in mean scores between the groups, where only the confidence interval for the comparison between Information Engineering and Computing and Control Engineering includes zero, indicating no significant difference between these two groups.

4. CONCLUSION

In conclusion, although the analysis shows no clearly significant differences in the pass rates between the groups, there are notable differences in the average number of points achieved on the Probability Theory colloquium across the three study programs. While no statistically significant difference was found between the students from Information Engineering and Computing and Control Engineering, the results revealed a clear distinction in performance between students from Engineering Management and the other two programs. These findings suggest that differences in prior mathematical preparation may influence student success in Probability Theory.

A limitation of this study is that students did not take identical colloquium tasks, which could have influenced their performance. Further research could explore additional factors affecting performance and examine whether adjustments to the curriculum could enhance student outcomes.

Moreover, the importance of mastering Probability Theory extends beyond this specific course, as it serves as a foundation for several advanced courses in later stages of study, such as Time Series Data Processing, System Modelling and Simulation, Decision Making, Risk Management, and Insurance. A solid understanding of probability is crucial for students' ability to successfully apply probabilistic methods in these fields.

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Numerical Methods for Finding the Root of a Polynomial

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Abstract. Formulas for calculating solutions can only be found for a small number of non-linear equations. For this reason, the equations are solved by numerical methods and the solution is approximated with the desired accuracy. This paper presents four numerical methods for calculating the roots of polynomials. The methods are tested on a relevant example and the essential features of each method are highlighted.

Keywords and phrases: Numerical methods, polynomial roots approximation.

1 INTRODUCTION

Students of the Faculty of Technical Sciences, University of Novi Sad, encounter numerical procedures only in their higher years of study, as part of elective courses. The need for solving equations numerically may arise earlier, so it is necessary to present to the students some of the basic procedures that are easy to use and are based on facts that are known to the students. Engineers use polynomials to model the curves, civil engineers use polynomials to design roads, buildings and other structures, and numerical root finding come into play when determining the stability of control systems, and in modelling and predicting environmental factors and their impacts. Therefore, methods for finding the root are handy tools for engineers. It would be a good idea to introduce them to students in existing courses in mathematical analysis after they have become familiar with the properties of continuous functions and the first derivative of a function. More about the role of numerical analysis in engineering can be found in (Burden & Faires, 2011) and (Chapra & Canale, 2010).

Four numerical methods for finding the root of a polynomial are presented below, namely the Bisection method, the False position method, the Secant method and Newton's method. The bisection method is one of the simplest and slowest but most reliable iterative methods. In other methods, the solution is obtained using a linear model approximating the function. Newton's method, one of the most popular, uses the function derivative, which significantly affects the convergence speed. The methods are applied to a simple example.

Let the equation

$$f(x) = 0 \tag{1}$$

be given, where $f(x) = a_n x^n + a_{n-1} x^{n-1} + \dots + a_1 x + a_0$ is a polynomial with $a_0, a_1, \dots, a_n \in R$. Every x^* such that $f(x^*) = 0$ is called the root of the polynomial or the solution of the equation (1).

Before starting to look for the roots of polynomials, it is necessary to examine their existence. If we are looking for roots in a set of complex numbers, then it is known that every polynomial of degree n has exactly n roots, and they do not have to be mutually different. When looking for real roots of polynomials of degree n , then it is known that there can be at most n of them. It is known that for polynomials of degree no greater than 4 there are formulas for calculating the roots, and if f is a polynomial of degree 5 or greater, no such formulas exist. This is the reason that such equations are solved numerically and approximate solutions are obtained.

Most of the iterative procedures are based on the idea that using the iterative rule and starting from the initial iteration, an iterative sequence is formed which, under appropriate conditions, converges to the solution of the observed equation. The initial iteration most often needs to be chosen in the neighborhood of the solution, while the speed of convergence is important for choosing the iterative rule. After the finite number of iterations, an approximation of the solution was obtained, so determining the error of the approximation is also of great importance.

The length of the initial interval, in which the solution and the initial iteration are found, can be used to estimate the approximation error. However, if the properties of the function whose roots we are looking for are known, a better estimate can be obtained. In this paper, the Lagrange error described in the following theorem was observed, (Herceg & Herceg, 2010).

Theorem: Let f be a differentiable function defined on the interval $[a, b]$ and let $m > 0$ be such that $|f'(x)| \geq m$ for every $x \in [a, b]$. If $x^* \in [a, b]$ is the solution of (1) then for every $x \in [a, b]$ it holds

$$|x - x^*| \leq \frac{|f(x)|}{m}. \quad (2)$$

Better error estimates can be found in (Herceg & Krejić, 1997).

2 MAIN RESULT

By applying numerical methods to calculate the root of a polynomial or the solution of a nonlinear equation $f(x) = 0$, approximations of the roots and approximate solutions of the equations are obtained. The first step is the localization of the solution, and after that, it is necessary to choose the appropriate procedure, taking into account the properties of the problem.

One convenient method for determining the interval containing the root of a polynomial is the graphical method. If it is possible to sketch the graph of the function and approximately determine the intercept with the x -axis, it is possible to obtain an approximate value of the root or the interval in which the root is located. Also, if it is simpler, instead of the initial equation, its equivalent equation $g(x) = h(x)$ can be considered, so the solution of the initial equation is found in the intersection of the curves $g(x)$ and $h(x)$.

After localization, it is necessary to choose a procedure by which the root will be calculated with satisfactory accuracy.

Below, several methods are presented that are based on the known properties of continuous functions and the approximation of the function by a linear model.

2.1 Bisection Method

Below, several methods are presented that are based on the known properties of continuous functions and the approximation of the function by a linear model. Among all the numerical methods for finding the root x^* of a polynomial $f(x)$, the Bisection method is the simplest one. Starting from the interval $[a, b]$ in which the root of the polynomial is localized, a series of intervals, all of which will contain the root of the polynomial. Each subsequent interval is obtained by dividing the previous interval in half.

For the initial interval $[a, b] = [a_0, b_0]$, $c_0 = \frac{a_0 + b_0}{2}$ is determined and $f(c_0)$ is calculated. If $f(c_0) = 0$, the required root is obtained. If $f(c_0) \neq 0$ and $f(a_0)f(c_0) < 0$, then $a_1 = a_0$ and $b_1 = c_0$, while in the case $f(b_0)f(c_0) < 0$ then $a_1 = c_0$ and $b_1 = b_0$. The middle of the interval is found again and the process is repeated.

In this way, a series of intervals $[a_k, b_k]$ is obtained such that each interval is contained in the previous one, i.e., $[a_{k+1}, b_{k+1}] \subset [a_k, b_k]$. New interval boundaries a_{k+1} and b_{k+1} are obtained using

$$c_k = \frac{a_k + b_k}{2}. \quad (3)$$

If $f(a_k)f(c_k) < 0$ holds, then $a_{k+1} = a_k$ and $b_{k+1} = c_k$, otherwise $a_{k+1} = c_k$ and $b_{k+1} = b_k$. So, it is guaranteed that at least one root of the polynomial belongs to all intervals. The approximation of the root x^* is the middle of the interval c_k that satisfies the exit criterion.

2.2 False Position Method

This method tries to make the procedure more efficient than the Bisection method by using linear model of the function.

For the initial interval $[a, b] = [a_0, b_0]$, the line through the points $(a_0, f(a_0))$ and $(b_0, f(b_0))$ is constructed

$$y - f(a_0) = \frac{f(b_0) - f(a_0)}{b_0 - a_0}(x - a_0). \quad (4)$$

The next iteration is obtained at the intersection of the line and the x -axis, i.e., for $y = 0$. Thus, the new approximation is

$$c_0 = \frac{a_0 f(b_0) - b_0 f(a_0)}{f(b_0) - f(a_0)}. \quad (5)$$

If $f(c_0) = 0$, the required root is obtained. If $f(c_0) \neq 0$ and $f(a_0)f(c_0) < 0$, then $a_1 = a_0$ and $b_1 = c_0$, while if $f(b_0)f(c_0) < 0$ then $a_1 = c_0$ and $b_1 = b_0$. Thus, a new interval $[a_1, b_1]$ is determined and the procedure is repeated. Therefore, starting from the interval $[a_k, b_k]$

$$c_k = \frac{a_k f(b_k) - b_k f(a_k)}{f(b_k) - f(a_k)} \quad (6)$$

was obtained and $f(c_k)$ was calculated. If $f(c_k) = 0$, then $c_k = x^*$. If $f(c_k) \neq 0$ and $f(a_k)f(c_k) < 0$, set $a_{k+1} = a_k$ and $b_{k+1} = c_k$, else if $f(b_k)f(c_k) < 0$ set $a_{k+1} = c_k$ and $b_{k+1} = b_k$. The intersection of the line and the x -axis that satisfies the exit criterion is the required approximation of the root of the polynomial.

2.3 Secant Method

The secant method is another recursive method for finding the root of the polynomials similar to the False Position method. As in the previous method, the approximation of the root is obtained in the intersection of the line and the x -axis, but in this case, the sign of the function at the ends of the interval is not taken into account.

Starting from the interval $[a, b]$, a line through the points $(a, f(a))$ and $(b, f(b))$ is placed and the intersection with the x -axis is determined. In this way, an iterative sequence is obtained, with members being the approximations of the roots. For the initial iterations, the ends of the interval are taken, so it is $x_0 = a$ and $x_1 = b$. The next iteration is given by

$$x_2 = x_1 - \frac{x_0 - x_1}{f(x_0) - f(x_1)} f(x_1) \quad (7)$$

and the procedure continues until an iteration is obtained that satisfies the exit criterion. Therefore, to determine each iteration with this method, it is necessary to use the previous two calculated iterations. The iterative sequence $\{x_k\}$ is obtained by applying the iterative rule

$$x_{k+1} = x_k - \frac{x_{k-1} - x_k}{f(x_{k-1}) - f(x_k)} f(x_k), \quad (8)$$

and the root approximation is the iteration that satisfies the exit criterion.

2.4 Newton's Method

One of the most popular methods for solving nonlinear equations is Newton's method. It is basically an approximation of the function by a linear function, the tangent of the function at a point that is close to the root that is being sought.

For the selected initial iteration x_0 , a tangent line is constructed at the point $(x_0, f(x_0))$

$$y(x) = f(x_0) + f'(x_0)(x - x_0) \quad (9)$$

and the new approximation of the root is represented by the intersection of the tangent and the x -axis,

$$x_1 = x_0 - \frac{f(x_0)}{f'(x_0)}, \quad (10)$$

provided that $f(x_0) \neq 0$. Then the tangent is placed at point $(x_1, f(x_1))$ and the procedure continues. Obviously, the procedure can be repeated provided that $f'(x_k) \neq 0$ and then

$$x_{k+1} = x_k - \frac{f(x_k)}{f'(x_k)} \quad (11)$$

is the approximation of the root if exit criterion is fulfilled. If f is a continuous function and if $f(x) \neq 0$ on the observed interval, then f is monotone and has at most one zero in that interval.

3 EXAMPLE

In this chapter, the numerical results obtained using the previously mentioned numerical methods are presented in an example. Consider the polynomial

$$f(x) = x^3 + x + 1. \quad (12)$$

This is one of the characteristic polynomials presenting the theorem on rational roots to students. Although it is clear that a rational root exists, it is not possible to calculate it directly. Using the graphical method, using the equivalent form $x^3 = -x - 1$, the root can be localized in the interval $(-1,0)$, see Fig. 1.

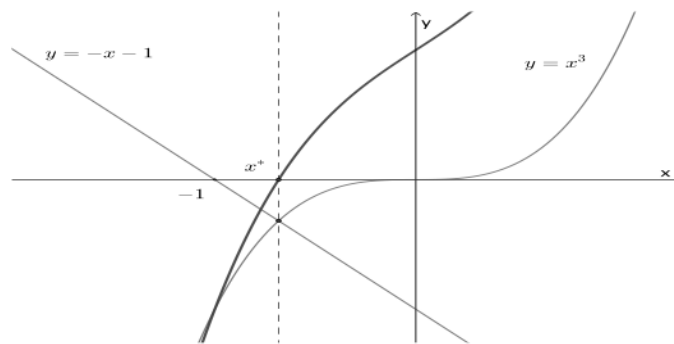


Figure 1. Localization

To calculate the approximation of the root x^* , it is necessary to define the accuracy the solution will be determined. Using the Lagrange error estimate, namely that $f'(x) = 3x^2 + 1$, it follows that $|f'(x)| \geq 1$ is satisfied on the entire interval $[-1,0]$, so it can be assumed that $m = 1$. Therefore, the function tolerance can be used as an exit criterion since $|x - x^*| \leq |f(x)|$ for $x \in [-1,0]$. In the following, the condition $|f(x_k)| \leq 10^{-3}$ is chosen for the exit criterion and the initial interval for the Bisection and the False Position method is set to $[a_0, b_0] = [-1, -0.1]$.

Applying the Bisection method yields the results presented in Table 1.

Table 1. Bisection Method

k	a_k	b_k	c_k	$f(c_k)$
0	-1	-0.1	-0.55	0.283625
1	-1	-0.55	-0.775	-0.240484
2	-0.775	-0.55	-0.6625	0.0467246
3	-0.775	-0.6625	-0.71875	-0.0900574
4	-0.71875	-0.6625	-0.690625	-0.0200275
5	-0.690625	-0.6625	-0.676563	0.0137487
6	-0.690625	-0.676563	-0.683594	-0.00303799
7	-0.683594	-0.676563	-0.680079	0.0053794
8	-0.683594	-0.680079	-0.681837	0.00117582
9	-0.683594	-0.681837	-0.682716	-0.000930704

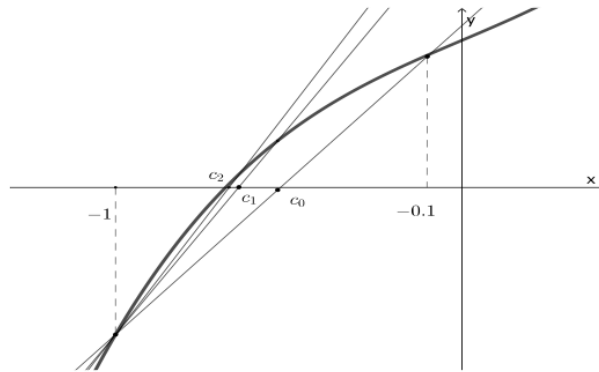
Since $|f(c_9)| < 10^{-3}$ we can take $c_9 = -0.681837$ as approximation of the root x^* .

The results obtained using the False Position method are presented in Table 2, while several iterations are in Fig. 2.

Table 2. False Position Method

k	a_k	b_k	c_k	$f(c_k)$
0	-1	-0.1	-0.526066	0.32834
1	-1	-0.526066	-0.643215	0.0906705
2	-1	-0.643215	-0.672876	0.0224712
3	-1	-0.672876	-0.680065	0.0054128
4	-1	-0.680065	-0.681787	0.0012955
5	-1	-0.681787	-0.682199	0.00030867

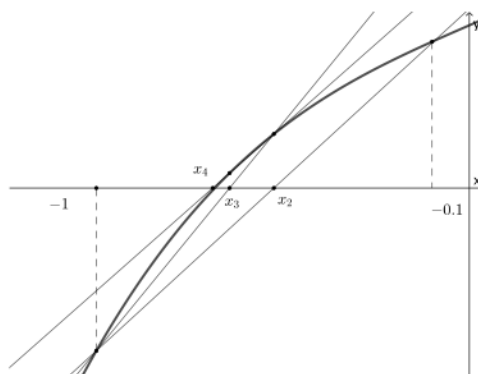
Iteration $c_5 = -0.682199$ satisfies the exit condition and it is a good approximation of the root.

**Figure 2. False Position Method**

For the application of the secant method for determining the approximation of the root of the polynomial, it is necessary to select two initial iterations x_0 and x_1 . The initial iterations for Secant method are chosen to be $x_0 = -1$ and $x_1 = -0.1$, because the conditions $f(-1)f'(-1) > 0$ and $f(-0.1)f'(-0.1) < 0$ are satisfied. Obtained iterative sequence is presented in Table 3 and several iterations are presented in Fig. 3. The solution approximation that satisfies the output criterion is $x_6 = -0.682337$.

Table 3. Secant method

k	x_k	$f(x_k)$
0	-1	-1
1	-0.1	0.899
2	-0.526066	0.328348
3	-0.77122	-0.229926
4	-0.670253	0.0286432
5	-0.681438	0.0213099
6	-0.682337	-0.00002204

**Figure 3. Secant method**

The construction of the Newton's iterative sequence requires the selection of an initial iteration that is close to the expected solution. The iterations obtained for $x_0 = -1$ are given in Table 4 and are graphically represented in Fig. 4.

Table 4. Newton's method

k	x_k	$f(x_k)$
0	-1	-1
1	-0.75	-0.171875
2	-0.686047	-0.00894221
3	-0.68234	-0.000029231

The iteration that satisfies the output criterion and represents a good approximation of the solution is $x_3 = -0.68234$.

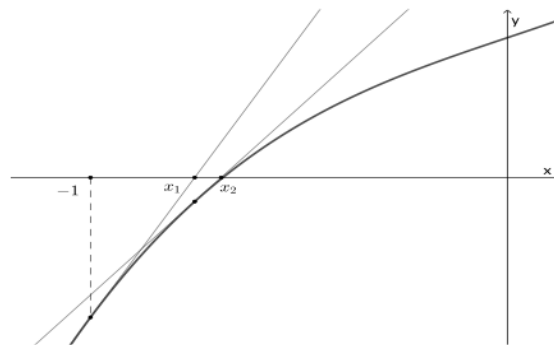


Figure 4. Newton's method

The obtained numerical results are expected. The procedure that required the most iterations to determine the root is certainly the Bisection method. A smaller number of iterations would be achieved if the starting interval is shorter. Although the convergence of the procedure is very slow, only linear, the procedure is useful because for continuous functions it can be guaranteed that the procedure will converge to the root. Slightly faster procedures are the False Position and the Secant method, although their convergence is also linear and is guaranteed for continuous functions. All three procedures require two initial iterations and since no derivative is used, they can be used for functions that are not differentiable. The fastest procedure is certainly the Newton's method. In addition to the condition that the initial iteration be close enough to the solution, the differentiability of the function is also required for the convergence of the method. The result is a very fast, quadratic, convergence in the neighborhood of the solution.

4 CONCLUSION

The goal of this paper is to present four numerical methods for finding solutions to nonlinear equations and applying them to the problem of finding the roots of polynomials. The definition and properties of each of the presented method show the connection of numerical mathematics with the areas of mathematics that students encounter at the very beginning of their studies. Therefore, it would be good to augment the teaching content and, when possible, provide the examples with numerical solutions to problems.

ACKNOWLEDGEMENTS

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Mentorship Lessons Learned from Lower Secondary School Reinforcement Learning Project

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Abstract. While specific young students' projects seldom receive scientific attention, a recent report on lower secondary school reinforcement learning and genetic algorithms project presented at the International Conference of Young Scientists in Izmir, Turkey, opened several opportunities for research on artificial intelligence (AI) in education. In this contribution, we use it to explicitly illustrate the eight types of risk identified in a recent meta-study by Li and Gu. We highlight the following insights gained: It has been reported that understanding AI is, in this specific example, 37 concepts away from the classic mathematical curriculum the participating student received. What does this say about including AI into secondary education mathematics curriculum? The project offers answers through comparing learning success while playing against different opponents. Key insight confirms and illustrates the intuition that learning is faster against skilled opponents, but if they allow no mistakes, nothing can be learned in several circumstances. Developing AI empowerment pedagogy through engaging motivated students can offer simultaneous reflection on several risk facets of applying AI technology in education, as well as motivate both students and mentors involved to shape the challenge domain with their individual experiences.

Keywords and phrases: Education, Artificial Intelligence, AI-related risks, Reinforcement Learning, Learning Space.

1 INTRODUCTION

Artificial intelligence has become a key enabling technology for the sciences and industry (Samek, Müller, 2019; Huynh-The et al., 2023; EC, 2023). It is reasonable to assume that it will significantly influence knowledge-related processes in the coming years and decades. Therefore, it makes sense to empower the upcoming generations of young learners to confront, use, and co-create the technologies associated with this term. Research on AI literacy in early education is on the rise, addressing topics such as curriculum development, the use of AI tools in teaching, the development of pedagogical practices, research design, and evaluation methods (Su & Ng, 2023). The key challenges highlighted by these studies are a lack of teacher competences, a lack of a properly developed curriculum, and a lack of pedagogical guidelines. Research shows the potential for AI to improve the well-being of individuals in education. This could be fostered through in-depth dialogue between researchers from different cultural backgrounds and scientific disciplines (Yang, Ogata, & Matsui, 2023), which would allow human intelligence to be enhanced by AI. The concept is called human-centered AI. There are also various risks associated with the use of AI in education. A review of these risks was presented in a meta-study by Li and Gu (2023). They identified eight dimensions of risks of using human-centered AI in education: misunderstanding of the human-centered AI concept, misuse of AI resources, mismatching of AI pedagogy, privacy security risk, transparency risk, accountability risk, bias risk, and perceived risk. It is concerning that more than half of the studies reviewed are aware of only three or fewer of these risks, making it necessary to systematically apply their framework and update it periodically.

The foundation of our contribution is an elementary reinforcement learning project implemented by a lower secondary school student between ages 11 and 12. The first part of the project that addresses reinforcement learning is hereby discussed and was implemented in 7th grade (Bokal, 2022). The project was later extended to include genetic algorithms and a comparison of (simulated) biological and reinforcement learning (Bokal, 2023; Bokal, 2024). Upon this project, we base the following threefold contribution of this paper:

- First, we describe the project as a comprehensible example and a case study of an early school AI empowerment project, in which the student not only understands and/or applies AI but also develops and deploys it,
- second, we compare the (simulated) learning experience when faced with the three distinct adversary strategies used in reinforcement learning and use this comparison, together with possible additional accompanying context, to illustrate aforementioned 8 types of risk of using AI techniques in educational setting,
- third, we parallel the context of reinforcement learning opponents, one with prescribed and another with learning strategy, with the context of mentor and mentee, and further reflect upon challenges individual teachers and their curious young students face when attempting to introduce AI into their curriculum.

2 METHODS

Our methods are twofold. First the reinforcement learning project is described to the extent that allows reproduction of the results using some basic programming language knowledge. Second, we detail the learning space traversed by the student learning to understand and develop AI. We use this space to compare the conceptual workload of the project with that of the regular 7th grade mathematics curriculum.

2.1 Reinforcement learning illustrated with the game of Nim

The game of Nim is a simple math game where players, in their turn, take one or two tokens from the playing field. The player who takes the last token loses the game. When the game is played by two players, the optimal Strategy can be found and proved by mathematical induction (Bokal, 2022). In a lower secondary school research project, a student investigated the effectiveness of a computer in finding this optimal Strategy. The investigation was performed using a learning player that played games with different simulated players. The learning player develops its Strategy through reinforcement learning (using AI). It begins by playing randomly. While playing, it remembers how many tokens it took in which situation. At the end of each game, the Strategy is updated based on the new experiences. If the learning player wins the game, it increases the probabilities for the decisions it made during the game and decreases the probabilities for the decisions it didn't make. If it loses the game, it does the opposite. During several games, the probability of choosing the winning moves approaches 1. However, the speed of learning is significantly influenced by the playing style of the opponent player. The following opponent players are discussed:

- **Random player** uses a random strategy. The probabilities of taking one or two tokens (except when only one token is available) are the same on each turn.
- **Winning player** uses an optimal strategy. If there are $3n+3$ tokens available, it takes two; if there are $3n+2$ tokens, it takes one. In the cases of $3n+1$ tokens, it cannot win (if its opponent plays optimally). A winning player is instructed always to take one token for this case (the two-token option would be equivalent).
- **Winning randomized player** uses the same Strategy as a winning player, except for the cases of $3n+1$ tokens, where it decides randomly with equal probability.

The distance between learning player's Strategy and optimal Strategy was computed after each game in 200 learning sessions, and the average of 100 of those learning curves for a fixed number of starting tokens was computed, playing against the above three fixed-strategy players starting with a different number of tokens (1 to 10). This allowed us to compare the ability to learn the optimal Strategy and the speed of learning in the cases where learning is possible.

2.2 Learning space for reinforcement learning of Nim

For the school research project addressing the game of Nim, it has been reported by Jerebic, Bokal G., Galun, Vogrinec, and Bokal D. (2023) that understanding AI is not far from the classic mathematical curriculum. The learning space for a student project has been prepared and studied for this purpose. Learning space is a formal mathematical structure that enables the modeling of a learning process. It consists of items of information to be learned and the states of knowledge in which the individual finds himself when he acquires knowledge (Jerebic & Bokal, 2024; Falmagne&Doignon, 2011). The analysis showed that the reinforcement learning algorithm in this specific example is 37 concepts away from 7th grade (lower secondary school, 11-12 years old students) math in Slovenia to understand, not accounting for the concepts required to program it in Python. For comparison, the whole learning space of mathematics of grade 7 has 85 concepts (Jerebic et al., 2023).

3 RESULTS

3.1 Distance between learning player's Strategy and optimal Strategy

Figure 1 shows the average distance to the optimal Strategy for variants starting with 1 to 10 tokens in a random player game averaged over 100 learning sessions of 200 games each. The fewer the tokens, the sooner the learning player converges to the optimal Strategy. Since the random player always chooses moves randomly, the learning player can win even when making suboptimal moves, and these moves are, in such cases, awarded. This makes learning more time-consuming.

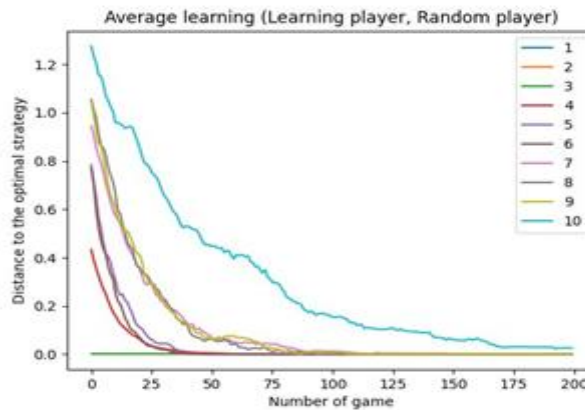


Figure 1: Average distance to optimal Strategy learning against a random player

Learning is faster when the learning player plays against a winning randomized player. When the learning player makes a mistake, the winning player wins, so it realizes which moves are suboptimal. Figure 2 shows that for any number of tokens other than $3n+1$, the learning player quickly learns to play optimally. The learning process is significantly faster compared to playing against a random player.

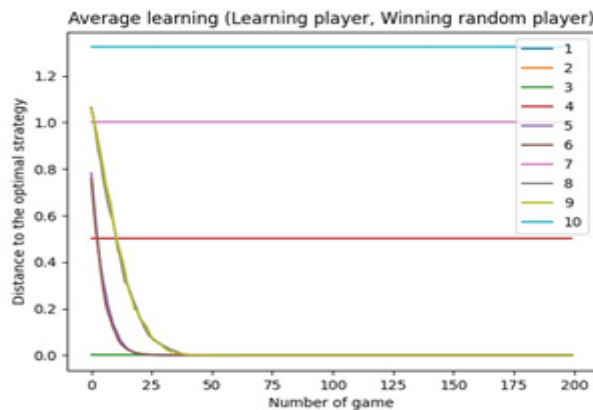


Figure 2: Average distance to optimal Strategy learning against a winning randomized player

But although learning is faster, the learning player has some advantages when playing against the random player. The optimal Strategy occurs in all cases since the learning player can learn to take advantage of the

random player's mistake, while in a game with a winning randomized player in cases of $3n+1$ tokens, such a mistake never occurs, and the learning player learns nothing.

One might expect that learning against a winning player would be similar to or even faster than learning against a winning randomized player. However, this is not the case (see Figure 3). The learning player never encounters certain situations since the winning player is instructed to always take one token when there are $3n+1$ tokens. Therefore, although it develops a strategy to beat the winning player, the distance between its Strategy and the optimal Strategy never reaches 0. In the absence of further learning, such a learning player would experience difficulties against a winning randomized player and even more severe difficulties when opposed with the winning player that opts for a complementary response in lost circumstances.

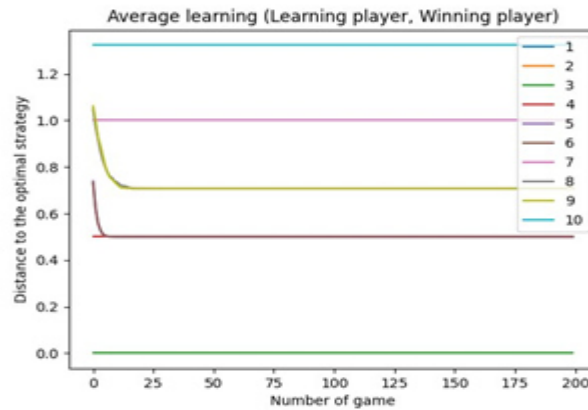


Figure 3: Average distance to optimal Strategy learning against a winning player

3.2 Description of the learning space

The description of the learning space for the reinforcement learning algorithm of the game of Nim (for two players) begins with the state **Game of Nim**, in which the learner becomes familiar with the game and proceeds to one of the independent states, **Token** or **Field**. Once the learner understands the meaning of both terms and evaluates a specific situation in the game, either in the order Token-Field or vice versa, they can (when it is their turn) continue to the state **Move**. At this point, the learner must learn all possible outcomes: **Last token**, **Loss**, and **Win**, which can be learned independently. Assuming that the state **Game** containing the successive states **Action**, **Players**, **Rules**, **Player goal**, **Move**, and **Reward** has already been reached in the learning space, the learner can begin learning the next dimension, which is called **Optimal Strategy**. First, they learn the concept of **Strategy** as a guideline used when playing games, depending on the circumstances. To understand and determine strategies, it is necessary to comprehend the basics of **Probability**, which the learner can study independently of other states in the learning space for the game of Nim. Learning begins with the definition of an **Event**. Then, in any order, the learner learns about **Certain event**, **Random event**, and **Impossible event**, from which they continue to **Simple event** and **Compound event**, where the order does not matter. Once they distinguish between events, they proceed to study their frequency of occurrence, learn how to calculate the **Frequency** and **Relative frequency** of an event, and understand the **Probability distribution** of elementary events. The achieved state enables the continuation of strategy learning, during which they independently learn **Pure**, **Mixed**, and **Completely mixed strategies**. At the next level, the learner focuses on Nim game strategies, analyzing situations based on the number of tokens: $3n+1$, $3n+2$, or $3n+3$, predicting the **Optimal Strategy**, and finally providing the **Proof of optimal Strategy**. The final stage in the learning space for the game of Nim is **Reinforcement learning**, which allows the optimal Strategy for the game of Nim to be found using AI. The computer player acquires the Strategy through played games (the learning player). It involves machine learning, which aims to train or optimize feedback-based behavior. It begins with the learning player **Developing the Strategy**. In the next step, the player independently **Records what was taken** and **Records the situation**. The Strategy is then updated with two out of four independent possibilities: **Loss decreases the probability of what was taken in the situation**, **Loss increases the probability of what was not taken in the situation**, **Win increases the probability of what was taken in the situation**, and **Win decreases the probability of what was not taken in the situation**. All 37 concepts that were identified are illustrated in Figure 4.

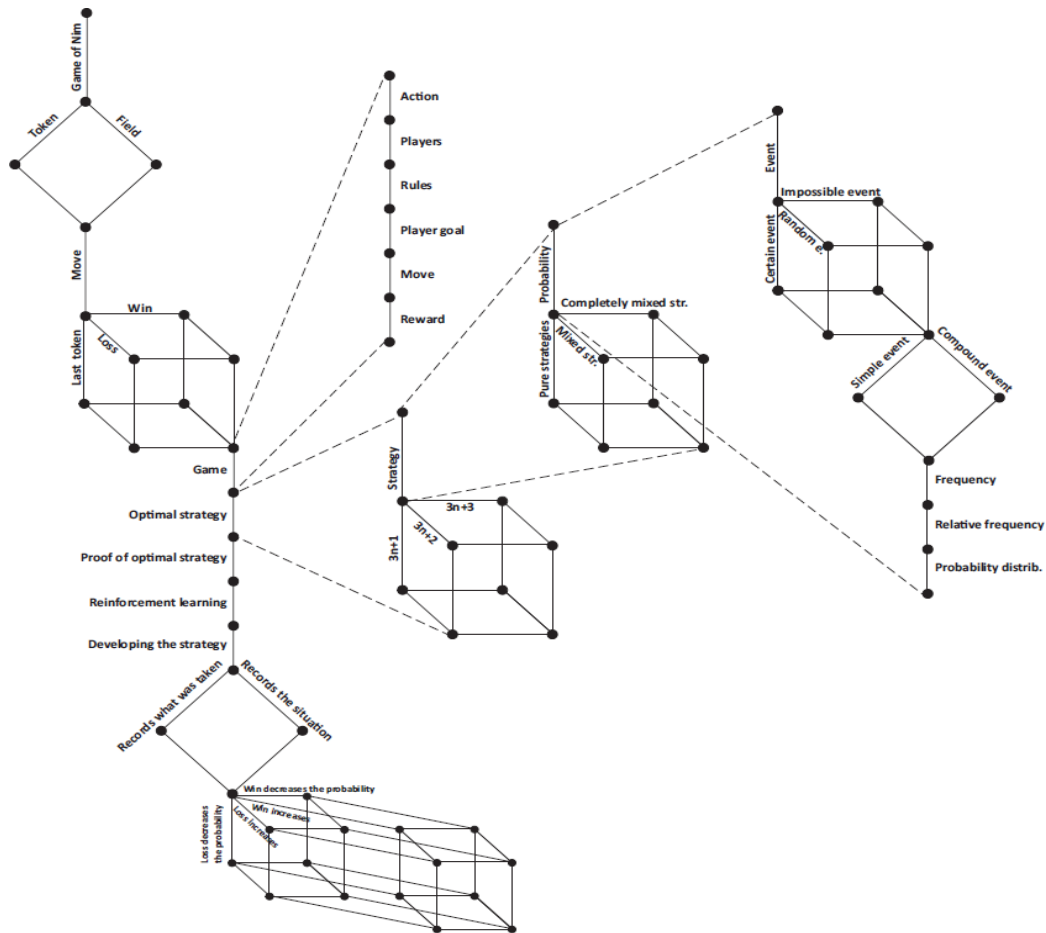


Figure 4: The graph of the learning space for the reinforcement learning of the game of Nim

4 DISCUSSION OF THE RESULTS

This elementary exercise in reinforcement learning illustrates several challenges in education. We set them up in terms of mentorship lessons and risks, assuming that the mentor has a broad overview of the material she is covering and can choose a strategy appropriate to the mentee's state of knowledge and skills. The key observations come from comparing the speed of learning charts of the learning player when learning against different opponents, as follows:

- Learning efficiency, authority and responsibility of the teacher. Without authoritative, disciplined supervision, learning process is slow (such as playing against a random player). However, the price for learning efficiency of disciplined authoritative learning, the learner does not learn anything in losing circumstances. This may be beneficial in the context of learning to avoid lost situations, but on the other hand, it yields apathy in such situations. A responsible teacher recognizes the opportunity to prevent apathy by (sometimes, not often) making a mistake in such circumstances, thus helping students exploit random chances of luck and learning despite possibly lost circumstances.
- Learning diversity and deception of monotonicity. When responses are not randomized in circumstances losing for the teaching opponent, some circumstances never occur for the learner. The learner learns nothing in such circumstances and is unprepared to react optimally. In practice, learners should be exposed to appropriate diversity of learning experiences to familiarize themselves with appropriate responses.

To put these challenges into perspective of current research, we use the findings of this small model to illustrate the risks of human-centered AI for education, as presented recently by Li and Gu (2003). We change the ordering of the risks so that those having conceptually more straightforward illustrations are listed earlier:

- **Perceived risk.** The general perception of the risks is probably the most vaguely defined meta-risk, but it is the one most intimately addressed by our scientific contribution. While first several and later many individuals in education, both teachers and students, as well as in government and business, may be or become literate about the risks of AI and issue appropriate regulation and guidance, few of those will actually be empowered to actually develop AI and understand its internal workings. The example project illustrates this by revealing the disparity of understanding the application of reinforcement learning which requires 37 concepts beyond 7th grade mathematics, vs. actually implementing the algorithms, which requires additional concepts for coding, for instance in Python. It is thus easier to understand the risks but more difficult to mitigate them.
- **Misuse of AI resources** by users has the most clear illustration: suppose a student would need to learn the optimal Strategy of the game of Nim. Should this student rather consult either of the (artificial) winning players instead of understanding the optimal Strategy to produce their own winning response, this would constitute an abuse of AI resources.
- **Mismatching of AI pedagogy** is understandable and likely unavoidable early in the process of introducing AI concepts and technology into curricula. Li and Gu (2003) argue this is the most considerable risk in human-centered AI education. Learning materials, teaching concepts, and intelligent tools vary considerably from one school to another, generally leading to an unsystematic pedagogy design (Zhang, Qin, Cheng, Marimuthu, & Kumar, 2021). The adoption of such curricula is further slowed down due to diverse approaches competing for resources. This is illustrated by comparing the learning against a random player to the learning against a winning player: convergence against the optimal Strategy is clearly slower. However, the illustration also demonstrates a benefit of the diversified approach: should AI pedagogy be harmonized too soon, the unified response of the winning player would prevent the system from reaching an optimal strategy. A coordinated response exchanging best practices and experimenting with diverse approaches to obstacles would be a reasonable compromise, as illustrated by the randomized winning player.
- **The risk of bias** is illustrated by comparing the learning while playing against the winning player and against the randomized winning player. The earlier is biased - never exposes the mentee to certain circumstances, so the mentee cannot develop an appropriate response to them.
- **Accountability risks** are illustrated through attributing resources to the learning process. When actual resources are attributed to the learning process, someone is responsible for possible inefficiencies in the process that result in extended learning periods consuming excessive amounts of resources and may be held accountable for strategies the mentee has not learned or has learned inappropriately.
- **Transparency risks** are illustrated through comparing the actual implementation of the winning player vs. the learning player. The winning player is implemented by encoding the actual optimal Strategy either as a set of decision rules or as rendering appropriate decisions certain by setting relevant probabilities to 1 and others to 0. The learning player has to play the game many times before these settings are approximated to a significant extent. Current AI models seldom, if ever, achieve such certainty levels and seldom achieve the explainability of the decision rules compared to their approximate numeric representation as probabilities. It can thus be argued that vague encoding of exact decision rules illustrates the risk of transparency.
- **Privacy security risks** are illustrated by reasoning about the applications of the outcomes of the learning process in relation to the process itself. While the previously addressed bias in learning does handicap the knowledge exchanged in the learning process, it poses no actual handicap to the mentee who never applies the exact knowledge in circumstances outside of the narrow ones faced with while learning. However, when such circumstances arise, the mentee's handicap results in inadequate responses, exposing the mentee to various risks, possibly including their safety or the safety of their operations. The risk of privacy can be illustrated similarly. An automated learning system can run a digital twin of the mentee, thus capturing the mentee's learning responses and learned Strategy. This constitutes an invasion of privacy, as the mentor has insight into mentees' learned responses. Such insight into learned biases can be abused, especially when digitalized and deployed at a large scale.

- **The risk of misunderstanding the concept of human-centered AI** is a meta-risk, a generalization of the risks of bias, responsibility, accountability, transparency, safety, and privacy. Each of these illustrates, in a specific way, how AI technology can diverge from serving humanity at large and serve the narrow interests of selected individuals or groups. Mitigating those risks and any new risks likely to be exposed in the future requires coordinated efforts of scholars, researchers, developers, educators, and users.

5 CONCLUSION

Amid the abundance of AI-related concepts that surround us, we asked ourselves what of this can be presented to students with a basic understanding of mathematical concepts. How much effort is required for them to grasp the fundamental principles of AI and acquire basic AI literacy? A literature review shows that the question is multidimensional, and answers must foresee AI-related risks. In this paper, we presented a systematic model for the case of a lower secondary school research project, where it was possible to meaningfully discuss these issues in an understandable and practical way. Using the learning space model, we illustrated the path from 7th grade mathematics to understanding one of the basic mechanisms of AI – reinforcement learning.

This raises several questions and opportunities for further research. It is clear that for older students (from higher school grades), the distance to the target state of AI understanding is shorter. Given the limited free time that students can dedicate to exploring such challenges, e.g., in the context of an extracurricular club or activity, it would be interesting to identify the optimal age at which they could acquire knowledge within such a club, leading them to the target understanding. Another practical research question concerns the relationship between attention or the time needed to understand the concepts and the depth to which these concepts should be explored. It is known that the same material can be conceptualized with several different learning spaces. Therefore, it is relevant to consider the representativeness of learning spaces and introduce the concept of an optimal or canonic learning space.

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The Influence of Modern Forms of Learning on Learning Motivation

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Abstract. The research aims to identify the influence of modern forms of learning on student motivation. A descriptive method was used, and the research technique was a survey. The research instrument is a survey questionnaire. Modern forms of learning represent the independent variable, and the dependent variable is the student's motivation. The research population comprises fourth- and fifth-grade students from "Alija Nametak" Junior High School in Zenica. The total research sample is 100 students. The statistical procedures used are descriptive statistics for calculating the mean, median and standard deviation, the Kolmogorov-Smirnov and Shapiro-Wilk tests for testing the normality of distributions and the One Sample T-test for examining statistically significant differences within the examined groups. The results confirmed the hypotheses that the application of modern forms of learning has a positive effect on student motivation and that it has a more favourable effect on the emotional climate for acquiring new knowledge, better communication between students, and socialisation of students in the collective.

Keywords and phrases: Motivation, motivational strategies, students, modern forms of work, teacher.

1 INTRODUCTION

Motivation is a factor that moves the student to study, and self-realization implies the willingness to put effort and effort into achieving a specific goal. Since it contains a positive attitude towards work and the desire for new knowledge, achievements and successes (Jovicic, Mandić 2019: 42), it activates the student for further work. It triggers his curiosity, creating an excellent working atmosphere. Brophy (Brophy, 2015, according to Weinstein & Mayer, 1986) believes that school learning is mainly a cognitive-abstract concept and conveys verbally coded information. The motivation for learning is the quality cognitive engagement of the student who decodes that information. Educators should teach students how to learn and actively process information, connecting it with previous knowledge while using motivation to achieve learning goals. On a practical level, this means that the student should be taught how to learn and how to actively process information and connect it with previous knowledge, where motivation is a strategy for achieving learning goals. According to Brofi, "motivation is a theoretical construct that explains the initiation, direction, intensity, persistence and quality of behaviour, especially goal-directed behaviour" (Brofi 2015, according to Maehr & Meyer, 1997).

Trebješanin (2009) emphasises the difference between internal and external motivation; where he believes that internal motivation exists in a situation in which the student puts in some effort and persists in those activities because he is interested, while in conditions of external motivation, the student works only as much as is necessary to get what he wants. According to Jorgić (2008), some of the activities that can help the teacher in his work and which connect the external and internal motivation of students are also motivational strategies: turning failure into success in learning, adjusting the student's learning style, mandatory feedback, creating a problem - situations, accepting students' mistakes, praising students for participating in work, individualising teaching and providing support for students to ask for help when they need it. Since motivational strategies are always emotionally coloured, the first condition for learning to learn is a person's openness to new experiences, which necessarily goes with the willingness to admit one's imperfection, ignorance or weakness (Suzić, 1998, p. 286). Modern forms of learning refer to methods and approaches that emphasize active student engagement and modern technologies to enhance motivation,

socialization, emotional climate, and interpersonal communication. These forms include group activities, competitive games, projects, simulations, problem-solving, personalised content tailored to students' needs, and diverse materials. These forms include group activities, competitive games, projects, simulations, problem-solving, as well as personalized content tailored to students' needs and the use of diverse materials. Such approaches give students greater autonomy in learning, encourage a spirit of inquiry, and develop their communication and social skills. As a result, a positive environment enhances students' emotional connection to learning while contributing to better socialisation and motivation. The introduction of modern forms of learning achieves greater student satisfaction, further stimulating their interest and commitment to the educational process and fostering a more lasting and deeper understanding of the material. According to the results of research by American authors on teachers' experiences about the effectiveness of strategies that increase students' interest in learning, these are practical activities (games, role-playing games, projects, simulations, problem-solving); personalised content (selection of content from the program, conversation based on their experiences, joint planning); techniques of trusting students (to share their ideas, debates, reports, plan lessons, express their creativity); group assignments; use of various materials and various activities; teacher's enthusiasm (Filgona et al., 2020). Using NTC methods such as illogical stories, riddles, enigmatic questions, associations, and searching for hidden words creates a cheerful and pleasant atmosphere for learning and cooperation, increases internal motivation for learning. It means that the teacher leads the development of motor and thinking abilities through the game by manipulating information and through spontaneous learning (Bobić, Rajović, 2021).

2 RESEARCH DESIGN

The assumption that motivational strategies can have positive effects if they satisfy the conditions found "in the student" determined the framework of the research design in terms of the following requirements:

- Classrooms for learning as a pleasant environment,
- A patient teacher who encourages the student in his work,
- Material that is interesting and challenging for students and tasks that create causal connections between prior knowledge and new information.

It is essential for students of the same age to feel a sense of belonging to a particular group, and the interaction between students, regardless of whether it is cooperative or competitive, also becomes an integral part of the learning process in which they achieve specific goals (Wolfock et al., 2014). In this regard, the subject of the research is a theoretical overview and empirical verification of the effects of motivational strategies through the application of modern forms of learning in teaching. The research aims to identify the influence of modern forms of learning on student motivation. General hypothesis: The application of modern forms of learning positively impacts student motivation. Particular hypotheses:

PH1: Modern forms of learning have a more favourable effect on the emotional climate for acquiring new knowledge.

PH2: Communication between students is better when new forms of learning are applied.

PH3: Modern forms of learning develop a more competitive spirit in students.

PH4: Modern forms of learning contribute to better socialisation of students.

A descriptive method was used, and the research technique was a survey. The research instrument is a survey questionnaire composed of closed, open and combined type questions. To measure the variables "modern forms of learning" and "motivation," a questionnaire was used containing questions about the frequency of using different learning methods and the level of student motivation. For measuring modern forms of learning, a Likert scale from 1 to 5 was applied, where students rated the frequency of using methods such as group activities, projects, simulations, and the application of technology. Specific items include the frequency of group work ("The teacher often organizes group work"), the use of digital tools ("Computer technology is used for teaching"), and the use of practical exercises and simulations. Motivation was measured using a scale of motivational factors that assesses intrinsic and extrinsic sources of motivation. Researchers also used a Likert scale to rate items such as: "I feel satisfaction while learning new things in class" (intrinsic motivation), "I strive to learn to get a good grade" (extrinsic motivation), and "I am

motivated to learn because I believe knowledge will help me in the future" (long-term motivation). In addition to administering the questionnaire, researchers observed classroom behaviour to record student engagement, such as asking questions, actively participating in discussions, and showing interest in tasks.

Modern forms of learning represent the independent variable, and the dependent variable is the student's motivation. The research population comprises fourth and fifth-grade students from "Alija Nametak" Junior High School in Zenica. The total research sample is 100 students from two classes of the fourth grade - 43 students (21 boys and 22 girls) and three fifth grade - 57 students (28 boys and 29 girls). The research was conducted on May 10 and 11, 2022, at the Elementary School "Alija Nametak" in Zenica, in the Municipal Community of Pehara. Researchers used IBM SPSS Statistics v26.0 to process the statistical data. The researchers presented the obtained data in tabular and graphical form. Researchers used descriptive statistics to calculate the mean, median, and standard deviation; the Kolmogorov-Smirnov and Shapiro-Wilk tests to assess the normality of distributions; and the One Sample T-test to examine statistically significant differences within the examined group.

3 ANALYSIS AND INTERPRETATION OF RESULTS

Researchers analysed and interpreted the obtained research results on the influence of modern forms of learning on student motivation within the framework of the four hypotheses stated in the research design.

a) Modern forms of learning have a more favourable effect on the emotional climate for acquiring new knowledge

The agreement of students in a high percentage (over 93%) that they are happy to learn in a pleasant environment that stimulates the psychological learning process emphasised the statistical significance of the students' answers that support the hypothesis that modern forms of learning have a more favourable effect on the emotional climate for acquiring new knowledge (which is presented sample T-test in the following table)

Table No. 1: The Influence of Modern Forms of Learning on the Emotional Climate and Acquisition of New Knowledge

One-Sample Statistics				
	<i>N</i>	Mean	Std. Deviation	Std. Error Mean
I enjoy learning in my classroom	100	1.07	0.256	0.026

The presented data indicate that 100 students ($N=100$) participated in the survey regarding their enjoyment of learning in their classroom. The mean score ($M=1.07$) reflects that, on average, students strongly agree or rate their enjoyment as very high on the scale used. This low mean value suggests a consistent and positive perception of the classroom learning environment.

The standard deviation ($SD=0.256$) indicates a small variation in responses, meaning that most students had similar opinions, reinforcing the consistency of the data. The standard error of the mean ($SE=0.026$) is notably low, which shows that the sample mean is a reliable estimate of the population mean.

In summary, the data reveal a highly favorable perception among students about enjoying learning in their classroom, with minimal variability in responses, confirming the reliability and consistency of the positive trend observed.

Table no. 2: Significance of the Influence of Modern Forms of Learning on the Emotional Climate and Acquisition of New Knowledge

One-Sample Test						
Test Value=1.5						
	<i>t</i>	<i>df</i>	<i>Sig.(2-tailed)</i>	<i>Mean Difference</i>	<i>95% Confidence Interval of the Difference</i>	
					<i>Lower</i>	<i>Upper</i>
I enjoy learning in my classroom	-16.769	99	0	-0.43	-0.48	-0.38

The results of the analysis indicate that students express a high level of satisfaction with learning in a supportive environment, as reflected in the mean score of $M = 1.07$. This value is statistically significantly

lower than the predefined test value $n = 1.5$, with $t = -16.769$ and a p -value of $p < 0.001$, indicating that the likelihood of this result occurring by chance is extremely low. The 95% confidence interval (-0.48 to -0.38) further underscores the reliability of these findings, showing that the difference is both consistent and significant.

The assumption that modern forms of learning have a more favourable effect on the emotional climate for acquiring new knowledge is strongly supported. Students' satisfaction demonstrates that a pleasant environment stimulates psychological learning processes, keeping them motivated and engaged, which significantly contributes to their overall success in the educational process.

The emotional attitude of the students is also visible from the answer that they like to apply modern forms of learning the most. According to 91% of students, using computers, individualizing learning, ensuring flexibility of place and time for study, fostering high motivation, and promoting faster memorization of material achieves high motivation for learning and work. Based on these data, researchers did not reject the specific hypothesis (PH1) regarding the application of learning forms that favourably affect the emotional climate for acquiring new knowledge.

b) Communication between students is better by applying new forms of learning

As part of the hypothesis that communication between students is better through the application of new forms of learning, 95% of students think that when they study in a group, they pay more attention to the ideas of their peers. Communication is essential in learning and socialisation because those who are more socialised can more easily and quickly understand the ideas of their peers and build better mutual trust. A one-sample T-test represents statistical significance.

Table no. 3: New Forms of Learning Facilitate Communication Among Students

One-Sample Statistics				
	<i>N</i>	<i>Mean</i>	<i>Std. Deviation</i>	<i>Std. Error Mean</i>
Using new forms of learning facilitates communication between students.	100	1.5	0.798	0.08

The data reflect the opinions of 100 students ($N=100$) on whether using new forms of learning facilitates communication between students. The mean score ($M=1.5$) indicates a generally positive response, suggesting that students largely agree that new forms of learning improve communication among peers.

The standard deviation ($SD=0.798$) shows a moderate level of variation in the responses, suggesting some diversity in students' perceptions, though the overall trend remains positive. The standard error of the mean ($SE=0.08$) is relatively small, indicating that the sample mean is a reliable estimate of the population mean.

Overall, the results suggest that students perceive new forms of learning as effective in enhancing communication, although individual opinions vary to a certain extent. The consistency of the responses, combined with a reliable sample mean, supports the conclusion that these methods positively impact peer interaction.

Table no. 4: Significance of the Impact of New Forms of Learning on Facilitating Communication Among Students

One-Sample Test						
	Test Value=3					
	<i>t</i>	<i>df</i>	<i>Sig. (2-tailed)</i>	<i>Mean Difference</i>	<i>95% Confidence Interval of the Difference</i>	
					<i>Lower</i>	<i>Upper</i>
Using new forms of learning facilitates communication between students.	-18.803	99	0	-1.5	-1.66	-1.34

The results of the one-sample t-test demonstrate that the mean response ($M = 1.5$) is statistically significantly different from the predefined test value ($n = 3$), with a t-statistic of $t = -18.803$ and a p -value of $p < 0.001$. This highly significant result indicates that students overwhelmingly agree that new forms of learning

facilitate communication among their peers, as their mean response is markedly lower than the neutral benchmark of 3.

The mean difference of -1.5 reflects a substantial deviation from the test value, further supported by the 95% confidence interval (-1.66 to -1.34), which confirms the reliability of the observed effect. This interval, excluding zero, underscores the consistency of the responses and validates the claim that these methods significantly enhance communication.

In summary, the findings reveal a strong consensus among students that the application of new learning methods fosters improved interaction and collaboration. The statistical significance of these results leaves little doubt about the positive impact of such approaches on student communication. Group activities and collaborative methods encourage students to listen to and value their peers' ideas, improving mutual understanding and trust.

These results support the specific hypothesis (PH2) that communication between students is better when new forms of learning are applied. They highlight that students perceive modern forms of learning as effective in fostering better communication and enhancing peer interaction.

c) Modern forms of learning develop a more competitive spirit in students

Group competition encourages responsibility and cooperation. Of the students, 96% believe that working together motivates them to learn, mainly due to cooperation and competition, which contribute to further motivation in learning. Researchers used a sample T-test to determine the statistical significance of this question.

Table No. 5: New Forms of Learning and Competitive Spirit of Students

One-Sample Statistics				
	<i>N</i>	<i>Mean</i>	<i>Std. Deviation</i>	<i>Std. Error Mean</i>
Group competition encourages responsibility and cooperation	100	1.04	0.197	0.020

The data indicate that 100 students ($N=100$) responded to the statement that group competition encourages responsibility and cooperation. The mean score ($M=1.04$) is very close to the lowest possible rating on the scale, indicating a strong agreement among students with the statement. This suggests that students perceive group competition as highly effective in fostering responsibility and cooperation.

The standard deviation ($SD=0.197$) is quite small, reflecting minimal variability in the responses, which suggests a high level of consensus among the students. The standard error of the mean ($SE=0.020$) is extremely low, indicating that the sample mean is a highly reliable estimate of the population mean.

These results strongly suggest that students universally recognize the benefits of group competition in promoting collaborative and responsible behavior. The low mean score and the minimal variability reinforce the idea that group competition is widely valued as a motivating and cooperative educational strategy.

Table No. 6: Significance of the Impact of New Forms of Learning on the Competitive Spirit of Students

One-Sample Test						
Test Value=1.5						
	<i>t</i>	<i>df</i>	<i>Sig. (2-tailed)</i>	<i>Mean Difference</i>	<i>95% Confidence Interval of the Difference</i>	
					<i>Lower</i>	<i>Upper</i>
Group competition encourages responsibility and cooperation	-23.357	99	0.000	-0.460	-0.50	-0.42

The results of the one-sample t-test provide strong statistical evidence about students' perceptions of group competition fostering responsibility and cooperation. The mean response ($M=1.04$) is significantly lower than the test value ($\eta=1.5$), as indicated by the t-statistic of $t=-23.357$ and a highly significant p-value ($p=0.000$). This demonstrates that students overwhelmingly agree with the statement, with their responses being far more favorable than the neutral or moderate agreement benchmark of 1.5. The mean difference of -0.460 confirms a

substantial deviation, showing that students' opinions lean strongly toward recognizing group competition as a tool for enhancing responsibility and cooperation. The 95% confidence interval (-0.50-0.50-0.50 to -0.42-0.42-0.42) further validates this finding, as it does not include zero and tightly brackets the observed difference, underscoring the precision and reliability of the results. This PH3 is supported by the data, with 94% of students reporting that group work enables them to share ideas, respect others' opinions, and develop creativity and critical thinking. Students highlight the social and emotional benefits of collaborative learning, such as camaraderie and mutual acceptance, which are reinforced by consistent responses. These findings suggest that modern learning methods create an environment where students feel motivated and supported through meaningful social interaction. The results confirm PH4 that modern forms of learning contribute to better socialization. Group competition also emerges as an effective strategy for fostering responsibility and cooperation. Statistically significant results, along with a narrow confidence interval, emphasize a strong consensus on the motivational impact of collaborative learning and group dynamics. Students consistently emphasize the value of group work in fostering social interaction, with 43% explicitly recognizing its role in promoting socialization. Furthermore, 45% of students agree that collaborative learning environments enable faster and easier learning, highlighting the practical and interpersonal benefits of working together. The data also reveal that 97% of students believe modern learning methods nurture essential skills such as curiosity, independence, and motivation, all of which are crucial for effective social and collaborative engagement. Qualitative responses provide deeper insight into these findings. Students report enjoying group work because it allows them to contribute their ideas and solve problems collaboratively. They appreciate opportunities to express their views, respect differing perspectives, and develop creativity and critical thinking. This combination of social and intellectual growth underscores the benefits of modern learning methods in enhancing interpersonal relationships and fostering a supportive environment for shared learning. In addition, students highlight the motivational impact of a positive social environment. The collaborative nature of group work fosters mutual acceptance, camaraderie, and teamwork, creating an atmosphere where learning is not only effective but also enjoyable. This emotional and social dynamic enhances their overall learning experience and reinforces their sense of belonging within a group. Modern forms of learning also play a significant role in developing critical social skills such as cooperation, communication, tolerance, and initiative. These competencies are vital for navigating both educational challenges and real-world situations. Together, these findings affirm that modern educational approaches are instrumental in promoting socialization, preparing students to thrive in collaborative and interactive environments. The hypothesis is confirmed based on both quantitative and qualitative data. Modern learning methods clearly foster better socialization among students by creating environments that encourage interaction, collaboration, and mutual support. The overwhelmingly positive responses, both in terms of percentages and open-ended feedback, demonstrate that these methods effectively enhance social engagement, motivation, and the development of critical interpersonal skills.

Main hypothesis, "**The application of modern forms of learning positively impacts student motivation, has been confirmed.** All collected data and research findings consistently indicate that modern learning methods have a positive effect on student motivation.

Key Evidence:

- **Improvement of the Emotional Climate:** Statistical results show that modern forms of learning significantly enhance the emotional climate for acquiring new knowledge ($M=1.07, t=-16.769, p<0.001$ $M = 1.07, t = -16.769, p < 0.001$ $M=1.07, t=-16.769, p<0.001$). Students expressed a high level of satisfaction in environments that stimulate psychological learning processes.
- **Better Communication Among Students:** The average student response ($M=1.5, t=-18.803, p<0.001$ $M = 1.5, t = -18.803, p < 0.001$ $M=1.5, t=-18.803, p<0.001$) indicates a significant improvement in communication through the application of modern learning methods. Group work fosters open idea exchange and strengthens mutual trust.
- **Development of a Competitive Spirit:** Data ($M=1.04, t=-23.357, p<0.001$ $M = 1.04, t = -23.357, p < 0.001$ $M=1.04, t=-23.357, p<0.001$) show that group competition through modern learning strategies promotes responsibility, cooperation, and motivation to achieve better results.
- **Enhanced Socialization:** Students reported that group work and modern forms of learning facilitate quicker success, encourage collaboration, and promote mutual respect for ideas. This is

further supported by 97% of students agreeing that modern learning methods stimulate curiosity, independence, and motivation.

The findings of the research consistently confirm the main hypothesis. Modern forms of learning not only improve motivation but also enhance the emotional climate, communication, competitive spirit, and socialization, collectively contributing to a more dynamic and engaging learning process.

CONCLUSION

For students to cope with new challenges in their work, in addition to factual knowledge, they should acquire communication skills, information management, use technology and solve complex problems. Along the way, it means a lot if students learn how to learn from the earliest period. The application of modern forms of learning helps to encourage internal motivation, which affects the energy of students and the persistence to reach a specific desired goal. The teaching process should use learning strategies that will motivate the student. Students are encouraged to develop their knowledge, skills, and attitudes through various modern methods, techniques, and strategies. The results showed that modern forms of learning positively impact student motivation. Students express a remarkably positive attitude towards group work, competitive spirit, cooperation, independence, motivation and camaraderie, which is encouraged by the application of modern forms of learning. These forms of learning also contribute to better socialisation of students, improve communication, develop creativity and critical thinking, and help develop more permanent knowledge. The findings unequivocally support the hypothesis that modern forms of learning significantly enhance students' socialization. The combination of quantitative and qualitative data illustrates the profound impact of collaborative learning environments on fostering social interaction, teamwork, and mutual respect. Students not only benefit from improved interpersonal relationships but also from the development of essential skills such as communication, cooperation, and critical thinking, which are integral to their academic and personal growth. The positive emotional and social environment created by modern educational methods motivates students to engage more deeply in their learning, reinforcing their sense of belonging and encouraging a proactive attitude toward collaboration. By preparing students to navigate both academic and real-world challenges, these approaches equip them with the tools needed for success in increasingly interactive and collaborative contexts. Modern learning strategies go beyond academic outcomes, nurturing a holistic development that combines intellectual achievement with social competence. These findings emphasize the importance of integrating such methods into educational practices to foster well-rounded, socially adept, and motivated learners.

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Teachers' Methods and Strategies for Developing Students' Computing Competencies

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Abstract. This paper aims to raise awareness among teachers regarding the development of students' competencies. Accordingly, the concept of competence is defined, and a clear overview of the key competencies for lifelong learning is provided based on the European Framework of Key Competencies for Lifelong Learning. Key competencies are divided into general and cross-curricular, but due to the paper's topic, the emphasis is placed on cross-curricular competencies. Competences that enhance students' knowledge, skills, and attitudes are listed, such as digital, Information and Communication Technology (ICT), mathematical, scientific-technological, problem-solving, learning, and social competencies. Additionally, some of the main computer competencies are outlined, along with an explanation of the term "specific computer competencies." The application of teaching tools and technologies in the subject of Informatics and Computing is explained through concrete methods of education, which include traditional teaching, ICT-supported teaching in computer classrooms, online teaching, and hybrid learning. Specific programs for creating and delivering lessons with the help of presentations are also mentioned. In the final section of the paper, teaching methods and learning strategies in the educational environment are outlined, highlighting the most important ones, including e-learning, mobile learning, hybrid teaching, and deep and surface learning approaches.

Keywords and phrases: Computing, Competencies, Teaching Methods, Learning

1 INTRODUCTION

We are witnessing the daily expansion of information technologies, which have brought about significant changes in people's lives, such as how we spend our time, acquire new knowledge, apply what we've learned, communicate, and more. In other words, the era of modern civilization demands extensive use of information technologies, and, consequently, the need for young people to advance in this field is growing. This is why great importance is placed on the development of information technologies in the Republic of Serbia.

The changes in 21st-century education systems are reflected in the transition from traditional to modern teaching, which adapts to the needs of the knowledge society, and in the changing role of the teacher, who evolves from a transmitter and interpreter of knowledge to a mentor and guide for students. The role of the teacher is becoming more complex in terms of methods and ways of working. The teacher remains the main factor in every educational process, and the challenges that are set before him require continuous professional development and building of competencies that enable further learning and application of knowledge. Acquiring competencies through the application of information technologies in learning and designing the teaching process for teachers becomes a prerequisite in order to successfully fulfill the set educational tasks (Bognar, 2024).

Competence represents a combination of knowledge, skills, and attitudes that an individual possesses in order to efficiently tackle tasks, approach specific problems, and solve them. The competencies acquired by an individual throughout their learning process can be demonstrated in various ways (British Council & Republic of Serbia Ministry of Education, Science and Technological Development, n.d.).

In 2006, the Institute for Educational Quality and Evaluation of the Republic of Serbia (Glušac, 2014) began identifying broadly defined key competencies and reforming school curricula accordingly. That same year, the European Union adopted the European Reference Framework of Key Competencies for Lifelong Learning. The knowledge, skills, and attitudes recognized in this document as key for individual development are essential for fostering innovation, productivity, and, consequently, the competitiveness of any society. These

competencies go beyond the traditional school subjects and engage academic knowledge in preparing students to be competitive and functional in both present and future educational and professional settings, enabling them to competently and actively fulfill their civic roles.

The focus on cross-curricular competencies in education does not imply the introduction of new subjects or additional classes dedicated to a specific competence. The fundamental shift brought by the orientation toward general and cross-curricular competencies, and competencies in general, lies in a more dynamic and engaged combination of knowledge, skills, and attitudes relevant to various real-world contexts that require their functional application. Fig. 1 illustrates the key competencies for lifelong learning.

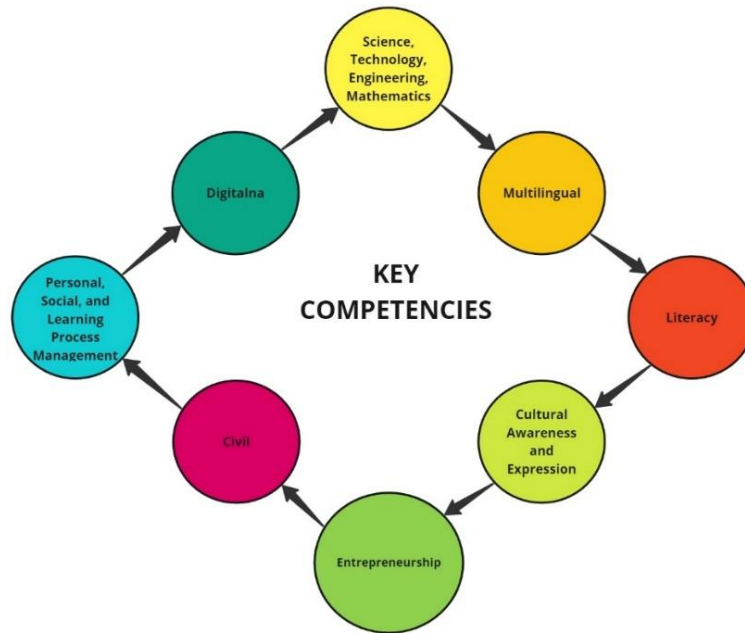


Figure 1. Key Competencies for Lifelong Learning

General cross-curricular competencies are based on the application of key competencies developed through the teaching of all subjects. They are applicable in many situations and contexts that require problem-solving and task completion. Moreover, they are essential for all students for personal development, social inclusion, and employment, forming the foundation for lifelong learning.

It can be concluded that students who master cross-curricular competencies will be more adaptable in daily life and work. The content and methods used to study these competencies are crucial for their development, emphasizing research, interactive methods, reflection, critical thinking, cooperative learning, and other approaches that enhance student participation in the educational process. Fig. 2 illustrates some of the cross-curricular competencies important for IT students in the Republic of Serbia.

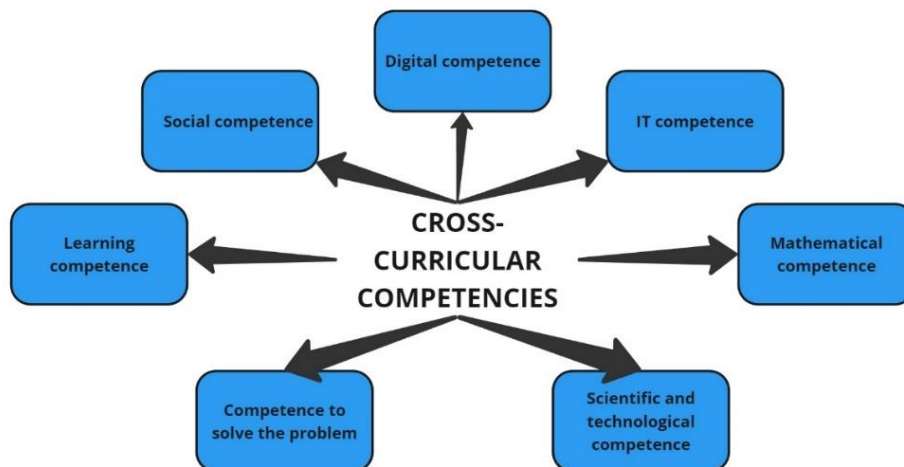


Figure 2. Cross-Curricular Competencies

2 LITERATURE REVIEW

In the educational system, the development of key competencies is an integral part of teaching, especially in the field of information technologies. According to (Aleksić, 2012), the competence of teachers through the application of ICT in teaching is the key that is needed for the development of today's modern educational system. In this context, the teacher is not only there to impart knowledge, but also to actively develop students' ability to use technologies in various educational and everyday situations. In addition, the Ministry of Education of the Republic of Serbia (Ministry of Education, Science and Technological Development of the Republic of Serbia, 2017) points to the increasing need for students to develop IT competencies, which is a basic skill for today's life and work. The education system challenges today's teachers to develop these competencies in their students by using technology as a tool to improve the teaching process.

Today's students must be able to apply the acquired knowledge in different contexts, which is the basic principle of cross-curricular learning. Through the work of (Milić, 2024), which deals with teaching methods for students who have a special inclination towards informatics, it is completely clear that learning within different subjects is connected with developing the ability to apply acquired knowledge in different areas. Teachers, who represent a key factor, must develop strategies that will enable students to use ICT in various forms, which should contribute to the development of these competencies.

The application of today's technologies in the teaching of computer science is becoming more and more necessary in order to prepare students for the challenges of the digital era. In order to achieve the goals in teaching informatics and computing, teachers must use different methods and a wide range of different tools. This includes the use of digital resources, ie. tools for online learning, integration of more advanced technologies such as various simulations and different forms of programming. The Institute for the Improvement of Education and Training (Institute for the Improvement of Education and Training, 2011) reminded of the importance of continuous professional development of teachers in this area, because if they constantly improve their competences, then they will be able to respond adequately to the needs of students in this dynamic and technological environment.

3 METHODOLOGY

This paper aims to investigate the experiences and attitudes of teachers, as well as students, when applying ICT in the teaching of informatics, as well as the impact of modern teaching methods such as electronic learning, m-learning and blended learning on education. The research was carried out with the help of surveys that were given to teachers and students that covered key aspects in the use of ICT in education.

The research was conducted among 50 students and 10 informatics teachers from different secondary schools in the territory of Serbia. Students were selected from different grades and majors to make the sample representative. The teachers were selected to include different schools with different levels of ICT implementation in their schools in order to obtain a wider range of data on its use in teaching informatics.

Surveys were used to collect data, which were designed to investigate the views of teachers and students on the use of ICT in teaching informatics. The questionnaires consisted of open-ended questions and several questions that had an option for additional comments. The survey for teachers contained questions related to the technologies that teachers use in teaching, what challenges they face in the application of ICT, as well as their attitude about the effectiveness of online teaching and electronic learning. The survey for students was designed so that they can present their experience of teaching with ICT, what are their preferences with different teaching methods, as well as their statement about the obstacles they encounter in the learning process when using technologies.

The data collected through the survey were analyzed using the descriptive statistical method. Graphical representation was used to facilitate data interpretation. A comparative analysis of the attitudes of teachers and students was also carried out. Results

The results of the research are based on the analysis of the survey, which included 50 students and 10 computer science teachers. The data that was analyzed allows the attitudes and experiences of teachers and students when it comes to the application of ICT in teaching. The data is classified into key areas, e.g. Frequency of ICT use, effectiveness of online teaching, challenges in ICT implementation, attitudes of teachers and students. In order to present a clearer interpretation, the results are displayed graphically, with comparative analyzes between teachers and students regarding their attitudes. Figure 3 shows the frequency of use of ICT in lessons

based on the answers in the surveys by teachers and students. The graphic shows that students use ICT more often than teachers, which indicates a generational age difference in the adoption of technology, as well as a different perception of the need in education.

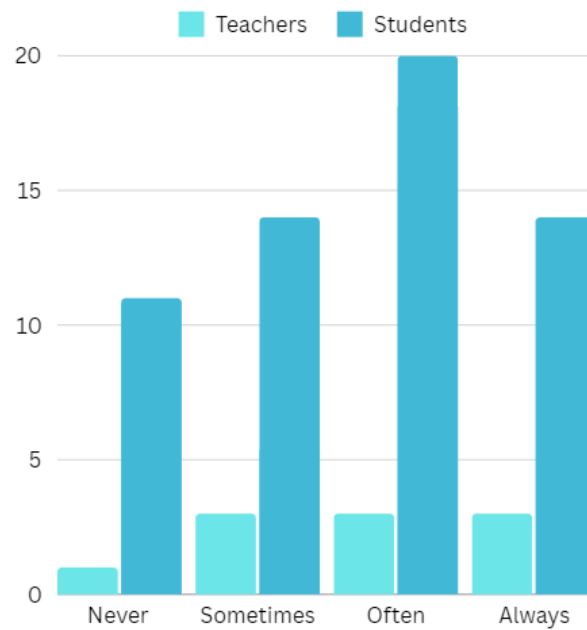


Figure 3. Use of ICT in teaching

Figure 4 shows the views of teachers and students on the effectiveness of teaching. Teachers generally believe that teaching is more effective compared to students who show a different approach to the effectiveness of teaching itself. This is due to the fact that students have different expectations, availability of resources and others.

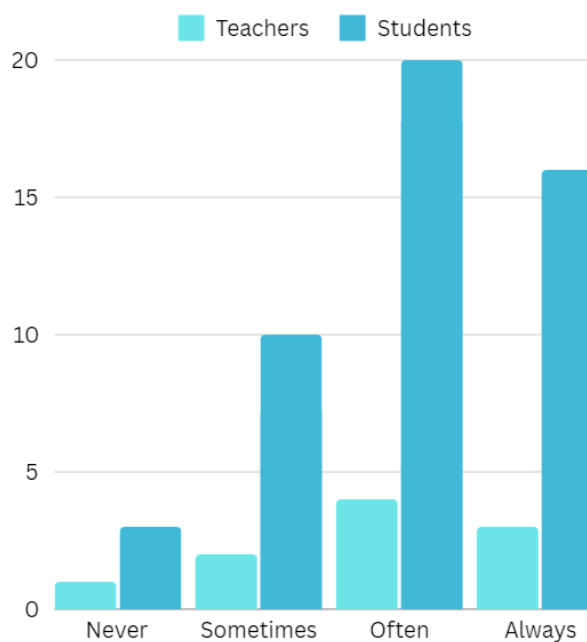


Figure 4. Effectiveness of teaching

Figure 5 and Figure 6 present challenges in the application of ICT in education for teachers and students. In both groups, technical equipment and access to the Internet were identified as significant obstacles, but even

the priorities differ, for example, teachers emphasized the importance of infrastructure and available resources they need for their teaching, while students emphasized the ease of using technology.

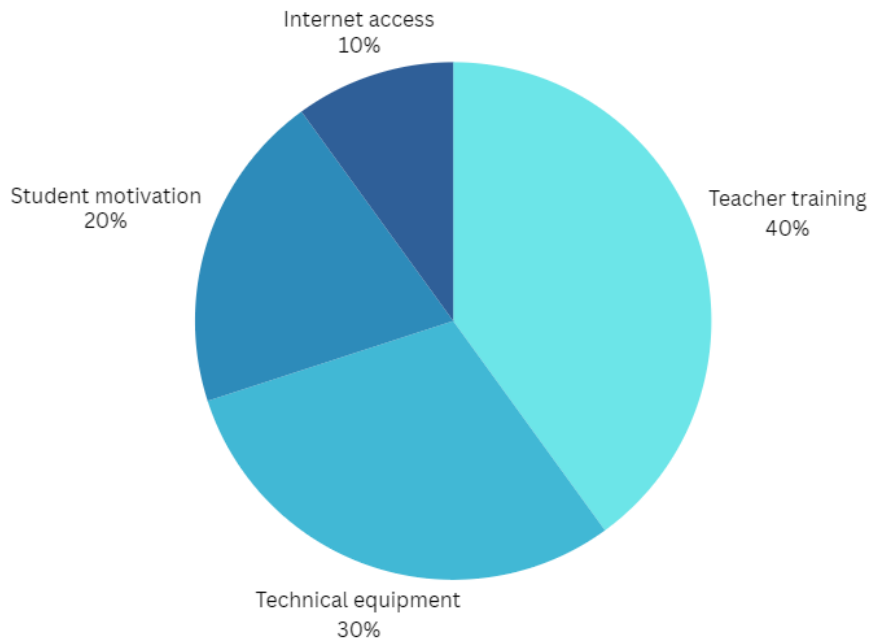


Figure 5. Challenges in the application of ICT in teaching by teachers

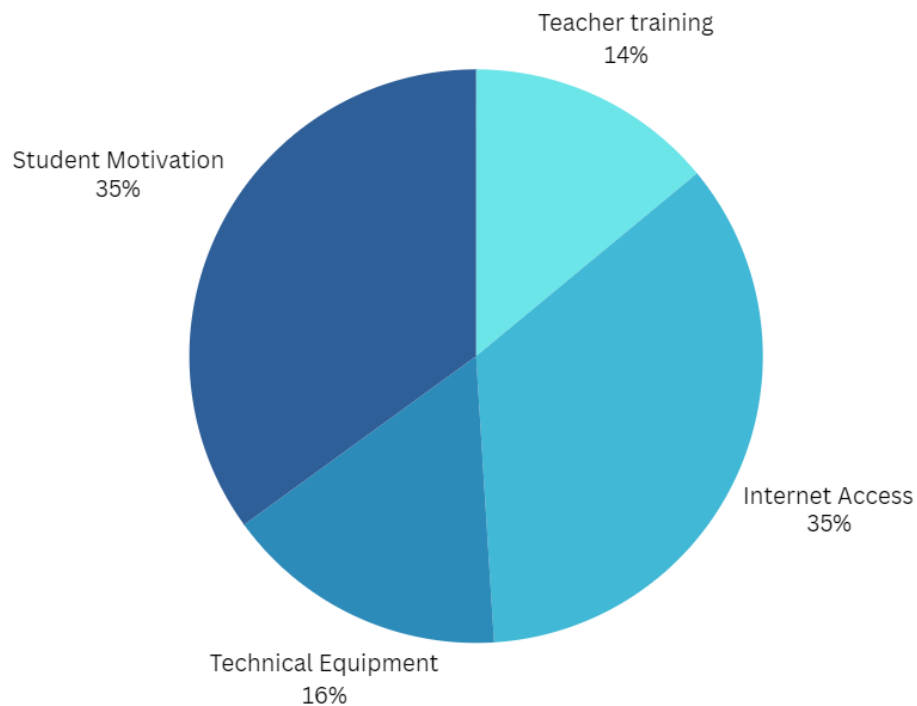


Figure 6. Challenges in the application of ICT in teaching by students

4 DISCUSSION

Based on the results of the survey, it can be concluded that there is a significant difference in the frequency of ICT use by teachers and students. Students use ICT more often, which is the result of greater exposure to everyday technology and willingness to use it in any form. This can lead to additional training of teachers, in order to improve their level of digital competence and prepare them for modern education.

Attitudes about the effectiveness of teaching also indicate differences. Teachers are optimistic about the effectiveness of teaching, while students are skeptical. This may be due to a lack of motivation and

concentration on the part of the students. For this reason, students must be offered a wider range of resources in the environment, as well as improving the content so that they are more interactive and modern in order to improve the quality of learning and reduce the challenge. Challenges in the application of ICT were recognized by both groups of respondents. Both samples highlight technical equipment and access to the Internet as a key barrier. Also, students point to the complexity of admission units, and teachers point to the lack of adequate support and training. These results point to the need for organized continuous professional training for teachers in order to increase the competence and caution in the use of ICT.

5 CONCLUSION

On the basis of this work, it can be concluded that the development of computer competences in students is for their preparation for the labor market. Teachers play a key role in imparting knowledge and shaping competencies that enable students to successfully navigate the digital and modern environment.

The paper emphasizes the importance of information literacy, which is necessary for the use of technologies and tools. The need for continuous professional development of teachers is emphasized in order to effectively transfer their knowledge and skills to their students. Methods such as m-learning and blended learning provide flexibility and adaptability in the learning process, allowing students to take responsibility for their education. Although students use ICT more often, teachers face challenges related to technical infrastructure and lack of support every day.

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Generic Framework for Online Multiplayer Turn-based Games Implementation Using Rust Programming Language

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Abstract. The paper deals with the design and implementation of a system for online turn-based games in the Rust programming language. The goal is to create an extensible framework that allows easy implementation of various turn-based games for multiple players. The system aims to generalize the basic aspects of turn-based games, providing game abstraction, infrastructure for online play, and various ways of game visualization. The features and ecosystem of the used programming language are suitable for developing full-stack systems from server-side to user interfaces on various platforms. The work emphasizes the modularity and scalability of the implemented framework, allowing its use in various types of games and easy extension with new functionalities. The result is a system that can compete with existing solutions and provides significant advances in performance and visualization capabilities. We provide a comparison-based evaluation. Our results support the decision for legacy simulator reengineering using the presented technologies for a tool used in software project management classes at the university.

Keywords and phrases: game development, Rust, turn-based games, game framework implementation.

1 INTRODUCTION

The turn-based games are widely known among the players around the world. Thanks to computers, players can enjoy playing more complex games with many variations without constantly thinking about all the rules. In addition, computer games with an implemented networking solution can connect players through the online space in one game or education session (Shurn, Hardnett, & Kearse, 2008).

There are many challenges that come into developing an online multiplayer game. For a complete and playable game system there must be implemented and integrated modules such as game core, game visualization and game state synchronization (Tekinbas & Zimmerman, 2003). The game system should ensure equal or similar conditions for all players and fairness during the whole session. Different games require different approaches, but the basic principles remain the same or very similar. Those similarities can be exploited by various abstractions that enable implementing a generic framework (Frez et al, 2024). Well defined basic structure and generic state synchronization could help the programmers focus on implementing game logic and user interface and finish development faster. Our solution is built on top of a formal game representation to ensure meeting all requirements for a game framework.

The framework is also created to support the AMEISE Modernization project, which was implemented by three students for their diploma thesis: simulation core by Š. Puci (2024), frontend visualization by Š. Porvazník (2024) and framework and backend by M. Semančik (2024). AMEISE is a legacy project management simulation system (Mittermeir et al., 2003; Bollin et al., 2018; Bollin, 2023), written in Ada and Java programming language. The latest simulation client requires Java Runtime Environment of version 1.8.

Despite its development state, this system is used in teaching software project management at different universities, including more than 150 students at the authors' institution every academic year.

2 FRAMEWORK REQUIREMENTS

2.1 Support for as many game types as possible

The framework should be general enough to allow the implementation of the widest possible spectrum of turn-based game types. The classification of games in Game theory will be used for reference of the possible properties of games. According to Huang (2010) there are multiple pairs of opposite properties which can be used to describe the type of game:

- Cooperative vs non-cooperative games
- Static vs dynamic games
- Perfect vs imperfect information games
- Complete vs incomplete information games

2.2 Design for fairness - challenges of the online environment

Algorithmically checking player actions in computer games can prevent invalid moves and inconsistent game state often seen while playing board games. Involvement of multiple devices and synchronization of the game state over the network introduces other ways to gain an advantage outside of game rules (Duh & Chen, 2009).

The solution is often to apply zero trust principle— assume that if player can cheat, he will. With this assumption in mind, decisions about system architecture, data structure or specific implementations are mostly clear. For example, server-client architecture will eliminate the need for trust with game state given to players in peer-to-peer architecture or type separation of the authoritative game state and game state visible to player should hide all unavailable information about the game for players so they cannot use them to take unfair advantage etc.

2.3 Build around formal game representation

The framework should model game data structures and behaviors according to well-defined formal representation (Jamieson et al., 2016). For this purpose, a game will be understood as a system with a configurable initial state that allows players to change its state by performing permitted actions and with defined conditions for ending the game with a specified result. The formal game representation will be an extension of the game definition of P. Riggings and D. McPherson (2020), which describes games without hidden state information.

The game definition begins with the game configuration - set of parameters that specify properties of the game. The parameters may include, for example, size or layout of the game board, number of rounds or seed for random number generator. The game configuration is used to create the initial state of the game as in (1).

$$\text{createGame} : \text{Configuration} \rightarrow \text{State}_0 \quad (1)$$

$$\text{getPlayerState} : \text{State} \rightarrow \text{Player} \rightarrow \text{State}_{\text{player}} \quad (2)$$

$$\text{makeMove} : \text{State} \rightarrow \text{Player} \rightarrow \text{Move} \rightarrow \text{MoveResult} \quad (3)$$

Next the set of entities that can interact with the game by making moves (player identifiers) must be specified. For example, for the game of chess that will be $\text{Player}_{\text{chess}} = \{\text{White}, \text{Black}\}$. All the information needed for correct game interpretation and progression should be described in game state. If State is authoritative set of information, then it is possible to define player state: $\text{State}_{\text{player}} \subseteq \text{State}$ as set of information available for specific player. The game definition then should define conversion function (2) to get state for player from current authoritative state.

In any moment during the game, player should know what moves $\text{Move}_{\text{player}} \subseteq \text{Move}$ from the set of all possible moves Move can be played in the state $\text{State}_{\text{player}}$. It is important that the set of playable moves is

computable from the player state which the player can access. The last defined set is the set of possible game results $Result$. For example, for the tic-tac-toe game $Result_{tic-tac-toe} = \{X, O, Draw\}$.

The progression of the game itself is controlled by function (3) which uses current authoritative state, player and his move to produce either next valid state or the result of the game $MoveResult = State \cup Result$.

2.4 Use Rust programming language to implement all parts of the system

Rust (Matsakis& Klock, 2014) is an open-source, multi-paradigm, compiled programming language with rich type system and unusual concepts that ensure memory safety, high performance and flawless concurrency (Klabnik& Nichols, 2018). Thanks to its properties, Rust is a great choice for systems applications, networking, web services and embedded solutions (Hong & Ryu, 2024). However, a strong community and a constantly growing ecosystem push Rust into other areas (Lyu & Rzeznik, 2023) as well.

3 IMPLEMENTATION

Due to the complexity of the project, a combination of two agile software development methodologies, Feature-Driven Development and Extreme Programming, were chosen to control the scope of the implementation process. During the development there were gradually implemented features, and the emphasis was on adding new functionality fast and expanding previous system instead of premature optimization and refactoring.

The first implemented modules were the core of the Tic-Tac-Toe game and the command line interface which allows interactively play and test the game. Another separately implemented game was Battleship. After implementing these simple games, many similarities were observed. The game loop steps were almost identical, and multiple parts could be abstracted and written generically. Implementation of the game core abstraction module enabled full refactorization and cleaning up the project resulting in a generic game runner module. Command line interface was great for the functionality testing, but players should have a more accessible graphical interface available.

The next module takes advantage of the game core abstraction for the implementation of generic web application. It uses the existing game core features and defined player state rendering and game result components to create and manage interactive game experience. The state component has access to the player state and a callback function for making moves and should render the game view with interactive inputs. This approach allows implementing the game core and visualization separately and isolating these parts from the game loop management.

The implementation of the next module extended the list of games along with game core abstraction. For the game of chess, it was decided to add a game configuration – the FEN string of starting position. With the final version of the core abstraction the next step was to implement server module with GraphQLAPI, so the games could be played in the online mode (Figure 1).

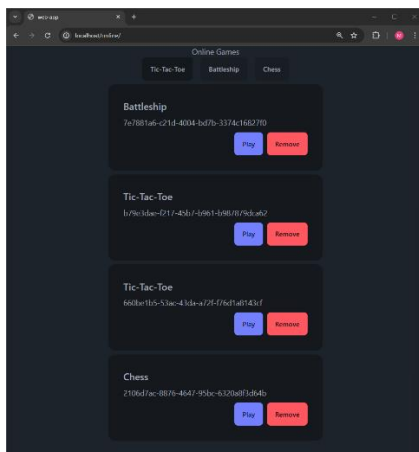


Figure 1. List of registered online games

```
#[derive(Clone, Debug, PartialEq, Routable)]
enum Route {
    #[route("/offline")] OfflineGames {},
    #[nest("/online")] #[layout(OnlineGames)]
        #[route("/")] OnlineGamesList {},
        #[route("/:id")] OnlineGame { id: String },
    #[end_layout] #[end_nest]
    #[route("/")] Index {},
}
```

Figure 2. Rust code for game routing abstraction

The implemented server solution (Figure 2) enables us to register the compatible games (core types supports JSON serialization), create multiple game instances and interact with them by making available moves. Server uses a GraphQL subscription operation to send updated player game state to the client after a certain

move is made in real time. The local game loop in the web client module was replaced with the API wrapper and the online game mode could be tested (Figure 3 and Figure 4).

The last module was implemented for the complex game visualizations also required by AMEISE Modernization project. One of the most popular Rust game engines, Bevy, was used as a base and the API communication was delivered as custom plugin with access to the API wrapper. The functionality of the plugin was demonstrated by implementing the clone of a simple card game – The mind. The last implemented feature was the data transfer size optimization. Instead of sending the whole serialized game state, server sends only the difference between current and new state which will then be reconstructed by the client. This will significantly reduce the size of transferred data for complex game state synchronization.

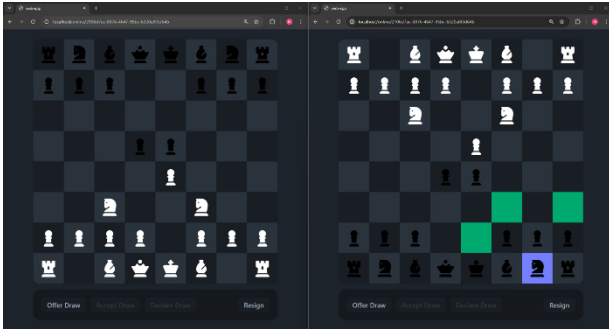


Figure 3. Chess session played online

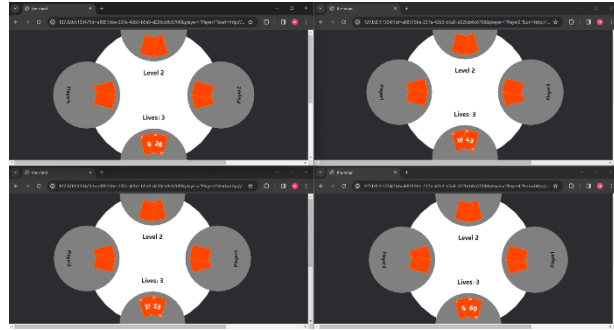


Figure 4. The mind game played by 4 players online

4 EVALUATION

At the time of writing, there was no similar framework written in Rust, so the features and the server module performance were compared to the closest equivalent framework written in JavaScript – boardgame.io.

4.1 Features

The ability of the framework to support all types of games was demonstrated by the implemented games. Although the implemented framework lacks some useful features compared to boardgame.io (Table 1.), in addition to support of various types of games, it also enables us to implement various types of game state visualization.

Table 1. Comparison of our solution and boardgame.io based on implemented framework features

Feature	boardgame.io	Our solution	Feature	boardgame.io	Our solution
Offline mode	✓	✓	Invalid move explanation	✗	✓
Online mode	✓	✓	Command line interface	✗	✓
Multiplayer support	✓	✓	Web client	React.js	Dioxus
Multiple game instances	✓	✓	Complex visualisation	✗	Bevy
Game bots support	✓	✗	Native client	✗	Dioxus, Bevy
Observer mode and chat	✓	✗	Server framework	Koa, Node.js	Actix Web
Game configuration	✗	✓	Games registration	✓	✓
Hidden info for players	✓	✓	API	REST	GraphQL
Order of player turns	✓	✗	Real-time synchronization	WebSocket	GraphQL (WS)
Game phases	✓	✗	Player authentication	✓	✗
Deterministic behavior	✗	✓	Persistent data storage	✓	✗

4.2 Performance

The performance of a server module is a key metric to determine if the system is ready for a large number of game instances used by players. A simple test scenario was designed to test and compare two frameworks: use the API to instantiate the game instance and then play the first move of the game. Multiple number of virtual

users (VUs) were used to simulate real traffic during a time span of 10 seconds (Table 2). The implemented solution handled an average of 680% more requests (iterations) with 3 times less RAM usage compared to boardgame.io. The implemented solution also managed to respond with a 100% success rate, while

Table 2. Comparison of our solution and boardgame.io using selected performance metrics, based on simulated traffic load for 10.0 seconds

<i>Framework</i>	<i>Duration</i>	<i>VUs</i>	<i>RAM Usage (start / peak)</i>	<i>Iterations</i>	<i>Success rate</i>	<i>Upload / Download</i>
Our solution	10.0 s	10	2.7 MB / 136.3 MB	252535	100%	84 MB / 55 MB
	10.0 s	100	2.8 MB / 140.6 MB	255920	100%	85 MB / 56 MB
	10.0 s	1000	2.8 MB / 153.9 MB	229206	100%	76 MB / 50 MB
boardgame.io	10.0 s	10	191.5 MB / 477.0 MB	37198	100%	7.8 MB / 5.8 MB
	10.0 s	100	191.1 MB / 480.0 MB	36868	100%	7.7 MB / 5.8 MB
	10.3 s	1000	188.8 MB / 454.0 MB	52092	49.96%	5.4 MB / 4.1 MB

boardgame.io rejected half of the request in the third test with 1000 VUs.

The difference in performance was definitely caused by Rust being a low-level compiled language and JavaScript being an interpreted language. However, it shows that the same or even more robust type-safe abstraction can be achieved without losing performance.

5 CONCLUSION

The implemented framework has great potential to become a robust platform for developing and deploying turn-based games. Modularity and flexibility have been demonstrated by implementing various types of games. The separation of game core and game visualization enabled colleagues Š. Puci and Š. Porvazník to work independently on their modules and then effortlessly integrate them into one functioning system. The Rust programming language was an excellent choice, and its advantages were shown not only during development and modeling, but also in performance testing.

The framework could be used in education for a Rust programming language course or a game development course. It offers a solid foundation for data structures and system behavior and supports the rapid implementation of a selected online multiplayer turn-based game. The game abstraction structure and Rust error handling principles could make students understand the benefits of good software design in team development.

Renewal and reengineering of AMEISE will allow the spread of the tool for software project management process education to a higher number of students (Shu Jiang et al., 2015 & Wong et al., 2019), eliminating several installation and setup problems that originated in the legacy state of the application. Such a modular framework representation will also allow inclusion of new principles and data into the existing application by preserving the user experience, making the learning tool easier to use by all students.

There are a lot of possible improvements and features that could extend the current framework capabilities. The ability to spectate the game and time management per player turn are easy to implement quality of life improvements. Adding more advanced features, such as a system for creating and registering game bots, partial generalizations of game types and generic matches and tournaments implementation should be possible thanks to the Rust type system and the current game abstraction implementation.

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Literature Review – Ontology Models for Knowledge Management in Software Engineering

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Abstract. This paper investigates the application of ontology models in knowledge management (KM) within the field of software engineering (SE). Through a systematic analysis of 108 selected papers, 29 of which specifically focus on models, the review highlights the importance of ontologies in knowledge sharing, collaboration and decision-making within SE. This paper deals with the application of ontology models in knowledge management (KM) within the field of software engineering (SE). Through a systematic analysis of 108 selected papers, 29 of which specifically focus on models, the research provides insight into how ontology models can improve efficiency and innovation in software engineering processes. Analysis highlights the key role these models play in organizing information and fostering collaboration across teams. Also, the paper examines the specific domains of application of these models, which underscores their value in the context of KM in SE, opening the way to more efficient practices and innovations.

Keywords and phrases: Knowledge Management, Software Engineering, Ontology, Model

1 INTRODUCTION

Knowledge Management (KM) discipline has matured significantly over the past 30 years. Evidence of this comprises a variety of models, typologies, and perspectives of knowledge, i.e. tacit versus explicit and objectivist versus practice-based knowledge [Hislop et al., 2018; Jasimuddin et al., 2005; Marabelli& Newell, 2014]. KM encompasses practical business applications and academic exploration. The procedure involves a methodical way of developing, sharing, using, and managing knowledge and information within a company with goal of improving effectiveness and achieving strategic objectives [McInerney, 2002].

In the Software Engineering (SE) field, the issue of how software development should be organized to deliver solutions that are faster, better, and cheaper has been widely discussed over the past few decades. Many methodologies, practices, techniques, and tools have been suggested for process improvement [Cabral et al., 2014]. In the context of SE, KM is fundamental to the capturing, organization, and leveraging of such mountains of knowledge created during Software Development to make work easier and to foster innovation [Vecštejn et al., 2024].

Ontology is useful in structuring complex definitions and is meant to provide an understanding of static domain knowledge by defining concepts, relationships, and properties. Models in the domain of KM in SE provide a structure to understand how knowledge is generated, shared, and applied throughout different processes and software development.

This Preliminary Literature Review contributes to the initial exploration of existing research. By identifying and analyzing selected scientific papers that focus on Ontologies within the context of KM in SE, this study initiates a systematic understanding. In the Related Works section, a comprehensive review of studies on Ontologies for KM in SE will be presented. Afterwards, the Methods section will outline the process behind the Literature Review, including search strategies, as well as the inclusion and exclusion criteria that are used to select relevant papers. Results and Discussion section will present the findings from

selected primary studies (PS), including an analysis and examination of tables and figures. The conclusion section will summarize the main insights and propose future research direction on Ontology models for KM in SE.

2 RELATED WORKS

In this section, several recent studies have explored a review of the use of ontologies in addressing KM within SE. These reviews shed light on ontologies' role and show where research stands in its current state.

Fraga et al. (2020) presented a Systematic Literature Review (SLR) to explore Ontology-based solutions used in Industrial Environments. To see if these standards became ontologies and helped make Ontology-based systems, they checked the standards or families that fix semantic interoperability problems in the industry. They also investigated other ways for academia to use to build knowledge bases for Product Lifecycle Management Systems (PLMS). SLR was conducted by following guidelines by Kitchenham et al. (2015) for conducting a systematic review in software engineering. This methodology involves comprehensive search strategies that include research questions, selecting relevant studies, and applying inclusion and exclusion criteria. Authors through research identified several groups of implementation approaches. 15 studies propose implementation of frameworks, 13 studies propose models, 9 methods, 2 plugins, 2 web applications, 9 desktop applications, and 4 prototypes.

Triandini et al. (2021) presented a systematic literature review of the role of ontology in modeling knowledge in software development. The findings provide answers to research questions related to the role of ontology in modeling and the challenges of using ontologies in software engineering. Use of ontologies in software modeling includes modeling data in software development, database, and application integration, using vocabulary for describing knowledge, assistance in software testing, resolving problems with change of software requirements, use in Internet of Things (IoT) systems, quality assessment and improvement of software development, detecting change in software systems, and use of patterns in development. The main identified challenges for using ontologies in software engineering are software development improvement, knowledge abstraction, limited knowledge in malware detection, evaluation of used ontologies, management in software development, ontology in the context of software security, and problems in adjusting to project plans in software development.

In an SLR, Karabulut et al. (2023) highlight the importance of ontologies for Digital Twins (DTs). They point out that these frameworks make it easier to combine architectural layers. Their study reveals that 31 of the ontologies examined have concepts that connect the physical and digital realms well. This showcases the semantic unity that is a key to the DT framework. When it comes to knowledge graphs, authors see that 17 of the papers they reviewed use such frameworks. These serve as semantic interfaces. Classification of knowledge graphs is enlightening as they are utilized for a range of purposes including querying, information extraction, anomaly detection, etc.

3 METHODS

A more comprehensive literature review has been performed on models, frameworks, and methods in Knowledge Management within Software Engineering. The initial objective was to investigate the activities and focus areas of individuals in the field. Our research concluded that models, frameworks, and methods are commonly employed to address specific problems. The objective of this paper is to focus solely on the review of models in Knowledge Management in Software Engineering based on Ontologies.

Certain procedures for Literature Review used in this study are adapted from [Kitchenham2015]. While our study is not a comprehensive Systematic Literature Review, specific methodologies presented from Chapter 22 of the book [Kitchenham et al., 2015] were employed to guide our Literature Review process, which is shown in Fig. 1.

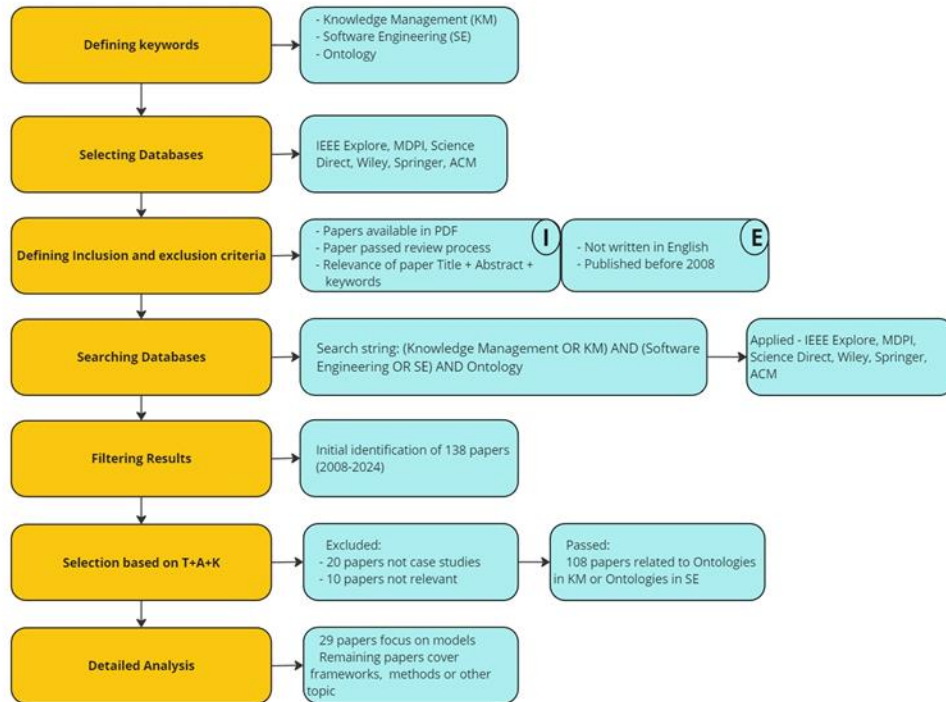


Figure 1. Literature Review process

As shown in Fig. 1. the yellow blocks show the stages of the literature search, while the cyan blocks show selected content.

Four main keywords were suggested for this preliminary Literature Review:

- Keyword 1 (KW1) – “Knowledge Management” OR “KM”
- Keyword 2 (KW2) – “Software Engineering” OR “SE”
- Keyword 3 (KW3) – “Ontology”
- Keyword 4 (KW4) – “Model”

These four primary keywords represent the basic concepts that guide the search for relevant literature. To improve the accuracy of the literature search, logical operators were used to combine search terms. Boolean operators AND and OR were used to connect key concepts in the search string. By combining these four keywords, the following search string was formed:

K1W AND K2W AND KW3 AND KW4

This literature search string was applied across databases such as IEEE Explore, MDPI, ScienceDirect, and Wiley. Additional searches were conducted using the Google Scholar Web search engine to find some articles that were not published in the specified databases.

The papers for this preliminary Literature Review were selected based on specific inclusion criteria.

- Inclusion criteria: (I1) To ensure accessibility, only articles in PDF format were included; (I2) Papers that passed the review process; (I3) Emphasis on the relevance of the article title, abstract, and keywords (T+A+KW) to ensure consistency with the research focus.

To ensure the relevance and quality of the literature selected for this preliminary review, certain exclusion criteria were used.

- Exclusion criteria: (E1) Articles not written in English; (E2) Articles published before 2008

A search was conducted in the selected databases based on the specified search strings, and inclusion and exclusion criteria. A total of 138 papers were published between 2008 and 2024. Upon analyzing the text of the collected research papers, it was found that 20 papers were not case studies, and 10 papers did not

correspond to the topic. The remaining 108 papers, which dealt with the subject areas of knowledge management, ontology, or software engineering, were included for a more detailed analysis.

A detailed analysis of these 108 papers showed that 29 of them focused specifically on models, while the remaining papers addressed frameworks, methods, or various other topics. These 29 research papers were selected as primary studies (PS) as shown in Table 1.

Table 1. Selected Primary Studies for Models in KM in SE

Primary studies	References	Year
PS1	Zhang, R., & Guo, L. (2008, December). Knowledge management based on ontology modeling in collaborative learning environment. In <i>2008 International Conference on Computer Science and Software Engineering (Vol. 5, pp. 337-340)</i> . IEEE.	2008
PS2	Wongthongtham, P., Chang, E., Dillon, T., & Sommerville, I. (2008). Development of a software engineering ontology for multisite software development. <i>IEEE Transactions on Knowledge and Data Engineering</i> , 21(8), 1205-1217.	2008
PS3	Latifi, M., Khotanlou, H., & Latifi, H. (2011, May). An efficient approach based on ontology to optimize the organizational knowledge base management for advanced queries service. In <i>2011 IEEE 3rd International Conference on Communication Software and Networks (pp. 269-273)</i> . IEEE.	2011
PS4	Li, X., & Zhang, W. (2012, April). Ontology-based testing platform for reusing. In <i>2012 Sixth International Conference on Internet Computing for Science and Engineering (pp. 86-89)</i> . IEEE.	2012
PS5	Khan, M. M. S., Khan, M. A. S., Goto, T., Nishino, T., & Debnath, N. (2014, June). Software ontology design to support organized open source software development. In <i>15th IEEE/ACIS International Conference on Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing (SNPD) (pp. 1-6)</i> . IEEE.	2014
PS6	Ahsan, M., Motla, Y. H., Anwar, A., & Azeem, M. W. (2014, December). Knowledge management model for support of requirement engineering. In <i>2014 International Conference on Emerging Technologies (ICET) (pp. 7-12)</i> . IEEE.	2014
PS7	Liem, I., Semiawan, T., & Chandra, A. (2015, October). A software system family: Learning from simple data processing to knowledge management system of research. In <i>2015 7th International Conference on Information Technology and Electrical Engineering (ICITEE) (pp. 24-28)</i> . IEEE.	2015
PS8	Zhang, S., Boukamp, F., & Teizer, J. (2015). Ontology-based semantic modeling of construction safety knowledge: Towards automated safety planning for job hazard analysis (JHA). <i>Automation in Construction</i> , 52, 29-41.	2015
PS9	Avdeenko, T. V., & Pustovalova, N. V. (2016, October). The ontology-based approach to support the requirements engineering process. In <i>2016 13th International Scientific-Technical Conference on Actual Problems of Electronics Instrument Engineering (APEIE) (Vol. 2, pp. 513-518)</i> . IEEE.	2016
PS10	Kajko-Mattsson, M., Sjögren, A., & Lindbäck, L. (2017, May). Everything is possible to structure-even the software engineering body of knowledge. In <i>2017 IEEE/ACM 1st International Workshop on Software Engineering Curricula for Millennials</i>	2017

	(SECM) (pp. 61-67). IEEE.	
PS11	Lamy, J. B. (2017). Owlready: Ontology-oriented programming in Python with automatic classification and high level constructs for biomedical ontologies. <i>Artificial intelligence in medicine</i> , 80, 11-28.	2017
PS12	Flynn, A. J., Friedman, C. P., Boisvert, P., Landis-Lewis, Z., & Lagoze, C. (2018). <i>The Knowledge Object Reference Ontology (KORO): a formalism to support management and sharing of computable biomedical knowledge for learning health systems</i> (Vol. 2, No. 2, p. e10054).	2018
PS13	Chugh, M. (2021, October). A Research Perspective on Integrating Knowledge Management for Software Engineering. In <i>2021 5th International Conference on Information Systems and Computer Networks (ISCON)</i> (pp. 1-5). IEEE.	2021
PS14	Bao, T., Chen, K., Zhang, H., Zhang, Z., Ai, Q., & Yan, J. (2023). Comprehensive Calculation Method of Semantic Similarity of Transport Infrastructure Ontology Concept Based on SHO-BP Algorithm. <i>Applied Sciences</i> , 13(19), 10587.	2023
PS15	Savić, G., Segedinac, M., Konjović, Z., Vidaković, M., & Dutina, R. (2023). Towards a Domain-Neutral Platform for Sustainable Digital Twin Development. <i>Sustainability</i> , 15(18), 13612.	2023
PS16	Kurteva, A., Chhetri, T. R., Tauqeer, A., Hilscher, R., Fensel, A., Nagorny, K., ... & Demidova, E. (2023). The smashHitCore ontology for GDPR-compliant sensor data sharing in smart cities. <i>Sensors</i> , 23(13), 6188.	2023
PS17	Mendoza-Moreno, J. F., Santamaria-Granados, L., Fraga Vázquez, A., & Ramirez-Gonzalez, G. (2021). OntoTouTra: tourist traceability ontology based on big data analytics. <i>Applied Sciences</i> , 11(22), 11061.	2021
PS18	Hamrouni, B., Bourouis, A., Korichi, A., & Brahmi, M. (2021). Explainable ontology-based intelligent decision support system for business model design and sustainability. <i>Sustainability</i> , 13(17), 9819.	2021
PS19	Tzagkarakis, E., Kondylakis, H., Vardakis, G., & Papadakis, N. (2021). Ontology based governance for employee services. <i>Algorithms</i> , 14(4), 104.	2021
PS20	Pileggi, S. F., Indorf, M., Nagi, A., & Kersten, W. (2020). CoRiMaS—An ontological approach to cooperative risk management in seaports. <i>Sustainability</i> , 12(11), 4767.	2020
PS21	Ali, N., & Hong, J. E. (2018). Failure detection and prevention for cyber-physical systems using ontology-based knowledge base. <i>Computers</i> , 7(4), 68.	2018
PS22	Ajami, H., & Mcheick, H. (2018). Ontology-based model to support ubiquitous healthcare systems for COPD patients. <i>Electronics</i> , 7(12), 371.	2018
PS23	Wang, S., Liu, X., Wang, H., & Hu, Q. (2018). A case study on spatio-temporal data mining of urban social management events based on ontology semantic analysis. <i>Sustainability</i> , 10(6), 2084.	2018
PS24	Carmody, L. C., Gargano, M. A., Toro, S., Vasilevsky, N. A., Adam, M. P., Blau, H., ... & Robinson, P. N. (2023). The Medical Action Ontology: A tool for annotating and analyzing treatments	2023

	and clinical management of human disease. <i>Med</i> , 4(12), 913-927.	
PS25	Chokwitthaya, C., Zhu, Y., & Lu, W. (2023). Ontology for experimentation of human-building interactions using virtual reality. <i>Advanced Engineering Informatics</i> , 55, 101903.	2023
PS26	Scheuer, S., Jache, J., Kičić, M., Wellmann, T., Wolff, M., & Haase, D. (2022). A trait-based typification of urban forests as nature-based solutions. <i>Urban Forestry & Urban Greening</i> , 78, 127780.	2022
PS27	Santos, G., Morais, H., Pinto, T., Corchado, J. M., & Vale, Z. (2023). Intelligent energy systems ontology to support markets and power systems co-simulation interoperability. <i>Energy Conversion and Management: X</i> , 20, 100495.	2023
PS28	Hernández, L., Estévez-Priego, E., López-Pérez, L., Cabrera-Umpiérrez, M. F., Arredondo, M. T., Fico, G., ... & Gatta, G. (2024). HeNeCON: An ontology for integrative research in Head and Neck cancer. <i>International Journal of Medical Informatics</i> , 181, 105284.	2024
PS29	Monaco, R., Liu, X., Murino, T., Cheng, X., & Nielsen, P. S. (2023). A non-functional requirements-based ontology for supporting the development of industrial energy management systems. <i>Journal of cleaner production</i> , 414, 137614.	2023

4 RESULTS AND DISCUSSION

Based on the preliminary research and through analysis and research, 12 model types were identified and listed in Fig. 2.

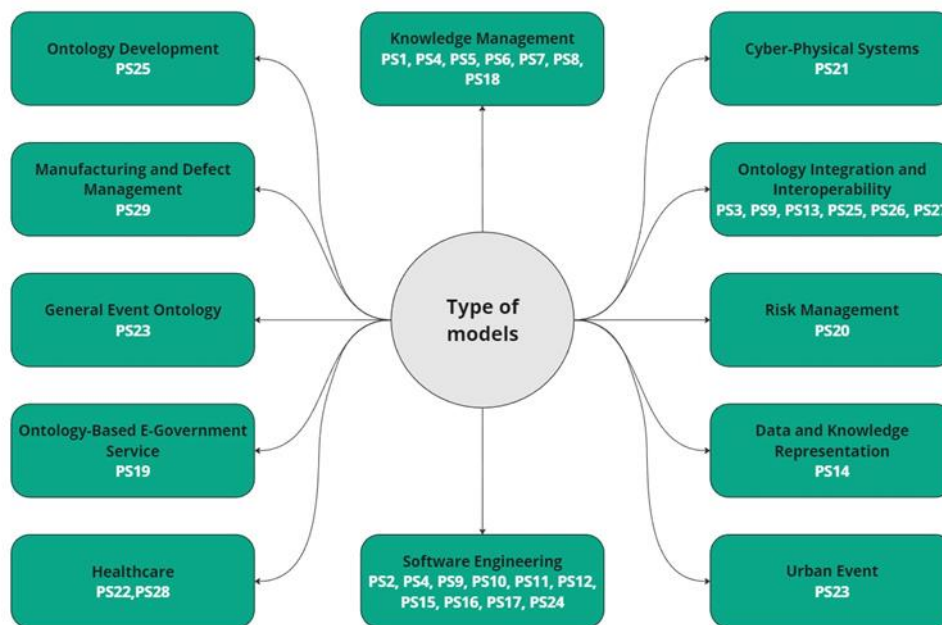


Figure 2. Types of Models

In the field of Knowledge Management, various models have been developed to improve knowledge organization and utilization. The primary studies that discuss or utilize Knowledge Management models include [PS1], [PS4], [PS5], [PS6], [PS7], [PS8], and [PS18]. These studies highlight the importance of structured mechanisms in the management and distribution of knowledge assets among members of the organization. In the realm of Software Engineering, models are quite central to software engineering

activities. The models construction of Software Engineering have also attracted many studies such as [PS2],[PS4],[PS9],[PS10],[PS11],[PS12],[PS15],[PS16],[PS17] and [PS24]. These studies reveal how software engineering methods should enhance the process of designing and developing the software so that the systems that are developed with needs and quality. Similarly, the type Ontology Integration and Interoperability has been investigated by studies [PS2], [PS7], [PS8], [PS11], [PS22], [PS26] and [PS29].

These studies consider building ontologies as an approach that would enable different systems to utilize the data they contain. In addition to these, some models are specifically focused on Manufacturing and Defect Management, Data and Knowledge Representation, Risk Management, General Event Ontology, Open Knowledge Repository for Ontology Integration, Ontology-Based E-Government Service, Context-Based Security Knowledge, Collaborative Learning, and Urban Event.

From the primary studies, specific domains focus on modeling across different sectors. Further, the primary studies associated with these areas illustrate various dimensions of knowledge, technologies, and management practices. Fig. 3. presents an overview of identified domains along with their corresponding primary studies, showing the vast range of research aimed at advancements within each area.

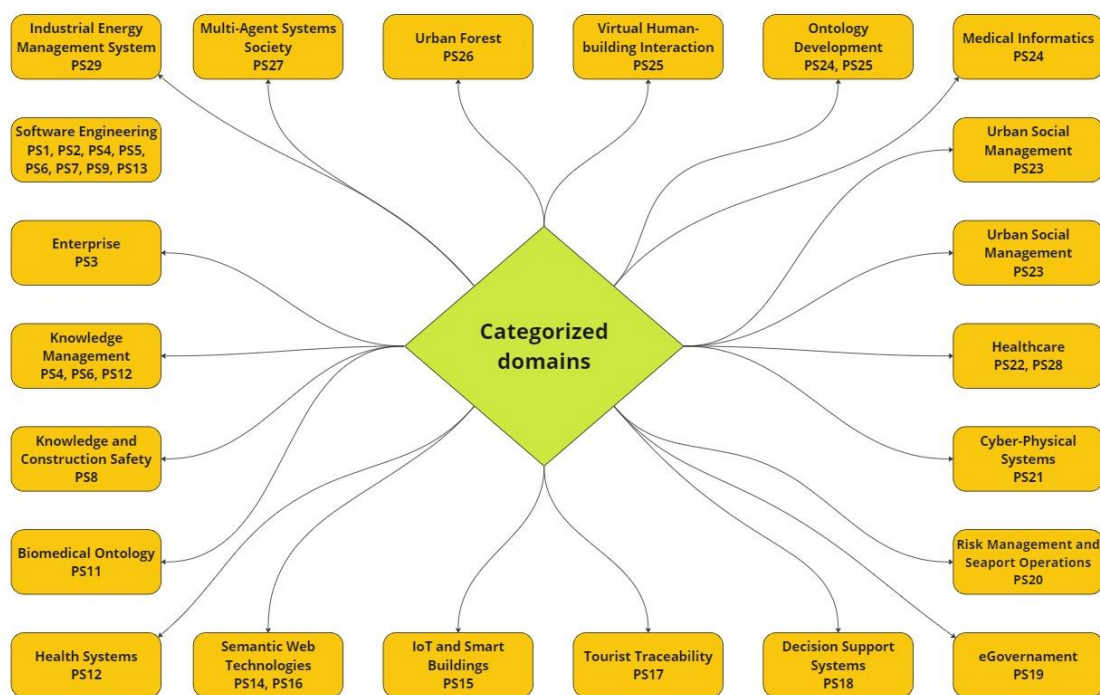


Figure 3. Categorized domains based on primary studies

Software Engineering models are an essential focus area, with primary studies including [PS1], [PS2], [PS4], [PS5], [PS6], [PS7], and [PS9]. Knowledge Management models follow closely, represented by studies [PS4], [PS6], and [PS12]. The other scope in terms of categories covers Enterprise [PS3], Biomedical Ontology [PS11], IoT, and Smart Buildings [PS15], among others, showcasing a diverse range of applications in the context of models.

5 CONSTRAINTS AND VALIDITY

Literature reviews in software engineering need to adjust to validity criteria to properly address identified threats and increase the reliability and usability of reported findings [Zhou et al.,2016]. The authors are aware of potential threats to validity, such as the construction of a search string, the selection of databases to search, the assessment of the quality of selected papers, and the construction of the findings. Literature review faced limitations related to access to certain papers that are only available through paid databases.

Presented details on planning and conducting a literature review are essential for addressing internal validity, which is done in the third section of the paper. Based on the description of the review process, including the search for papers and their analysis, enables traceability from findings to the selected primary studies. This increases the reliability of the presented findings. External validity relates to the generalizability of the

findings. Since the findings are specific to the stated field, there is no intention to generalize findings to other fields in software engineering. However, the authors suggest that the presented literature review process can be generalized and applied in other fields.

6 CONCLUSION

In this literature review, the different ontology models used within knowledge management in software engineering are explored. Through the analysis of selected primary studies, ontologies play a crucial role in different domains along with Software Engineering, Knowledge Management, Healthcare, Cyber Systems, Medical Informatics, Decision Support Systems, etc. By identifying and analyzing 108 relevant papers related to Ontologies in KM and SE, 29 papers were specifically focused on models. The review process was guided by methodologies that were adapted from existing literature and ensured the relevance and quality of selected papers for analysis. This paper contributes to the understanding role of Ontology models in KM in SE through the analysis of relevant literature. By identifying key papers and classifying them into different types and domains, this study provides insights into diverse approaches to ontologies. The analysis of selected studies emphasizes the importance of ontology models in structuring information.

Insights from this review may include the development of different tools that would aid the implementation of these models in daily life. It is also important to explore how ontologies can be used to improve teamwork in environments that change rapidly.

Future research could include the development of tools that would facilitate the implementation of these models in the daily practices of teams in different domains. Also, future investigations could go in the direction of exploring how ontologies can be used to improve collaboration among teams, especially in environments that change rapidly and require flexibility. These investigations would not only contribute to theoretical understanding but also provide practical guidance for industry professionals.

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Enhancing Mathematics Education through Project-Based Learning and Modern Technologies: A Practical Approach

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Abstract. This paper explores the integration of Project-Based Learning (PBL) and modern technologies as a practical approach to enhance mathematics education. On the example of PBL activity realized within mathematic course in Zrenjanin Gymnasium, this paper aims to provide educators with actionable insights and strategies to foster a more engaging and effective mathematics education. Through a detailed explanation of the presented PBL activity and recommendations for application of adequate AI and software tools, the paper highlights the potential of combining PBL with modern technologies to prepare students and teachers for the demands of the contemporary mathematics education.

Keywords and phrases: Project-Based Learning, Mathematics Education, Technology.

1 INTRODUCTION

In an increasingly complex and technologically driven world, the ability to apply mathematical knowledge to real-world situations is more crucial than ever. Traditional mathematics education often emphasizes theoretical learning and procedural fluency, leaving little room for students to explore the relevance of mathematical concepts beyond the classroom. As a result, many students struggle to see the value of mathematics, which can lead to disengagement and a lack of confidence in their abilities.

Project-Based Learning (PBL) is an educational approach where students learn by actively engaging in real-world problems and projects. PBL has recently gained meaningful attention in education. Over the past decades, it has been increasingly adopted by various educational institutions worldwide (Kokotsaki et al., 2016). PBL shifts the focus from memorization and repetitive exercises to problem-solving, collaboration, and critical thinking. Students engage with projects, encouraging them to explore mathematical concepts in depth and connect them to other disciplines.

In parallel, modern technologies, such as dynamic software and AI tools, have transformed the approaches to education. When integrated effectively into PBL, these technologies can further enhance students' engagement and provide diverse avenues for exploring complex mathematical ideas. Tools like interactive simulations, virtual manipulatives, and coding environments allow students to visualize abstract concepts and experiment with them in real-time, fostering deeper understanding and creativity (Demir and Önal, 2021).

In this paper we present one example of implementing the PBL approach in mathematics education. By examining the practice, benefits and challenges, for integrating PBL and technology, the paper aims to provide educators with actionable insights into how to transform mathematics education into a more engaging, relevant, and effective experience for students.

2 PROJECT BASED LEARNING AND ITS INTEGRATION IN THE MATHEMATICS EDUCATION

2.1 Project based learning

PBL is defined as an instructional approach where students engage in real-world tasks and challenges, fostering autonomy and critical thinking. This approach is student centered and the teacher play the role of a coordinator. Students design inquiries, plan, research, and create projects with real-world applications, often working in teams under teachers' supervision. Teachers act as facilitators, guiding students towards their goals. PBL emphasizes learning through constructing new ideas based on prior knowledge (Thuan, 2018). One of the main contributions of the PBL environment is that it engages the students and teachers into the learning process, and by that, motivate all of them for using their knowledge and skills for purpose of further research and development.

Due to its emphasis on creativity and collaboration, PBL is most effective when students have the chance to work across different disciplines, use technology to improve communication and project execution, and tackle real-world problems presented by external organizations or companies. Projects don't have to be highly complex for students to gain from PBL methods. Often, quick and simple projects can provide valuable opportunities for students to connect different content areas and practice their skills.

The process of PBL consists of several steps. Depending of the author, it can have 4-10 steps. Some recommendations, concerning the efficiency of the learning process and activities which contribute to application of students' skills, are that PBL process need to have five steps (Felipe et al., 2016). These steps are: project presentation and identification, individual/team research, design development, building, testing and evaluation, and project delivery, Figure 1.

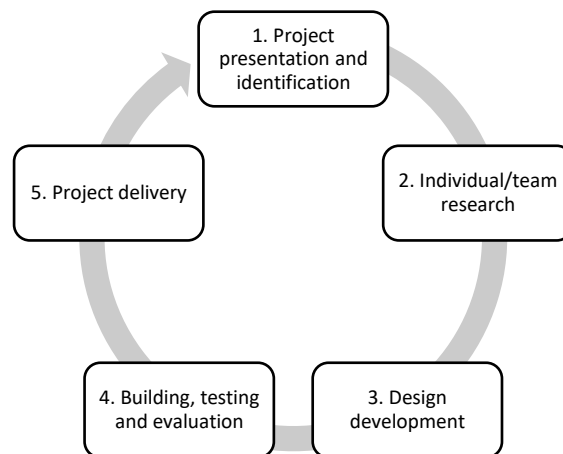


Figure 1. Five steps of PBL process

PBL process begins with the presentation and identification of the project, where the problem or challenge is introduced and objectives are defined. Students then engage in individual or team research to gather relevant information and resources, forming a solid foundation for their solutions. This leads to the design development phase, where they create detailed plans using their knowledge and skills. Based on their designs, students develop the solutions or build prototypes or models. The next step involves testing and evaluating these solutions to ensure they effectively address the problem, making necessary adjustments as needed. Finally, students deliver their completed projects, presenting their work and reflecting on their learning process.

2.2 Modern technologies and project based learning

Technology can significantly enhance PBL by providing diverse tools and platforms that facilitate exploration, collaboration, and critical thinking. It allows students to engage with real-world problems through simulations, virtual labs, and interactive software, making learning and exploring more dynamic and relevant (Balakrishnan et al., 2009).

Additionally, technology supports collaborative inquiry by enabling students to communicate and work together seamlessly, regardless of their physical location. This fosters a more inclusive and interactive learning environment where students can share resources, ideas, and feedback in real-time. Moreover, technology aids

in the development of essential 21st-century skills such as digital literacy, problem-solving, and self-directed learning, preparing students for future challenges in a technology-driven world (Shpeizer, 2019).

2.3 Contemporary mathematics education

Contemporary mathematics education emphasizes the relevance of mathematics to real-world situations by focusing on practical topics like logic, statistics, finance, and probability. That kind of approach aims to develop students' problem-solving skills and quantitative literacy, essential for modern life (Fisher et al., 2020).

The integration of digital technology has also become crucial for mathematics education, especially the using of simulations and digital tools for enhancing learning and engagement of students. In that manner, contemporary mathematics education tends to integrate PBL techniques to improve student engagement and understanding. PBL encourages students to work on real-world problems, fostering critical thinking and collaborative skills. This approach shifts the focus from traditional teaching and learning methods to active problem-solving, making mathematics more relevant and interesting (Kirabo et al., 2024).

3 EXAMPLE

The application of the PBL will be explained on the learning activity realized within Mathematics course in Zrenjanin Gymnasium with students of the third class.

3.1 Project task and realization of activities

The problem-based task "From the Parking Lot to Udarnik" was carried out outdoors, at the city parking lot by the Bega River, located near the Zrenjanin Gymnasium. The objective of the lesson was for students to apply their acquired knowledge of trigonometry in a real-world setting using the project-based learning method to identify and solve practical problems.

The students of one class, with whom the lesson was conducted, were divided into three groups. Each group had the same task: to calculate the width of the Bega River (canal). As for the tools, the students were allowed to use a wooden protractor with accompanying equipment, a measuring tape, and a calculator. Each of the three groups performed their own measurements and calculations.

At the beginning of the lesson, the teacher clearly defined the task, introduced the students to the tools and their usage, and provided basic guidelines on potential ways to solve the given problem. During the measurements, the students worked as a team, using discussion and planning to carry out individual steps in solving the project task, Figure 2.



Figure 2. The task, tools and project activities

Additionally, the teacher reminded the students to follow safety rules and maintain a respectful attitude towards others present (to not disturb passersby and fishermen). The students recorded their observations and measurement results in pre-prepared documents, which also included a section for describing the process of solving the task and calculating the results. The activities planned for two lessons were completed within the scheduled time frame, and the students returned to the school after conducting the necessary measurements and collecting all the data.

3.2 Presentation and the discussion of the obtained results

After completing the outdoor activities, the next Mathematics lesson was planned for the presentation and discussion of the results. Each of the three groups of students presented their approach to solving the given problem and their results. The groups compared their problem-solving methods and the obtained results, Figure 3.

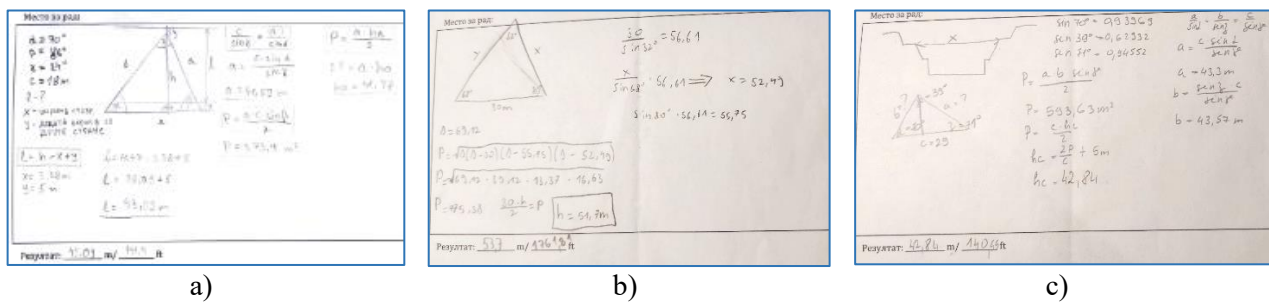


Figure 3. Solutions and presentation of the task

The teacher then initiated a discussion on the topic of measurement errors. The students actively participated in the discussion and came to the following conclusions:

- "Measuring instruments" are one of the sources of error in measurement because they are not sufficiently precise. In connection with this conclusion, the students immediately explored digital tools and applications that can be used for more precise measurements.
- The landmarks used by the students for the measurements were not at the same level on both sides of the river.
- The path that runs alongside the river is not parallel to it.

The achievement of the objectives and the presence of the anticipated competencies were confirmed through the analysis of the problem-solving methods, the obtained results, and the discussion of errors during the projects' implementation.

In the final part of the lesson, the students expressed satisfaction with having the opportunity to apply their acquired knowledge in Mathematics to solving real-world problems. The students positively evaluated the project-based learning approach, particularly appreciating the opportunity to independently devise problem-solving methods, discuss the obtained results, and, most importantly, work in teams.



3.3 Computer technologies

For the purpose of enhancing the PBL process and outcomes, various technologies could be used. On the example presented above, we will give some recommendations for possible use of AI tools and software GeoGebra.

3.3.1 AI tools and designing of the project activities

AI tools can be helpful for PBL, especially in the phase of research and design development. On the example of measuring the width of the river, we used and compared responses of two AI tools, MS Copilot and ChatGPT, Table 1.

Table 1. Comparison of the responses given by Copilot and ChatGPT

Question: I want to measure the width of the river. I have a meter and a theodolite. Suggest the steps to take in order to measure the width of the river.	
 Copilot	 ChatGPT
<p>Sure! Here are the steps to measure the width of the river using a meter and a theodolite:</p> <ol style="list-style-type: none"> Select two points: Choose two points on opposite banks of the river that are directly across from each other. These will be your reference points. Set up the theodolite: On one bank, set up the theodolite at your chosen point. Ensure it is level and properly calibrated. Measure the angle: Sight the theodolite towards the point on the opposite bank and measure the horizontal angle. Record this angle as θ_1. Measure the baseline: Using the meter, measure a straight line distance d along your bank from the theodolite to a second point. This distance should be as long as possible to increase accuracy. Move the theodolite: Move the theodolite to the second point on your bank and set it up again. Measure the second angle: Sight the theodolite towards the same point on the opposite bank and measure the horizontal angle. Record this angle as θ_2. Calculate the width: Use the following formula to calculate the width of the river W: $W = \frac{d \cdot \sin(\theta_2)}{\sin(\theta_1 + \theta_2)}$ <p>Where: d is the measured distance along your bank, θ_1 is the first measured angle, θ_2 is the second measured angle. This method uses trigonometry to accurately determine the width of the river.</p>	<p>Steps to Measure the Width of the River:</p> <p>Choose Measurement Points: Identify two points on opposite banks of the river that are as directly across from each other as possible.</p> <p>Set Up the Theodolite: Position the theodolite on one bank (Point A), aiming it towards the opposite bank (Point B).</p> <p>Level the Theodolite: Ensure the theodolite is level. Use the leveling screws to adjust if necessary, ensuring accuracy in your measurements.</p> <p>Measure the Angle: From Point A, measure the angle to a reference point (Point C) that is perpendicular to the river. This point should be at a known distance from Point A.</p> <p>Measure the Distance: Use the meter to measure the distance from Point A to Point C (let's denote this distance as d_1).</p> <p>Move to Point C: Go to Point C and set up the theodolite again, aiming towards Point B.</p> <p>Take the Second Angle Measurement: Measure the angle from Point C to Point B. Note this angle as well.</p> <p>Calculate the Width: Use the tangent function to calculate the width of the river. You can apply the formula:</p> $\text{Width} = d_1 \times \tan(\text{angle from C to B})$ <p>This will give you the approximate width of the river.</p> <p>Repeat for Accuracy: It's advisable to repeat the measurements for increased accuracy. If possible, take multiple readings from different points.</p> <p>Document Results: Record all your measurements and calculations for reference.</p> <p>By following these steps, you should be able to accurately measure the width of the river.</p>

It can be observed that both AI tools we used, gave more or less, similar responses. MS Copilot used the formula for calculation of the width of the river based on the Law of Sines, while ChatGPT used slightly different formula and also gave further recommendations concerning accuracy of the measuring and for documenting results.

AI tools can be very useful for PBL because it can be used as some kind of “adviser” in situations when problems regarding planning further steps of the project arise. Although, students need to be warned about AI tools, always to check the proposed solutions and the mathematical models within them, in order to surpass eventual errors which might occur when using AI tools.

3.3.2 GeoGebra

GeoGebra software can also be effectively applied in PBL by using its features and tools. We imported picture of the river whose width students measured, and by applying GeoGebra tools, we measured the distances, angles and the width of the river, Figure 4.

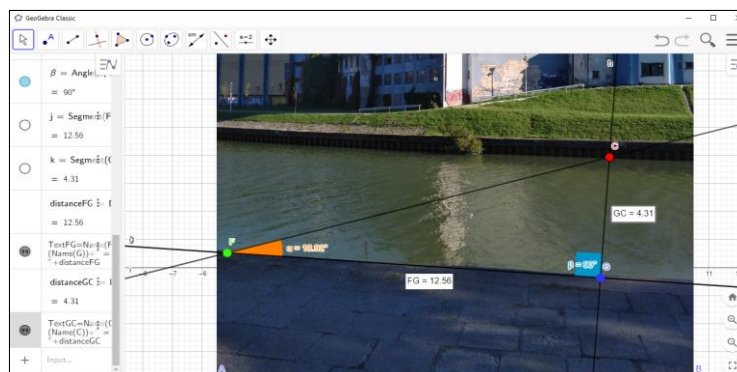


Figure 4. Application of the GeoGebra software for measuring the width of the river

It is very interesting that this kind of GeoGebra application can contribute further more to the PBL process. In this example of measuring the width of the river, the question of accuracy of the result obtained by GeoGebra might be asked. Namely, the discussion about the picture which was used in this GeoGebra material can lead to some interesting conclusions and new insights about the measuring problem. For example, it could be asked about the angle the picture was taken and would the accuracy be more precise if the river was photographed above, using the drone if that is possible? Such questions can enhance the PBL process. By leveraging GeoGebra capabilities to add visual and dynamic elements to the project, illustrating both the problem and its solution, the fundamental principles of PBL can be supported.

4 CONCLUSION

Integrating PBL and modern technologies into mathematics education offers a more engaging and practical approach for students. By shifting from traditional methods to real-world problem-solving, PBL enables students to apply mathematical concepts meaningfully. Modern technologies enhance this by providing tools for visualization, collaboration, and experimentation.

While implementing PBL and technology in the classroom requires careful planning and teacher support, the benefits are significant. Students develop critical thinking, problem-solving, and teamwork skills that are essential for academic and future success.

Finally, combining PBL and technology in mathematics education not only makes learning more relevant and efficient, but also equips students with the skills they need to thrive in an increasingly complex, technology driven world.

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Enhancing Mathematics Education Through Digital Technologies and Innovative Approach

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Abstract. The digitalization of education represents a profound transformation in the manner in which teaching and learning are conducted, particularly with regard to the development of digital competencies and skills among teachers and students. The "Digital Skills for All" programs are designed to enhance the digital competencies of both students and teachers, thereby facilitating more effective utilization of information and communication technologies (ICT) within the educational process. The use of software tools that have been designed with the specific intention of supporting mathematics learning is becoming increasingly common. These tools provide approaches that facilitate interactive learning and problem-solving. These tools are distinguished by a didactic purpose, interactivity, and the capacity to adapt to the pace of the learner. The available evidence indicates that such approaches not only enhance students' interest but also facilitate a redefinition of the teacher's role, moving away from that of a mere lecturer towards a more active and facilitative role as a mediator of knowledge. It can be reasonably deduced that fostering critical thinking in students, solving logical problems based on analysis, motivating engagement in activities, and problem-solving contribute to the sustainable development of education. In this context, the present research aims to analyse the effectiveness of digital learning software, the success of students in using digital software depending on their academic level, the intensity of software use, the form and reason for using the software, and the impact of teachers' ICT competencies on achieving greater student success.

Keywords and phrases: digitalization, education, digital skills, competencies, mathematics

1 INTRODUCTION

In the contemporary era, new opportunities for dynamic life and contemporary education have emerged, necessitating the utilisation of digital resources and tools. The European Union's action plan for digital education (2021-2027) aims to facilitate the adaptation of education to the digital era, with a particular emphasis on ensuring inclusive and accessible education at all levels. This plan is an integral component of the vision for a digitally-enabled Europe, and it provides the foundation for the realization of the Digital Compass initiative up until the year 2030.

The Republic of North Macedonia is a member of the European educational community, and thus the participation in this initiative is of great consequence. The digital transition alters the manner in which digital educational content is utilized by teachers, students, and parents, who are becoming increasingly creative, interactive, and accessible in a multitude of formats. The advent of new technological achievements, such as virtual reality and artificial intelligence, has further augmented the production of digital educational content.

In the Republic of North Macedonia, there are several digital platforms that facilitate the provision of educational resources and tools. One notable example is the www.eucebnici.gov.mk digital library, which offers e-textbooks for primary and secondary education. Additionally, www.nastava.mk provides supplementary digital resources and tools to support the educational process. Nevertheless, there is a need for

further digitalization and digital transformation of textbooks, specifically the creation of interactive materials that will enhance the digital competence of students and teachers.

Concurrently, the outcomes of international assessments indicate a discrepancy between Macedonian mathematics textbooks and the European standards. This necessitates further endeavors to digitize and transform the teaching of mathematics and to provide teachers with the requisite support during this transition.

The objective of this study is to assess the efficacy of digital software, the impact of students' academic levels on their performance, the extent of software utilization, and the role of teachers' ICT competencies in enhancing student outcomes.

2 LITERATURE REVIEW ON THE USE OF DIGITAL TOOLS IN MATHEMATICS

The advent of digital tools has introduced novel avenues for interaction and comprehension of mathematical concepts. Students can engage in exploration and study through the use of games, simulations, and digital resources that facilitate the conceptual development process and provide valuable feedback. Such tools facilitate the visualization and comprehension of mathematical concepts, while affording educators the opportunity to elucidate and highlight details that may otherwise remain unnoticed (Hoyles, 2018). While these tools have been shown to have a significant impact on mathematical performance, their effect remains moderate (Drijvers, 2018).

The integration of traditional education with digital technologies facilitates enhanced support for independent study, thereby increasing students' success and fostering the development of independent thinking skills (Golding et al., 2021). The influence of intelligent tutoring systems and adaptive digital tools on student success has been demonstrated to be significant (Ma et al., 2014). However, these technologies are most effective when used in conjunction with traditional pedagogical methods, rather than as a replacement for them (Hillmayr et al., 2020).

The utilisation of digital tools in mathematics facilitates the creation of novel experiences for students, thereby fostering heightened interest and engagement (Wijaya et al., 2022).

3 METHODOLOGY OF RESEARCH

This research examines the efficacy of digital software in education, its impact on student success contingent on their academic level, intensity, and mode of utilization, as well as the role of information and communication technology (ICT) competencies of teachers. For students in fourth, fifth, and sixth grades, data regarding their academic performance and the extent to which they utilize digital tools is analyzed. For teachers, the level of their ICT competencies is evaluated through a survey comprising 23 indicators, as well as their impact on students' success.

The *objective of the research* is to examine the utilization of digital tools in mathematics instruction and to assess their impact on student achievement, with a particular emphasis on the role of teachers' information and communication technology (ICT) competencies.

The research is conducted through two databases: the Platform for Student Success and a survey for the evaluation of information and communication technology (ICT) competencies of teachers. Quantitative methods are used for data analysis, utilizing descriptive and conclusive statistics, including the F-test and chi-squared -tests. A total of 227 students and 43 teachers from diverse geographical and ethnic backgrounds participated in this research. Three exploratory hypotheses were formulated and subsequently evaluated. H1: The intensity of digital tool and platform usage is contingent upon the academic success and achievement of students in mathematics at the primary school level. H2. The manner in which students from primary school utilize digital tools and platforms for mathematical studies is contingent upon their academic success. H3. The level of success achieved by students in mathematics is significantly influenced by the extent of ICT competencies demonstrated by their mathematics teachers.

4 FINDINGS AND RESULTS

As previously indicated, the survey was completed by 227 students in grades four through six, as well as 43 mathematics educators who instruct students from diverse ethnic backgrounds in the eastern and western regions of the country and multiple educational institutions in Skopje. Of the students who participated in the survey, 114 (50.2%) were female and 113 (49.8%) were male.

Table 1 presents a description of students' success in mathematics in the last two school years. The arithmetic mean is significantly high at $M=4.23$ ($SD=0.71$), indicating a normal distribution of mathematics success among this group of students. In other words, the majority of this group of students, in addition to the arithmetic mean, also exhibit a lower proportional division at the edges of the curve, indicating a distribution of psychosocial phenomena.

With regard to the shape and manner of utilization of the digital tools and the digital platform e-teaching in mathematics, the students have indicated their preferences according to the frequencies presented in Table 2.

Over 45% of students, primarily in the fifth grade, have indicated that they utilize the digital tools for a range of activities, including leisure and completing assignments assigned by the teacher. Forty-four percent of students, predominantly in the sixth grade, have stated that they employ digital tools as a substitute for traditional study methods. Additionally, 43% of students, primarily in the fifth grade, have reported using digital tools for both supplementary and recreational purposes.

Table 1. Descriptive statistics of students' success

		<i>Students' Academic Success</i>
N	Valid	227
	Missing	0
Mean		4,2341
Median		4,3600
Mode		4,90
Std. Deviation		,71257
Minimum		2,27
Maximum		5,00

Table 2. Form and intensity of use of digital tools and platforms in mathematics in primary education

			Class		
			Fourth	Fifth	Sixth
Form and way of using a digital tool in mathematics	I use it for studying as a supplement	Count	9	13	8
		Row N %	30,0%	43,3%	26,7%
	I use it for studying as a substitute	Count	8	6	11
		Row N %	32,0%	24,0%	44,0%
	I do my homework with it.	Count	16	13	18
		Row N %	34,0%	27,7%	38,3%
	I previously demonstrated my abilities and knowledge.	Count	18	13	17
		Row N %	37,5%	27,1%	35,4%
	I utilize it for recreational purposes.	Count	15	19	10
		Row N %	34,1%	43,2%	22,7%
	A little bit of everything	Count	9	15	9
		Row N %	27,3%	45,5%	27,3%
Intensity of use of digital tools and platforms in math classroom	I don't use	Count	13	18	12
		Row N %	30,2%	41,9%	27,9%
	Several times a month	Count	35	34	34
		Row N %	34,0%	33,0%	33,0%
	Two or three times a week	Count	17	18	16
		Row N %	33,3%	35,3%	31,4%
	Every day	Count	10	9	11
		Row N %	33,3%	30,0%	36,7%

In the second part of Table 2, a proportional division of the use of digital tools and digital platforms for e-teaching is observed according to the intensity of use. Notably, 42% of fifth-grade students have indicated that they do not utilize these tools, in contrast to the other students from the fourth and sixth grades. All other frequencies are proportionately distributed between 30% and 36%.

Conversely, data from the school's pedagogical service (based on an interview with one staff member) and data collected following the survey of teachers indicate that over 39% of these teachers have a significant proportion of teachers (37%) demonstrate a high level of ICT competencies for using and teaching through digital platforms in mathematics. However, a notable number of teachers (34%) exhibit a middle level of ICT competencies, while approximately 24% display a low level of ICT competencies for using and teaching through digital platforms in mathematics (Fig. 1).

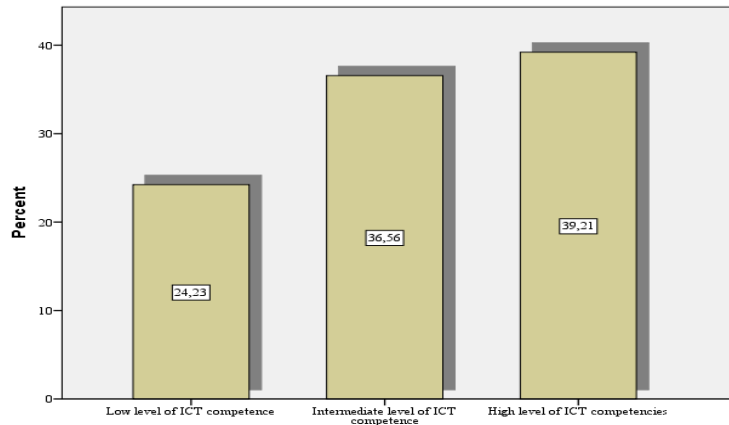


Figure 1. The level of ICT competencies of mathematics teachers in primary education

The data regarding the utilization of digital tools and platforms in mathematics among students reveals some definitive findings regarding the F-test. These findings indicate that the intensity of digital tool and platform usage is influenced by success and students' achievements in mathematics at the primary education level (represented by the first hypotenuse). Table 3 illustrates the mean success rates of students according to their reported frequency of digital tool and platform usage. The table also presents an F-test to assess potential differences between the two most frequently used categories (i.e., "Several times a month" and "Two or three times a week") and the least frequently used category (i.e., "I don't use").

Table 3. The academic success of students in mathematics and the intensity of use of digital tools and platforms in primary education

	<i>N</i>	<i>Mean</i>	<i>Std. Deviation</i>	<i>Std. Error</i>	<i>F</i>	<i>Sig.</i>
I don't use	43	4,1414	,78042	,11901	3,306	,021
Several times a month	103	4,3132	,58562	,05770		
Two or three times a week	51	4,0196	,82196	,11510		
Every day	30	4,4597	,73162	,13357		
Total	227	4,2341	,71257	,04729		

In accordance with the findings of the study, which yielded a value of $F=3,306$ with $sig=.021$ and a p-value less than 0.05, it can be concluded that there are notable differences between the levels in question. Consequently, it can be posited that the success of students in mathematics is contingent upon the extent to which they utilize digital tools and platforms in the context of primary education. In other words, the routine utilization of digital tools and platforms exerts a considerable impact on enhancing students' proficiency and comprehension of mathematics at the primary educational level. This is in contrast to students who do not employ such tools and platforms (Fig. 2). It can be concluded that the initial hypothesis is valid.

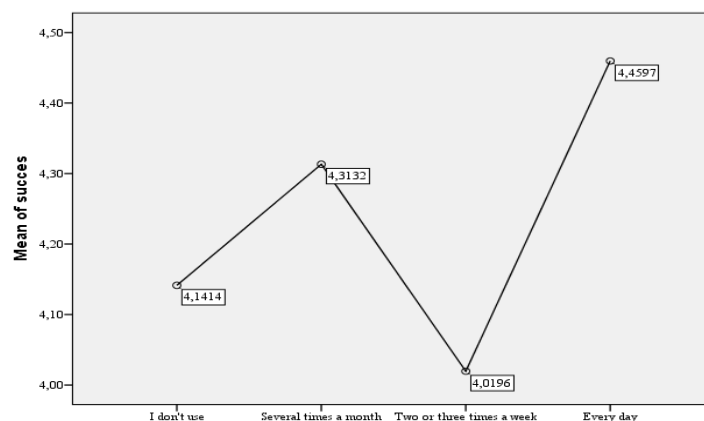


Figure 2. The success of students in mathematics and intensity of use of digital tools and platforms in primary education

However, an F-test analysis of the data presented in Table 4, which shows the mean success of students in mathematics according to the shape and manner of use of digital tools and platforms, yields an F-value of 1.078 with a significance level of .373 and a p-value greater than 0.05. This indicates that there is no statistically significant difference in students' success in mathematics at the primary education level based on the shape and manner of use of digital tools and platforms for studying mathematics. Based on these findings, we conclude that the second hypothesis that the shape and way of using digital tools and platforms for studying mathematics by students from primary education is determined by students' success itself, is not supported by the evidence.

Table 4. Students' academic success in mathematics and the form and reason for using digital tools and platforms in the subject of mathematics in primary education

	<i>N</i>	<i>Mean</i>	<i>Std. Deviation</i>	<i>Std. Error</i>	<i>F</i>	<i>Sig.</i>
I use it for studying as a supplement	30	4,1190	,63157	,11531	1,078	,373
I use it for studying as a substitute	25	4,4432	,71903	,14381		
I do my homework with it.	47	4,1213	,81656	,11911		
I previously demonstrated my abilities and knowledge.	48	4,2523	,61046	,08811		
I utilize it for recreational purposes.	44	4,1961	,72703	,10960		
A little bit of everything	33	4,3648	,73162	,12736		
	227	4,2341	,71257	,04729		

Following the processing of all data pertaining to students' success, as measured by the utilization of digital tools and platforms for the study of mathematics, four statistical levels have been identified with regard to the impact of digitalization on the teaching of mathematics. These are as follows: The level of difficulty in learning remains unchanged, with the same level of performance observed in the context of traditional teaching methods. However, there is a discernible improvement, both in terms of its magnitude and its significance. Subsequently, students were classified according to the aforementioned levels, and teachers were classified according to their level of ICT competencies. The results of this classification are presented in Table 5, made with chi-square test to analyze the significant differences between the frequencies.

Table 5. Influences (effect) of the teacher's ICT competencies to students learning mathematics

		<i>The Effect in Students Learning</i>			
		Difficult learning	Same level as before - with classical teaching	A small improvement	A significant improvement
<i>ICT Competencies of the teachers</i>	Low level of ICT competence	9	9	14	23
	Intermediate level of ICT competence	10	7	19	47
	High level of ICT competencies	11	13	20	45

As evidenced in Table 6, the chi-square quotients range from 15,133 with a significance level of .049 and a p-value less than .05. The crossing frequencies in Table 5 demonstrate significant differences, with higher numbers observed when crossing the last two levels (Intermediate and High levels of ICT competencies). This indicates a notable enhancement in mathematical learning among students, particularly among those who teach mathematics and possess advanced ICT competencies, and vice versa.

Table 6. Pearson Chi-Square Tests for crosstabs

		<i>The Effect in Students Learning</i>	
		Chi-square	15,133
<i>ICT Competencies of the teachers</i>	Df		6
	Sig.		,049
	Results are based on nonempty rows and columns in each inner most sub table.		

The results of this study support the third hypothesis, which posits that students achieve significantly greater success in mathematics depending on the high level of ICT competencies that their mathematics teachers possess.

5 CONCLUSION

This research is primarily concerned with the analysis of mathematics education in primary school settings, with a particular focus on the utilization of digital tools and resources in the classroom. It aims to investigate the efficacy of various digital software tools in the contemporary digital age, and to examine the factors that contribute to students' success in using digital software, including their academic level, the frequency and intensity of their software usage, the specific purposes for which they employ the software, and other relevant considerations. Furthermore, the impact of teachers' ICT competencies on enhanced student outcomes was investigated. Based on the findings, it can be concluded that the utilization of digital tools and digital platforms has a notable influence on the improvement of success and mathematics teaching among primary school students who employ them, in comparison to those who do not. It can be concluded that there is no significant difference in the success of students in primary school mathematics education based on the manner in which digital tools and platforms for studying mathematics are utilized. However, there is a notable improvement in students' mathematical abilities, particularly when their teachers possess a high level of ICT competencies, and vice versa. Therefore, it can be concluded that the objective of this research has been met.

In general, based on the theoretical findings and empirical analyses of this research, it can be concluded that the use of digital mathematics software has a positive influence on students' learning. Further opportunities for improvement exist, particularly in the design of study activities that integrate the software, the utilization of manuals for study relief and promotion of study through gaming. In conclusion, it is recommended that digital tools and platforms be reinforced and enhanced, and that additional educational software be developed, with the aim of facilitating more effective and efficient learning in the future. Furthermore, the implementation of techniques for disparate data analysis is recommended in order to predict academic performance based on a compilation of data from students.

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Use of Mobile Phones for Mathematics Learning in Primary School

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Abstract. We are witnesses that throughout history, learning has been an inseparable part of all world cultures and civilizations. Learning paradigms have changed over the centuries and adapted to social values. For example, in the 1970s, knowledge was discovered through active participation in the learning process and such learning was called discovery learning. Then, in the 1980s constructivist learning was popular while 90s problem-based learning was represented. It can be concluded that learning theories changed over time and went in the direction of focusing on the individual and his needs, which was made possible by the development of information and communication technologies. With the advent of mobile phones, there was also a revolution in IT technologies. The concept of mLearning or learning using mobile devices was first introduced in 1970s and learning is no longer limited to the classroom. This paper aims to present some characteristics of mLearning along with platformms and popular maths applications. Also, some advantages and disadvantages of mLearning in education will be given and in the end the research results of a survey taken on the eightgraders will be shown.

Keywords and phrases: M-learning, mathematics, mobile phones, primary school.

1 INTRODUCTION

Learning has represented an important factor of survival both for the individual and for the nation as a whole. Paradigms of learning has changed over time from discoverz learning which was popular in 1970s to constructivist learning where knowledge was obtained throuigh interaction with the environment. In the 90s, problem-based learning was introduced. Knowledge was acquired through solving problem tasks and developing skills related to the environment where those skills will be used. Another paradigm of learning called, socio-constructivist learning, was represented in the 90s of the last century. In this type of learning, it is considered that social and individual processes are interdependent and inseparable and that together they influence the acquisition of knowledge by an individual.

The conclusion is that learning theories changed and with time information and communication technologies have developed enormously changing the focus towards individual and his needs. The new concept of mLearning was introduced by Alan Kay in the 1970s. He joined the research center of Xerox Corporation and founded a group to develop the first portable and personal computer named "Dynabook". The aim of this project was to give children access to the digital world. Unfortunately, the project failed due to the lack of technological support at the time. A few decades later, in 1994, Mitsubishi Electric Corp. created the first smartphone and named it IBM Simon and since then the era of smartphones began. Today, mobile devices have revolutionized the field of learning and education and have become a new indispensable educational tool. Learning is nowadays, due to mobile technologies, made possible anywhere and anytime with permanent wireless Internet access.

2 MOBILE LEARNING CHARACTERISTICS

During 2005, mobile learning began to appear as a new pedagogical term. The concept of mobile learning or M-learning involves learning using small, portable mobile devices and a suitable wireless two-way Internet connection. The devices that can be used usually include mobile phones, smartphones, PDAs (personal digital assistants), tablets, laptops, portable media players and other personal devices (Behera, 2013). First mobile phones were not very functional and had issues with screen size, processor speed and battery life. In the early 2000s interest in smartphones increased, compared to PDAs, due to some additional features they had. The need for mobility has led to the emergence of laptops that have replaced traditional desktop PCs. In 2010, Apple launched its first tablet computer called the iPad. Mobile devices became more accessible to every individual as the price decreased. Technology slowly but surely began to be applied more and more in classes, offering, not only to children but to everyone who wants to acquire new knowledge, a more interesting and interactive way of learning. The learning process itself has become flexible, accessible and convenient, and more adapted to the individual and his needs.

Mobile learning according to Traxler (Traxler, 2005) can be characterized as:

- spontaneous
- personal
- portable
- located
- informal
- easy
- context-oriented
- learning in small steps
- interactive.

Figure 1 shows characteristics of mLearning and E-learning. It can be seen that E-learning shares some features of M-learning such as interactivity, personalization and connectivity, but there are also some differences such as portability.

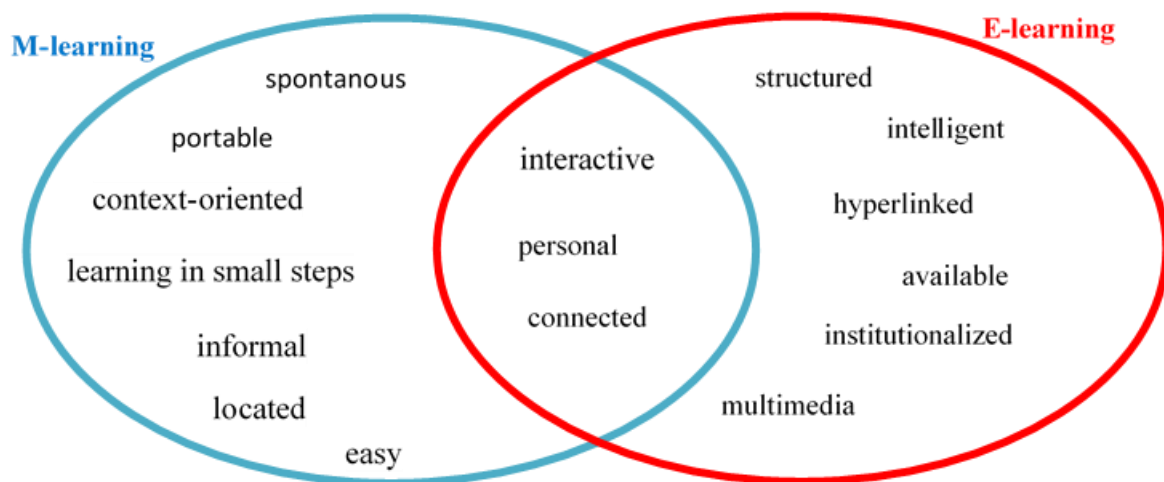


Figure 1. Characteristics of M-learning and E-learning

First definitions of mobile learning also appeared with the first appearance of mobile devices in teaching. All definitions can be divided into four categories (L. Korenova, 2018).

- **Techno-centric:** These definitions are generally the most prevalent in the literature. Mobile learning refers to learning using mobile devices.

- **Student-oriented:** These definitions have in their focus a student who learns whenever he has the opportunity to do so and uses mobile technologies as an aid to learning without being in a fixed and predetermined location.

- **Related to E-learning:** This view emphasizes that M-learning is an extension of e-learning.

- **They improve formal education:** By formal education we mean standard learning in a classroom where the professor carries out the teaching process in a traditional way. Some definitions of mobile learning mean traditional teaching enhanced by the use of mobile devices.

However, it can be concluded that there is no consensus among researchers on what M-learning actually is. Thus, some authors such as Traxler have a techno-centric definition of mobile learning that focuses on technology and hardware, and excludes the experience of this type of learning. Traxler defines M-learning as "any educational process where the only or dominant technologies are mobile devices." According to his definition, mobile devices that can be used in the process of mobile learning include mobile phones, smartphones, personal digital assistants (portable digital devices that are usually palm-sized), but not desktop computers and other similar devices.

In Figure 2, we can see an illustrated example of the ambiguity of whether tablets and devices such as gaming consoles and iPods belong to devices used in M-learning or not.

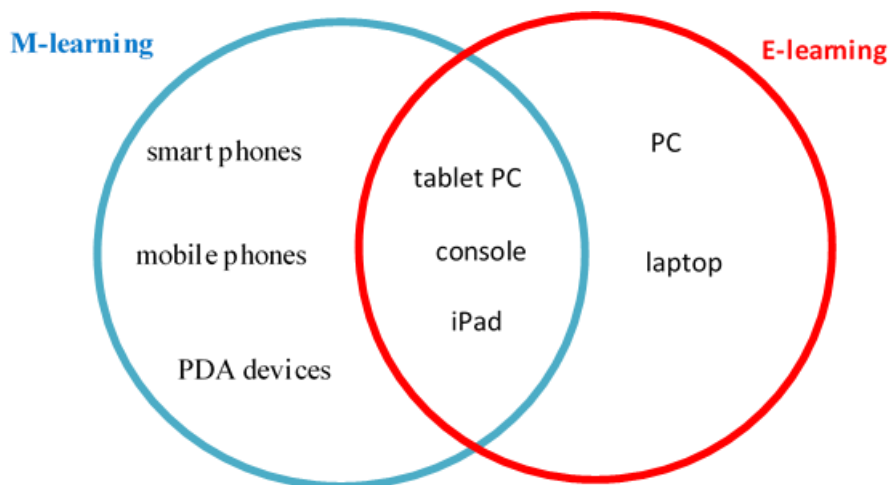


Figure 2. Display of devices used in M-learning and E-learning

The definition of M-learning based on a set of hardware devices places M-learning as a type of portable E-learning and emphasizes the technical limitations rather than the unique pedagogical advantages and characteristics of this type of learning. (Traxler, 2005).

Kiger (2011) gave a definition of mobile phone and app learning by different authors stating that IT environments in teaching can become functional environments. Also, an example is presented in which the topic of creating an individual digital environment that allows students to choose their own way of learning the material, which is based on their previous knowledge and their progress in learning, is elaborated. The flexibility of this approach in teaching is highlighted.

3 ADVANTAGES AND DISADVANTAGES OF M-LEARNING IN EDUCATION

The advantages of using M-learning are multiple and Behera (Behera, 2013) list some of them, namely:

1. **Mobility** – M-learning is location independent as all it takes is a mobile device and an internet connection to access learning content in locations such as museums, hospitals, cafes, shopping malls, etc.
2. **Protects the environment** - Considering that mobile devices have their own memory for storing information, it is not necessary to print educational material, which saves the environment.
3. **Interactivity** - Mobile technologies allow students to interact with their peers, teachers and other students around the world
4. **Connectivity** - One of the important factors of M-learning is connectivity, which can be achieved by using technologies that every mobile device has, such as Bluetooth, Wi-Fi, infrared and others.
5. **Ease of use** – Today's mobile devices are very simple and easy to use even for children. Information can be shared with friends in a fairly simple way.
6. **Rich multimedia content** - Mobile devices provide a variety of content in the form of music, video clips, games, mobile applications, podcasts, blogs, e-books and other entertainment and information content.
7. **Functionality** - Although small in size, mobile devices such as smartphones and PDAs have the same functionality as modern personal computers. They can support various software used for mobile learning purposes.
8. **Economical accessibility** – In the very beginning when they appeared, mobile devices were considered a luxury and were not available to the common man. Over time, they became more and more accessible, which led to an expansion and began to be used for learning.
9. **A modern way of learning** - M-learning is primarily interesting for younger students because it uses new technologies that are modern and trendy. Children are happy to adopt new technologies because they are part of their lifestyle and way of expression.
10. **Personalized learning pace** - M-learning allows everyone to learn at their own personal pace depending on the time available.

Although there are numerous advantages of using mobile learning Behera (2013) also mentioned some disadvantages which are listed below:

1. **Internal memory capacity** - Some devices such as PDAs have very limited capabilities when it comes to internal memory for data storage.
2. **Screen Size** – Most mobile devices have quite small screens which can be quite tiring for the eyes while learning.
3. **Network limitations** - The network may have limitations regarding the reduced flow of information or the problem may be an excessive number of users who want to connect to the network, which affects the speed of the network.
4. **Size of the device** - Although one of the advantages of mobile devices is their small size which allows for mobility, it is also one of the disadvantages at the same time as using buttons and electronic pens on small devices can sometimes be quite difficult. There are accessories for mobile devices such as keyboards but they are also quite small in size which only partially solves the problem.
5. **Rapid obsolescence** – Mobile devices can quickly become obsolete and therefore can no longer be effectively used for M-learning.

4 PLATFORMS AND APPLICATIONS USED IN TEACHING OF MATHEMATICS

Recently, a large number of online and mobile applications have been developed to support the teaching of algebra, geometry, mathematical analysis, statistics and other areas of mathematics. Such mathematical applications enable users to explore functions by providing graphical features and offering many types of specific calculators (Drigas, 2015). They also help teachers by making their lessons as interactive and interesting as possible, which certainly contributes to children's love for mathematics. The apps are suitable for all ages and skill levels from beginner to expert and most are free to use. Some of the most popular applications and platforms are GeoGebra, Photomath, Geometry Pad, Khan Academy, Shapes- 3D Geometry Learning and many others.

4.1 GeoGebra

GeoGebra is a mathematical software that covers all levels of mathematics teaching in primary and secondary schools. It can be used for learning geometry, algebra, displaying various graphs, for statistical and various other calculations necessary for learning mathematics. It represents one of the best applications from the point of view of pedagogy, used for the purpose of learning not only mathematics but also science, technology and engineering. GeoGebra can be used for desktop computers but there is also an application for tablets and mobile phones (there are versions for operating systems: Windows, Android and iOS). It is free and available in more than 50 languages.

GeoGebra Materials (<https://www.geogebra.org/>) is a platform that offers more than a million GeoGebra lessons that are located on the cloud service which teachers can use to prepare teaching materials in the form of GeoGebra books. Students can view and use that material on their mobile devices. Figure 3 shows a screen layout in the GeoGebra application.

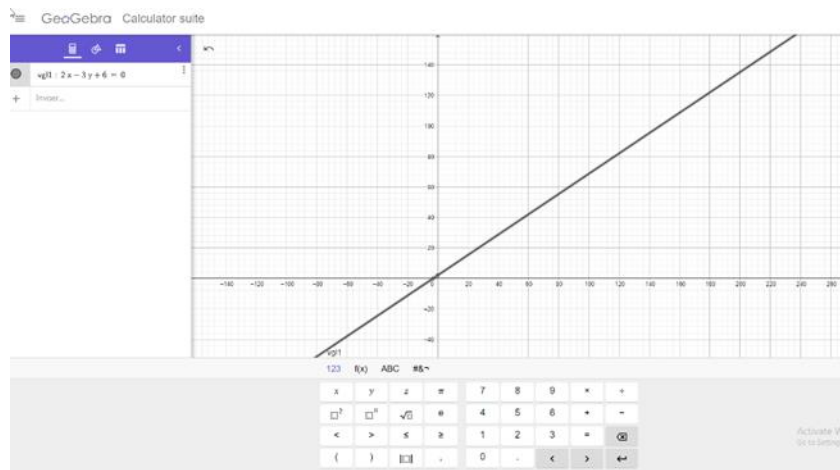


Figure 3. Display of a function in GeoGebra app

4.2 Geometry Pad

Geometry Pad (<http://www.stemonmobile.com/geometry-pad/>) is a dynamic hands-on geometry application suitable for use on iMac, iPad and Android tablets. It allows the user to create geometric shapes, explore and change their properties and calculate metrics. Shapes are displayed on a desktop with a rectangular coordinate system that can be zoomed and scrolled. This powerful tool is intended for anyone who wants to develop and improve their math skills in the field of geometry and is invaluable for teachers as it allows adding an interactive component that makes learning geometry fun. A screen layout in the Geometry Pad application is displayed in Figure 4.

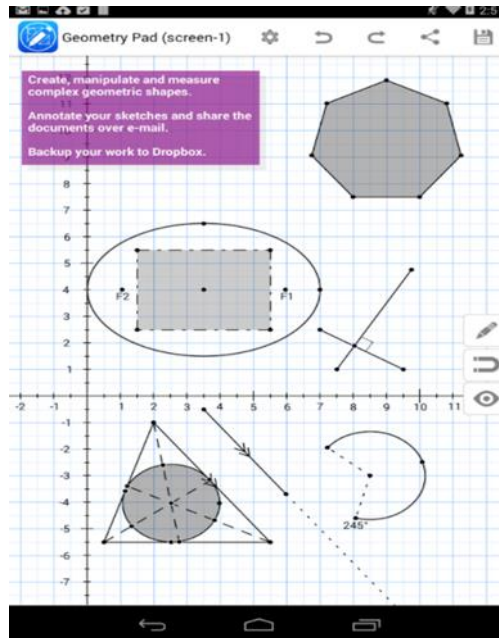


Figure 4. Screen layout in the Geometry Pad app

4.3 Photomath

Photomath (<https://photomath.net/en/>) is another very popular educational app for learning math. It uses the latest artificial intelligence capabilities and allows users to scan, accurately solve, and intuitively explain math problems step by step in an effort to promote understanding of fundamental concepts. It is very popular and has over 100 million users worldwide. Additionally, this application contains a handwriting recognition plugin. The layout of the Photomath application screen is shown in Figure 5.



Figure 5. Photomath application screen layout

5 RESEARCH

Twenty-one students of the eighth grade of the elementary school "Sveti Sava" in a separate department of the school "Đorđe Kožbuk" from Torak participated in the research. Students attended classes in both Serbian and Romanian. The goal of the research was to see how familiar students are with the concept of mobile learning, to what extent they use mobile devices for learning mathematics, and how familiar they are with applications and platforms that would help them master the material. The school is bilingual and classes are held in both Romanian and Serbian.

An online survey technique was used for data collection, and the survey itself was conducted using a Google questionnaire. Students filled out the questionnaire before class at school, and those students who did not have a mobile device with them filled out the survey at home in consultation with the teacher. The questionnaire contained eight questions where students answered about their habits related to the use of mobile devices during learning in class and outside of school. The survey was anonymous and the questionnaire is attached to the paper.

Although all the students started to fill out the survey, the obtained data contain a significant number of missing data. The reason for this may be that students are not skilled in filling out online surveys or do not read the question completely and do not mark the "no" option. Out of 21 students, less than half (9 students) gave all the answers, while 6 of them skipped a third of the questions. In order for the analysis to be carried out on the entire sample, missing answers to the first and second questions were treated as "no" answers. In this way, the number of respondents with all answers increased to 12, while all respondents answered at least 2/3 of the questions.

6 RESEARCH RESULTS

The first group of questions related to students' equipment for the application of E-learning and M-learning. The results are shown in Table 1 and indicate that the students have access to the Internet (the students did not state about the speed of the Internet), and that a little more than half of the students use a computer for learning, while the educational software is largely unknown to the students. All students own a mobile phone, while only 1/7 students own another mobile device such as a tablet or laptop. Based on the obtained results, it can be concluded that M-learning can be accessed in this group of students because they are technically equipped.

Table 1. Possession of mobile devices, enabled access to the Internet and use of devices and educational software for learning mathematics

Questions	Answers	
	YES	NO
A computer which you can use for learning	11	10
Software with educational content	3	18
Internet	21	0
Mobile phone	21	0
Tablet (iPad, Blackberry, PlaybookTM)	3	18

The second group of questions related to students' experience in using devices in the process of learning mathematics. The results are shown in Table 2.

Table 2. Frequency of using math learning devices

Questions	Answers			
	<i>Daily</i>	<i>Once a week</i>	<i>Rarely (once a month)</i>	<i>Never</i>
A mobile phone	3	5	10	2
Computer/laptop	0	2	5	9
Calculator	4	1	4	8

Regarding the use of mobile phones shown in Table 2, it can be seen that 10 students (50%) rarely use a mobile phone for learning mathematics, 5 students (25%) use it once a week, only 3 students (15%) use it daily, 2 students (10 %) never use a mobile phone to study mathematics. One student did not answer the question. 9 students (56%) never use a computer or laptop, while 5 students (31%) use it rarely and 2 students (13%) use it once a week. The rest of the 5 students did not answer how often they use a computer or laptop to study mathematics. Digitron or calculator is never used by 8 students (38%), 4 students (19%) use digitron daily, also 4 students (19%) use rarely and 1 student (5%) uses it once a week while 4 students (19%) do not answered.

The obtained results indicate that students, although they have a device, do not know how to use it in the process of learning mathematics. Taking into account that the students of the VIIIth grade are concerned, the obtained data are even more worrying. Although at the end of the second decade of the 21st century, younger generations spend a significant part of their time using various mobile devices or computers and a significant part of their time in school or independent study, the obtained data can seem even more worrying and indicate that the teaching process does not sufficiently follow the habits and student experiences.

In order to additionally see the way of (not) using the device, the students answered two open-ended questions where they had to describe how they use the device for learning mathematics. When asked where they should describe an example of using a mobile phone for learning mathematics, the students answered in a variety of ways. Some of the answers were that they use the mobile phone as a calculator, that they use it for the purpose of checking the final result, but also that they sometimes use it if they do not know how to do a task. Also, some students denied that they use the phone at all to study mathematics, while some answered that they use the phone to send a photo of the completed task they receive for homework via Google Classroom. Students were also asked to describe one example of using a computer or laptop to learn mathematics. The answers were similar to the answers to the previous question. One of the differences is the more frequent response that they do not use the computer to learn mathematics.

The analysis of the answers to these two questions indicates that students do not use mobile devices or computers at all for the process of mastering the material, that is, even when they do use them, it does not directly relate to the process of learning mathematics.

Only three students responded to the first question that they had some educational software. This is in line with the answers given by the students to the sixth group of questions which related to the knowledge of two applications to support the learning of mathematics, GeoGebra and PhotoMath. The results are shown in Table 3.

Table 3. How much students know mathematical applications

Questions	Answers	
	<i>Geogebra</i>	<i>Photomath</i>
I am using it independently	0	1
I only use it in class	1	1
I know what it is but I don't use it	4	9
I don't know that app	13	9

When asked about the use of the mathematical applications GeoGebra and Photomath, the largest number of students, 13 (72%) answered that they had not heard of the GeoGebra application, while 4 (22%) answered that they had heard of the application. They use it, while only one student (6%) answered that he only uses it in class. Three students did not answer this question, nor did any of the students answer that they use the application independently.

As for the Photomath application, the situation is similar, with even fewer students hearing about that application. More precisely, 9 students (45%) do not know about the application and the same number of students (45%) have heard about the application but do not use it. One student uses Photomath only in class (5%) and one student (5%) uses it independently. One student did not answer the question. Finally, the last two questions were about two typical math problems, first was calculating an extensive numerical expression and second was solving a linear equation.

Both tasks are "template" tasks and the applications solve them in one step, while the calculation without using the device takes time and gives the possibility of an error. Nevertheless, the students chose to do the tasks "on foot" from the offered methods, which was displayed in Table 4.

Table 4. Solving the mathematical tasks

Questions	Answers	
	<i>Numerical expression</i>	<i>Equation</i>
With the help of an application on a laptop or computer	3	3
With the help of a digitron/calculator	1	1
only using paper and pencil	16	16

From Table 4, it can be seen that 16 students (80%) answered that they would do the mentioned expression "on foot", i.e. using only paper and pencil while three of them (15%) answered that they would do the task with the help of an application on laptop or computer and 1 student (5%) declared that they would do the task with the help of a digitron or a calculator. One student did not answer the question. All 20 students who answered these questions chose the same option for both tasks.

7 CONCLUSION

The aim of this paper was to present definitions of mobile learning, its advantages and disadvantages and some applications and platforms for learning mathematics. Also, quantitative research of the mobile phones usage in the teaching of mathematics in higher grades of elementary school has been done. The aim of the research was to discover the attitudes and habits of students regarding the use of mobile devices, and above all mobile phones in teaching.

It can be concluded that the students showed a positive attitude towards the use of mobile phones in teaching and learning and they reacted positively to the held interactive mathematics lessons and that they liked the work in the software packages GeoGebra and Photomath, which proves the main hypothesis (H1) that the students have a positive attitude towards mobile learning. The research found that students mostly own a mobile phone or some other mobile device, but they do not have the habit of using these devices for learning to a greater extent. They mostly use them once a month or once a week. In relation to the use of other mobile devices such as a laptop or computer, we can say that students still use and give priority to mobile phones. It is obvious that the digitron or calculator is still the most common device used for learning mathematics and that students do not use mobile devices to a sufficient extent but rather use traditional learning aids. It can be said that students are less informed about the applications they can use to learn mathematics. The problem was also noticed that students who have heard about the GeoGebra and Photomath applications do not use them enough in practice. It is evident that students should be encouraged and animated as much as possible to use these applications more often and show them the advantages of using them. The problem of insufficient use of mobile devices should be mostly addressed by teachers, showing students the advantages of mobile learning compared to traditional ways of learning. Also, teachers should more often introduce new teaching aids into the teaching process so that students "get rid" of their fear of using technology in class and become independent to continue using this type of learning outside of school.

The results of the research showed that mobile learning, although it is not sufficiently represented in the modern educational process, has its potential because students mostly own a mobile phone, which provides technical support for the introduction of mobile learning into teaching. In addition, the positive attitude of students towards the use of interactive materials and appropriate software should encourage teachers to be more involved in the introduction of new modern ways of learning in the teaching process, and all of this would result in greater motivation of students to learn mathematics, which is the ultimate goal.

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Education in Specialized IT Departments in the Republic of Serbia - Comparison with International Practices

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Abstract. In this paper, authors investigated how specialized IT departments function in secondary schools in Serbia. An attempt is made to understand how these departments fit into the wider context of education and how they are compared with similar programs in other countries.. In today's world, where technology is changing day by day, it is important that education systems follow these changes and prepare students for the future. Specialized IT departments aim to help students acquire important skills, such as programming, web application development and data management. In this paper, we investigate how these programs are organized, what teaching methods are used and how teachers can motivate students to achieve the best results. Also, we want to highlight how these programs help young people prepare for careers in the IT sector and how they can shape their future professional path.

Keywords and phrases: education, specialized it departments, practice, school, informatics

1 INTRODUCTION

In the modern educational system, the integration of information technologies into high school curricula is becoming increasingly significant. With the rapid advancement of technology and its impact on all aspects of life, specialized IT programs in secondary education aim to teach students the skills and knowledge necessary for success in the digital world. These programs focus on various segments of information technology, including programming, web application development, data management, databases, computer networks, and more.

Specialized IT classes are high school programs intended for students with a particular affinity for computing and informatics. By attending these classes, students will study information technology subjects alongside the "standard" high school subjects. A student who wishes to enroll in this track must take an entrance exam in the form of a mathematics test, which includes tasks of intermediate and advanced levels. Specialized IT classes are limited to a maximum of 20 students, similar to other specialized classes in high schools. Classes, especially practical exercises conducted in computer labs, are organized in groups of 10 students. This way, students will follow along more effectively, work in a higher-quality manner, and be more motivated to achieve success on tests and competitions. In addition to being suitable for students who want to acquire prior knowledge to continue their education at IT faculties, these classes do not strictly bind them to these fields; students can also choose other faculties, as high schools offer a broad education [1]. The Government of the Republic of Serbia has recognized the ICT sector as one of Serbia's greatest developmental potentials. This is one of the reasons why programming has been introduced as a mandatory subject in primary schools starting from fifth grade. Another step to better prepare students for future careers is the introduction of specialized IT classes. Three years ago, a larger number of specialized IT classes were opened in high schools throughout Serbia [2].

According to the Ministry of Education, Science, and Technological Development of the Republic of Serbia [3], it has been concluded that classes for students with special aptitudes in computing and informatics are one of the ways the educational system aims to respond to labor market needs. Specialized education for high school students with pronounced digital competencies increases the quality of students in various IT

programs at different faculties. Thanks to these competencies, these students can immediately become part of innovative startup companies upon completing high school.

2 METHODOLOGICAL ASPECTS OF EDUCATING STUDENTS WITH SPECIAL APTITUDES FOR COMPUTING AND INFORMATICS

This scientific paper focuses on the specialized education of students with special aptitudes for computing and informatics, with an emphasis on the implementation of teaching in these classes. In high school IT departments, subject teaching, especially concerning specialized subjects, is conducted in double classes. Students, divided into groups, attend classes in computer laboratories. Each group consists of up to ten students to enhance the quality of the instruction, allowing students to follow along more effectively, understand more deeply, and successfully assimilate the material.

Computer laboratories should be equipped with high-performance computers, the latest development tools, necessary programming software, a stable network infrastructure, and interactive devices for effective learning and presentation display. Teachers play a crucial role in improving the education and upbringing of students, as they influence the learning and development of their students. Therefore, teaching-oriented activities should encompass practical work and the application of ICT, as well as correlations with other subjects. In this way, student motivation is enhanced, encouraging them to achieve significant success in control assignments and competitions in this field.

Teachers should be aware that not all students possess the same prior knowledge, so before conducting classes, they should assess the student's knowledge and skills to adapt to individual differences. During the instruction, the emphasis should be placed on project-based, problem-based, and active learning, as well as teamwork, collaboration, and problem-solving. When it comes to the teaching model, the primary focus should be on hybrid learning and a deepened approach to learning [1].

3 BENEFITS OF SPECIALIZED IT DEPARTMENTS IN THE REPUBLIC OF SERBIA

Students will master all basic, as well as some advanced programming concepts, and they will become familiar with different approaches to problem-solving through programming. They will understand computer networks, network layers, and protocols, and know what is necessary for computer networks to be secure. In addition to a greater list of specific computer competencies, it is particularly important to emphasize that students will be trained to effectively use programming and database management to solve various problems in further education, professional work, and everyday life. By attending this educational program, students will enhance their strategies and techniques for independent learning using computer resources and will develop the readiness to keep up with new solutions in the field of information technology [3, 4]. The advantages of attending specialized IT departments during four school years are:

- 934 scheduled classes of informatics subjects
- Division of the class into smaller groups (up to 10 students per group)
- Qualified teaching staff
- Fully equipped computer laboratories

4 GOALS OF EDUCATION FOR GIFTED STUDENTS IN THE DOMAIN OF COMPUTING AND INFORMATICS

According to the curriculum for IT departments prescribed by the Ministry of Education, Science, and Technological Development of the Republic of Serbia [5], the goal of education and upbringing for gifted students in the field of computing and informatics is to provide, through the acquisition of functional knowledge, mastery of skills, and the formation of attitudes and values within the prescribed subjects:

- Full intellectual, emotional, social, moral, and physical development of students in accordance with their abilities, needs, and interests
- Acquisition of knowledge, mastery of skills, and formation of value attitudes that contribute to the development of digital literacy essential for further education, life, and work in modern society
- Enhancement of linguistic, artistic, cultural, scientific, technical, and mathematical literacy, which is necessary for continuing education and professional development
- Support for the development of interdisciplinary competencies

5 IT DEPARTMENTS IN GYMNASIUMS IN THE REPUBLIC OF SERBIA

Based on the Regulation on the Curriculum and Instruction for Gymnasiums for Students with Special Abilities in Computing and Informatics [6], Table 2 presents a list of some gymnasiums founded by the Republic of Serbia, autonomous provinces, or local units, that have established departments for students with special inclinations for computer science and informatics. Zrenjanin Gymnasium, as one of the gymnasiums with an established IT department, did not have enough students this year who passed the entrance exam in mathematics and consequently did not form this department. It can be concluded that the reason for this is the excessive number of specialized IT departments in the Republic of Serbia, which totals 48, whereas the initial plan was to have a maximum of 5 departments. Table 1 includes some of the gymnasiums in the Republic of Serbia that have established IT departments.

Table 1. IT Departments in Gymnasiums in the Republic of Serbia

Name of Gymnasium	Location of the Gymnasium
Zrenjaninska gimnazija	Zrenjanin
Gimnazija "Uroš Predić"	Pančevo
Gimnazija "Veljko Petrović"	Sombor
Gimnazija "Jovan Jovanović Zmaj"	Novi Sad
Prva beogradska gimnazija	Beograd

6 OVERVIEW OF SPECIALIZED IT SUBJECTS

Specialized subjects will be covered in different grades throughout the four years of schooling. The specialized subjects are [7] shown in Fig. 1:

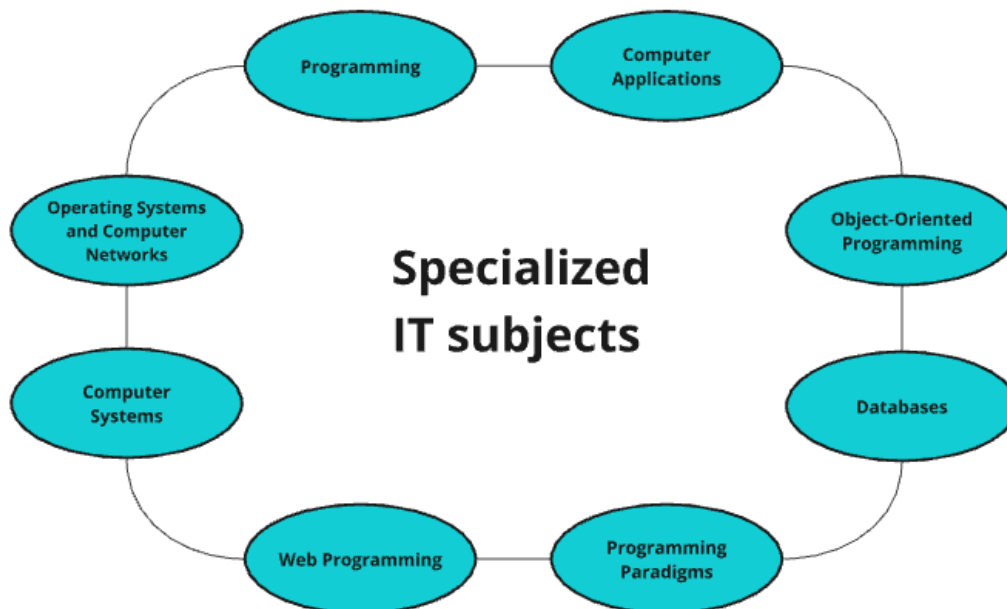


Figure 1. Specialized IT subjects

The curriculum for some of the specialized subjects, as well as the division of classes into groups for all four years, is structured as follows:

- Subject Computer Applications are conducted during the first, second, and third year. There are 72 exercise periods (each lasting 45 minutes) in the first and second grades, while 70 class periods are conducted in the third grade. During the first three grades, there are also block teaching sections with 30 class periods. The number of students per group ranges between 8 and 12
- Subject, Programming is conducted during the first, second, and third year. 72 exercise periods in the first and second grades, while 70 class periods are conducted in the third grade. During the first three grades, there are also block teaching sections with 30 class periods. The number of students per group ranges between 8 and 12

- Subject Object-Oriented Programming is conducted during the third year. There are 70 exercise periods and there are 30 block teaching sections. The number of students per group ranges between 8 and 12
- Subject Databases are conducted during the third and fourth year. During the third year, there are 70 exercise periods. During the fourth year, there are 62 exercise periods and there are 30 block teaching sections. The number of students per group ranges between 8 and 12
- Subject Programming Paradigms are conducted during the fourth year. During the fourth year, there are 62 exercise periods and there are 30 block teaching sections. The number of students per group ranges between 8 and 12

7 FOREIGN IT DEPARTMENTS

High school students in Europe and America gain significant advantages and opportunities by building strong academic foundations and developing educational and personal qualities such as maturity, self-confidence, and independence at an early age. Educational systems in different countries vary in their characteristics but provide the essential knowledge and qualifications crucial for admission to the world's best universities and the development of successful future careers. Several prominent high schools in Europe and America offer specialized IT programs. Each school approaches IT education through its curriculum in a unique way, providing various models and methods for training high school students in the field of information technology. These include:

- NTI Gymnasiet (Sweden) – a prestigious high school specializing in education in the field of information technology. The school offers a modern curriculum that emphasizes key aspects of IT. Their educational program is designed to provide students with a solid foundation in technical skills as well as practical experience. The school is connected with the industry through various projects and collaborations, allowing students to gain experience on real projects. Some of the subjects taught at this school are presented in Fig. 2.

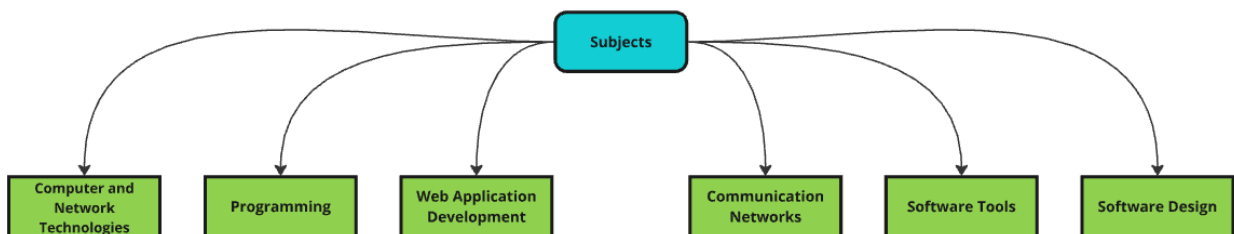


Figure 2. Subjects Covered at NTI Gymnasiet

- State Scientific High School Albert Einstein (Italy) – a high school that focuses on advanced fields in science and technology, with a special emphasis on information technology. They offer a modern curriculum that includes subjects in advanced IT skills, robotics, and digital systems. This school enables its students to develop analytical skills and technical expertise that are essential for science and technology [10]. Some of the subjects covered at this school are shown in Fig. 3.

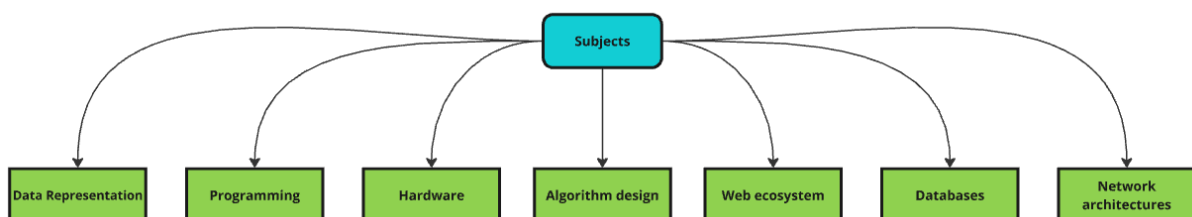


Figure 3. Subjects covered at State Scientific High School Albert Einstein

- Thomas Jefferson High School for Science and Technology (USA) – a high school focused on STEM (science, technology, engineering, and mathematics) fields. This school offers a wide range of advanced courses in information technology and related disciplines. The school provides its students with research projects that allow them to work on real-world problems. Students have

access to state-of-the-art laboratories and are offered collaboration with numerous industries and prestigious universities [11]. Fig. 4 shows some of the subjects that students at this school attend.

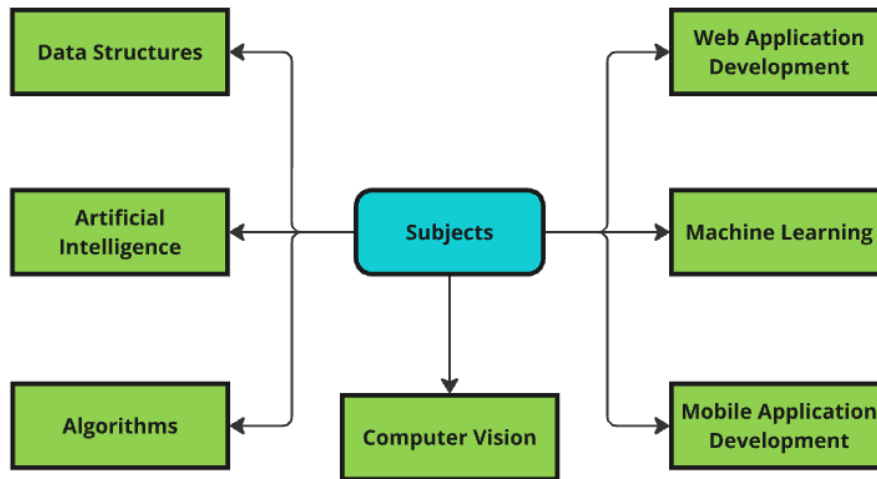


Figure 4. Subjects covered at Thomas Jefferson High School for Science and Technology

CONCLUSION

Specialized departments designed for students with a particular inclination towards computing and informatics represent the essence of enhancing specific computing competencies, aiming to prepare students for future career challenges as well as everyday life. This research encompassed the reasons for establishing these departments, the skills that students will acquire through attending them, and the curriculum prescribed by the Ministry of Education. Additionally, the paper presents high schools across the Republic of Serbia that offer this type of specialization, the technical subjects covered over the four-year program, as well as international IT departments.

The insights presented in this research could serve as a reference point for future studies, such as career outcomes of students with special aptitudes for computing and informatics after completing high school, a comparative analysis of curricula in high schools and other IT schools across the Republic of Serbia, etc.

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School Without Mobile Phones - Impact on Socialization

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Abstract. Although mobile phones are part of today's society, without which one cannot imagine a day, the initiative of schools without mobile phones is joined by an increasing number of educational institutions in the Republic of Serbia. With the introduction of this initiative, as well as with the adoption of new regulations, mobile phones are being kept away from the youngest, at least in school classrooms. The effects are already measurable. The paper you are reading is the result of research that is still being carried out in several schools in Serbia, and it presents the results obtained by analyzing the questionnaires that were filled out by all actors of the teaching process. The positive aspects that are reflected in the better socialization of students, socializing and the development of emotions and empathy are emphasized, but also some negative ones that primarily lead to inevitable changes in the teaching process.

Keywords and phrases: mobile phones, socialization, education, innovation

1 INTRODUCTION

The development of technologies at the beginning of the twenty-first century brought many changes in the concept and approach to the educational process. In the first years of this century, efforts were made to digitize the teaching process as much as possible, and the purchase of devices for teaching purposes was primary for all stakeholders in education. Already after the first decade, we reached the point where over 50% of students have a mobile phone, and at the end of the second decade, that percentage exceeded 90%. Now, in the middle of the third decade when almost every student has a mobile phone, the question arises whether mobile phones have a place in school. (Djukic Popovic, Vuletic, Popovic, etc. 2023) On the other hand, the twenty-first century brought many reforms, between among other things, the reform of the school system. The indiscipline of students that has been present for decades is coming to a climax. Children's rights and forgotten obligations are one of the key arguments used to justify the illegal behavior of students. Often times, the teaching staff's hands are tied and inappropriate behavior is justified by the fact that the school has lost its educational role. (Popovic, Jevtic, Djukic Popovic, etc. 2023)

Mobile phones are one of the forms of technology that in the 21st century are undergoing extremely rapid development and innovation. Their progress and revolution are based on the emergence and development of other technologies, such as communication technologies in general, computers and the Internet. Mobile phones today are called "smart phones" because they offer many diverse options for users and integrate a large number of functions and operations. They are usually used for communication, which was the primary reason for their creation, but they are also used for entertainment, doing business, orientation in space, shopping, banking, information and education. (Sad, Ranisavljevic, 2016)

In recent years, the use of mobile phones has become increasingly common among young minors, both at home and at school. The mobile phone has become an integral part of almost every child's life.

In schools already in 2022, the need to limit the use of mobile phones or to introduce strictly defined rules for when and how they can be used was seen. (Hercog, 2023) From the idea that it becomes one of the basic teachings of the modern educational process, we come to the conclusion that it is actually one of the basic obstacles to the development and progress of young people. (Djukic Popovic, Vuletic, Popovic, etc. 2023) No device has experienced such wide and rapid application and use as the mobile phone. Ling (2004) points out that one of the most popular ideas when using mobile phones is that of providing the appearance of security and protection. It is also one of the main reasons that lead to buying and owning a mobile phone. Security and protection have become part of the social image of mobile phones, which we use when understanding and understanding the integration of mobile into our lives. (Nasar, Heckt, Wener, 2007) The desire for security and protection is one of the main reasons why parents want their children to have mobile phones. It is also the card that children play when they ask their parents to buy them a phone. (Relja, Bozic, 2012) We have reports of the paradoxical nature of the feeling of security and protection provided by the mobile phone. They say that for an individual, a mobile phone can have beneficial, but also harmful effects in terms of security and protection. The user can call for help or report an accident, but this will encourage many to engage in riskier behavior and consciously expose themselves to a potentially dangerous situation. (Gordon, 2002) Having a mobile phone also reduces awareness, distracts the user's attention, slows down reactions, and thus increases the possibility of accidents, especially traffic accidents, which are very common among young people. (Milisa, 2006)

One of the main disadvantages of using mobile phones among young people is the emergence of digital violence. This can lead to unforeseeable consequences for the upbringing of all actors of violence. Cyberbullying, as it is now modernly called violence through new technologies, signifies a new danger for young people, especially children. Many experts, especially in the field of psychology, pedagogy and sociology, warn of a new scourge brought by the development of new technologies. (Campbell, 2005) We are reminded that violence perpetrated by mobile phone is often worse than that which happened face to face. Namely, when the abuser harasses verbally, the victim will often not remember every word addressed, while by sending a message, the victim exposes himself to violence every time he re-reads it. Also, mobile violence can happen at any time, and it is difficult to avoid it. (Butler, Desmond, Kift, 2010) We can point out that the victim of violence through new technologies typically feels very powerless to refuse or fight against the bully. Even greater powerlessness is created by the possibility that the victim is attacked 24 hours a day, seven days a week and that in his own home, which is otherwise the greatest place of safety and protection. (Stanic, 2007)

Using a mobile phone allows young people to expand their own freedom, but at the same time it also expands parental control and authority. It is very important to see the fact that the use of a mobile phone without full supervision in children can have incalculable consequences on growing up, social life, emotional and physical changes during growth and development. Using a mobile phone allows young people to expand their own freedom, but at the same time it also expands parental control and authority. It is very important to see the fact that the use of a mobile phone without full supervision in children can have incalculable consequences on growing up, social life, emotional and physical changes during growth and development. (Djukic Popovic, Vuletic, Popovic, etc. 2023) Just a few years ago, in the transition before the Covid pandemic, we had reports that mobile devices and the media are not the causes of violence among young people and that banning the use of mobile phones will not reduce the number of violent acts. Rather, preventive pedagogical measures for working with young people, their motives, cultural and social environment, and experience are more necessary. (Andevski, Banić, 2019) We can see in many works about the positive influences and futuristic ideas that the teaching process will accept the mobile phone as one of the basic teaching aids. (Matijevic, 2014) Already with the end of the Kovid pandemic, there are new initiatives on the project of schools without mobile phones. Teachers, as well as the professional public, come to the conclusion that their use in school exceeds the positive effects that are reflected in the control of safety and the improvement of teaching and learning. There are frequent cases of illegal use of mobile phones for the purpose of copying tests, using applications for "quick and easy" homework, recording illegal video and audio recordings of classes or various situations during vacations and posting content on social networks, as well as the inability to separate students from of the mobile phone during the lesson itself as a form of some kind of addiction. (Djukic Popovic, Vuletic, Popovic, etc. 2023) Unpleasant events in an elementary school in Belgrade further agitated the public and led to decisions being made at the school level to remove mobile phones from school desks. In the year 2024, most schools in Serbia adopted a regulation

on the use of mobile phones, which implies their complete ban. In the continuation of the work, we will present the methodology, a review of previous research and give a brief overview of the latest results that were obtained from the research that was carried out in several primary and secondary schools of the School Administrations in Belgrade and Niš, in which mobile phones were completely omitted not only during classes, but also during time provided for rest, recreation and study after regular classes within extended stay and outside of teaching activities.

2 RESEARCH METHODOLOGY

During 2020 and 2021, an empirical test was started on how the impact of leaving a mobile phone on the chair during class will be reflected. The research was carried out by individual teachers of mathematics, physics and computer science. This idea was subsequently discussed at key meetings, the Republican Seminar on Teaching Physics in 2022 and the Republican Seminar on Teaching Mathematics in the same year. The initiative without mobile phones in the classes of these three subjects is joined by a large number of colleagues, some of whom are involved in this research. In 2023, in a Čukarica elementary school, a decision was made to leave mobile phones in boxes at the entrance. After a short resistance of some students and parents, an agreement is reached that the decision will be respected and after a certain time they will summarize their impressions. Soon, schools in different parts of Serbia joined the initiative. With the beginning of the 2024/2025 school year and the adoption of the rulebook on the use of mobile phones in schools, a large number of schools are deciding on this very measure. In schools that introduced this ban as early as 2023, polls are conducted in which all participants in the teaching process participate. The results are published and available to the public in the work *The challenge of modern education - a school without mobile phones*. Since positive results are being observed, the research is being extended to several more schools. The number of schools included in this research is not finalized and is constantly expanding. The School without Mobile Phone project is a pilot project supported by the Ministry of Education, Science and Technological Development. Before surveying students, parents and teachers, individuals from the field of security are included in the final research, who will fill out anonymous questionnaires and consider the impacts.

3 REVIEW OF RESEARCH CONDUCTED UNTIL 2024

A. Mathematics teacher's view

The students' reactions were expected. Most of the students did not believe that this could happen even though it had been announced before. They believed that carrying a phone is their right that no one can challenge. It was a challenge to work with them during that period. They showed some kind of restlessness and uneasiness both in classes and during breaks. Results on control tasks and written tests were in decline. On the other hand, the collective awakening of entire departments was noticeable. Interest in the material and participation in the class gradually grew. Also, from being estranged on vacations, we slowly moved on to a somewhat clumsy, but more frequent conversation. Students became more focused on each other and helped each other in situations when needed. Even in the case of written tests, they tried to remember the tasks in order to convey to their friends what was on the control sheet, instead of previously taking pictures of the tasks in secret so that those working later would have time to do and then copy those solutions on the test.

On the other hand, the quality of teaching in today's age of digitization has undoubtedly declined. In math classes, I often asked students to research a term or find a definition on the Internet in order to simultaneously point them to verified and unverified sources of information. This way of working proved to be interesting for the students, they absorbed information faster and easier, they competed to find a better definition or an example from life and they connected mathematics with the world around them. Also, I often used a platform like mozaBook to show them geometric bodies and their elements, then rotations of certain geometric figures and the formation of oval geometric bodies, relationships between lines in space or planes and lines, demonstration scales from phet applications as a model for equations or interactive construction board. They could watch it all on their mobile phone or tablet and try it out in class. Quick quizzes or assignments that I would leave on Google Classroom were always available for them to work on in class, which saved us time rewriting assignments or printing materials. However, in a way, we won there as well. The students tried to write down all the definitions and tasks done in class, as well as the assigned homework instead of painting the blackboard and copying at home. They used the textbook more as the only means of finding information related to the lesson in class. The creativity and imagination initiated by the lack of

digital means led the children to team up and make geometric bodies out of wire themselves that facilitated their tasks and understanding of space. They themselves initiated the creation of panels with different topics and areas of mathematics. Through the construction of irrational numbers, they created real small works of art that now stand on the cabinet panel.

B. Views of teachers of informatics and computer science

During the 2022/2023 school year, mobile phones in informatics and computing classes were used for certain applications and platforms that enabled children to research information, take photos and videos that were later used for various school projects. By limiting usage, students are encouraged to focus more on the material at hand, and are encouraged to use their imagination and creativity. It has been observed that topics such as children's safety on the Internet arouse greater interest among children, because after a few months of reduced time spent on mobile devices, students have an increased dose of caution. Without the use of mobile phones, students often suggest to the teacher a lesson in nature and the use of certain teaching aids such as drones and Mbot robots in the school yard. Students show interest in participating in various IT workshops, where communication among students is in the foreground. Certainly, the use of digital devices in the modern world is necessary, so even in the classes of informatics and computer science, students are forced to use them. The difference between using mobile phones and computers in the office is that the computers in the office are not personalized, but each student has a uniform profile that can be used exclusively for teaching. Such computer use excludes any form of potential digital violence, and disables the distractions that phones can bring. As students do not use mobile phones during other classes during the day, and do not have access to digital content, when they come to the informatics and computer science class, their interest in the content that they can access in class, which are exclusively educational in nature, is significantly increased. The higher the interest in the subject, the higher the student's productivity. And so, during the preparations for the school day, the students also proposed the preparation of a collage that would present their view of digital technologies.danas.

C. View of the physics teacher

The experience is that students, when they are not denied the use of mobile phones, cannot break away from the influence of social networks and the games they play on their phones. This is one explanation for the trend towards less independent learning at home. We had the opportunity to see this at school in the past few school years. During breaks, and more and more often during classes, students stare at mobile phone screens as if in a daze, not having the strength to resist this habit, even when we warn them about it. If no one at home disturbs them from constantly looking at the mobile phone screen, students spend all their time on it, often at the expense of time needed for sleep. The habit becomes an addiction of epidemiological proportions.

The benefits of eliminating cell phones at school are great. Attention in classes is undivided, there are no isolated students staring at phone screens during breaks, we have completely abolished the possibility of secret recording and sharing on social networks, which is becoming a trend and a problem that is difficult to deal with. And which, unfortunately, continues when their mobile phones are returned, regardless of education about the dangers of such behavior. Communication between students is visibly better, and there is also a great progress in communication between students and teachers. The number of inappropriate appeals to the teacher has decreased, which was expressed especially in situations where the teacher indicates the illegal use of a mobile phone. The number of unnecessary calls to parents for every little thing was also reduced, which disturbed both parents and teachers. Of course, the students are left with the option that, in justified cases, they can take their phone and call their parents. It would seem that we have canceled the benefits of using modern technology in the classroom in this way, which is, of course, a huge shame. The use of mobile phones in classes is diverse and would greatly improve teaching. Unfortunately, the use of mobile phones in the classroom is also very difficult to implement. The reasons are that not all students have an available internet connection, we do not have the right to ask for a regular mobile phone, the installation of certain applications requires parental permission and the like. Even when the city handed out free tablets to students, since their service was not efficient, it quickly became apparent that their use in class was disrupting class dynamics. Until the awareness of the appropriate use of new technologies changes, until we find a way to counter the addiction to social networks and games, it is far more effective to deny students access to mobile phones during class.

4 CURRENT RESEARCH

The current research is reflected in the effects on the socialization of students, their achievements, the opinion of parents, teachers and students about this step. The results obtained by surveying students just a few days after the ban and a month later are presented. The survey material was distributed through the teachers who participated in the research.

4.1 First survey:

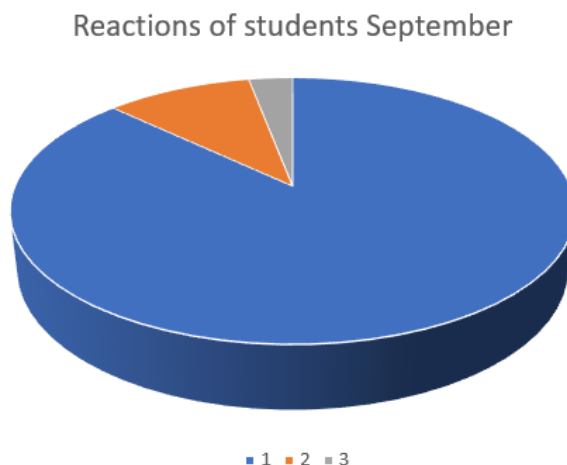
The first survey was conducted in the first week of September, when the implementation of the rulebook began. The research was conducted on a sample of 8163 respondents, of which 3453 are students, which represents 42.30%, 452 are teachers, which is 5.54% of the total number, and 4258 are parents, which represents 52.16% of the total sample. We discuss the results in the following paragraphs.

Table 1. Structure of respondents

No	First survey		
	Category of respondents	Number of responses	%
1	Students	3453	42.30
2	Teachers	452	5.54
3	Parents	4258	52.16
	Total responses	8163	

Student reaction to cell phone ban:

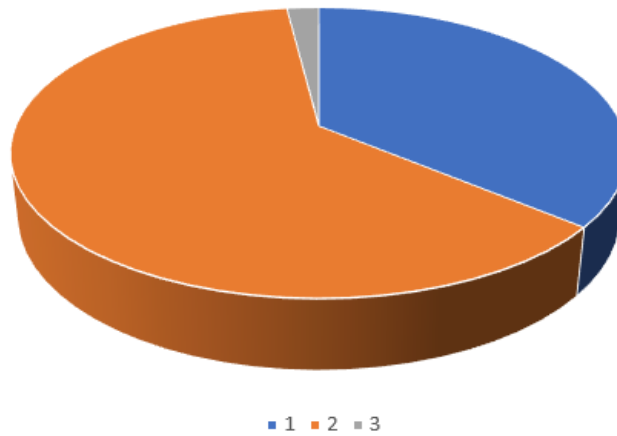
On the attached graphic under number 1, the number of students who oppose the ban on the use of mobile phones is represented, this percentage is very high 87.23%, i.e. 3012 students, under number 2 is 9.73%, i.e. 336 students who decided to support the ban on their use mobile phones. The rest, i.e. 105 students, did not decide.



Teacher's reaction to the ban on mobile phones:

On the attached graphic under the number 1, the number of teachers who oppose the ban on the use of mobile phones is represented, this percentage is low, 36.50%, i.e. 165 teachers, under number 2 are 66.12%, i.e. 281 teachers who have decided to support the ban on the use of mobile phones. The rest, i.e. 6 teachers, did not decide.

Reactions of teacher September



Parents' reaction to the ban on cell phones:

On the attached graphic under the number 1, the number of parents who oppose the ban on the use of mobile phones is represented, this percentage is 38.02% or 1619 parents, under number 2 is 45.00%, i.e. 1916 parents have decided to support the ban on the use of mobile phones. The rest, i.e. 723 parents, did not decide.

Reactions of parents September

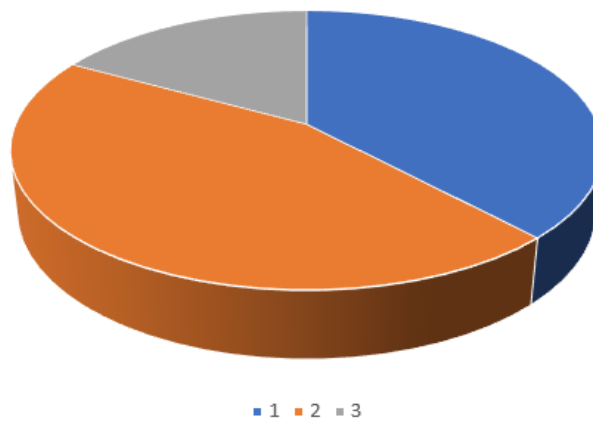


Table 2 . Reaction to cell phone ban

No	First survey			
	Category of respondents	Reaction	No	%
1	Students	oppose the ban	3012	87.23
		decided to support	336	9.73
		did not decide	105	13.04
2	Teachers	oppose the ban	165	36.50
		decided to support	281	66.12
		did not decide	6	7.48
3	Parents	oppose the ban	161	38.02
		decided to support	1916	45.00

Reactions of parents September

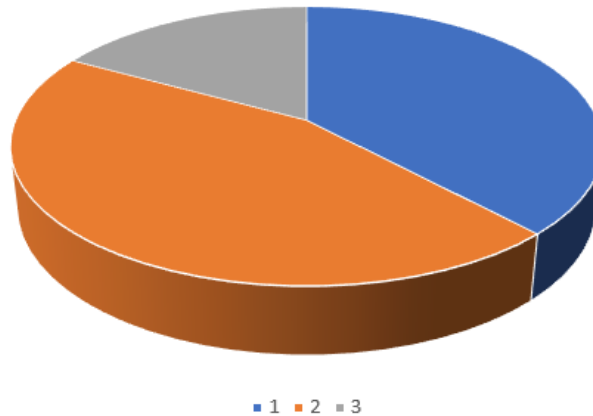
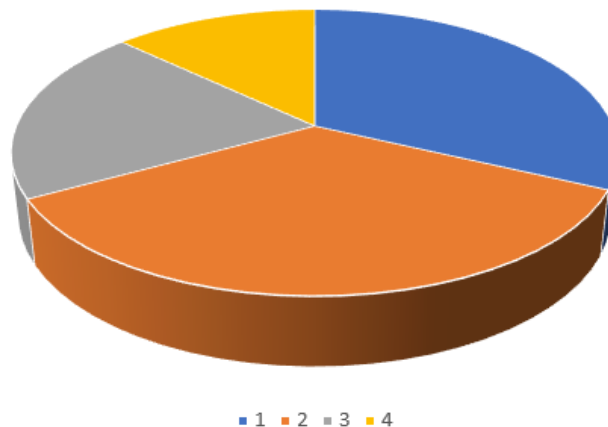


Table 2 . Reaction to cell phone ban

No	First survey			
	Category of respondents	Reaction	No	%
		did not decide	723	26.98
		Total responses	8163	

The opinions of all actors influence socialization:

Reactions of respondents - September



The opinions of students, teachers and parents have almost the same dispersion, which is presented in the graphic. Banning the use will have a positive effect (number 1) on socialization, socializing and increasing empathy, said 32.00% or 2612 respondents. 35% or 2857 respondents said that the ban will have a negative impact (number 2), 1632 respondents declared that this ban will not affect the current scope of socialization (number 3), which represents 20% of the sample, while 1062 respondents did not answer this question (number 4).

4.2 Second survey:

The second survey was conducted on the first and second week of October, one month after the start of the implementation of the rulebook. The research was conducted on a sample of 3752 students, 375 teachers and 3351 parents, which represents 7478 respondents, which in percentages is 50.17%, 5.01% and 44.81%. We

discuss the results in the following paragraphs. But first of all, we must note that the interest of students in participating in the survey increased slightly, while the interest of parents and teachers decreased. This needs to be researched separately.

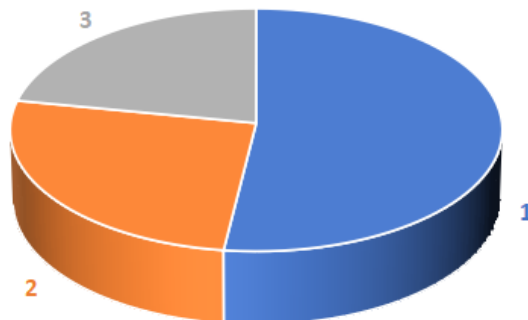
Table 3. Structure of respondents

No	Second survey		
	Category of respondents	Number of responses	%
1	Students	3752	50.17
2	Teachers	375	5.01
3	Parents	3351	44.82
	<i>Total responses</i>	7478	

Student reaction to cell phone ban:

On the attached graphic under the number 1, the number of students who oppose the ban on the use of mobile phones is represented, this percentage has decreased compared to the previous survey and is 52.00%, i.e. 1951 students, under number 2 is 26.07%, i.e. 978 students who decided to support the ban on the use of mobile phones. The rest, i.e. 823 students, did not decide.

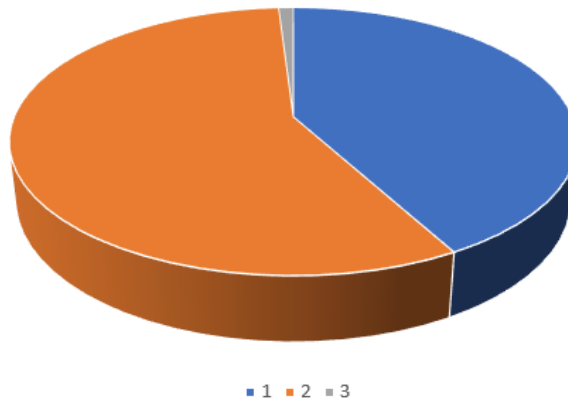
Reactions of students - October



Teacher's reaction to the ban on mobile phones:

On the attached graphic, under number 1, the number of teachers who oppose the ban on the use of mobile phones is presented, this percentage is low, 42.47%, i.e. 151 teachers, under number 2 is 56.53%, i.e. 212 teachers who have decided to support the ban on the use of mobile phones. The rest, i.e. 12 teachers, did not decide.

Reactions of teacher October



Parents' reaction to the ban on cell phones:

On the attached graphic, under number 1, the number of parents who oppose the ban on the use of mobile phones is represented, this percentage is 21.40% or 717 parents, under number 2 is 74.10%, i.e. 2483 parents have decided to support the ban on the use of mobile phones. The rest, i.e. 151 parents, did not decide.

Reactions of parents - October

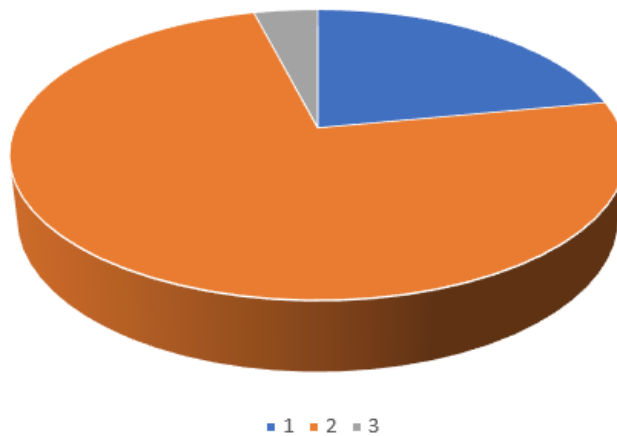


Table 4 . Reaction to cell phone ban

No	Second survey			
	Category of respondents	Reaction	No	%
1	Students	oppose the ban	1951	52.00
		decided to support	978	26.07
		did not decide	823	21.93
2	Teachers	oppose the ban	151	42.47
		decided to support	212	56.53
		did not decide	12	2.00
3	Parents	oppose the ban	717	21.40
		decided to support	2483	74.10
		did not decide	151	5.50

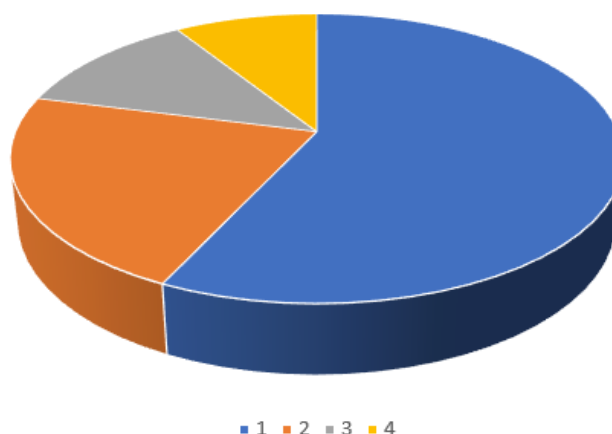
Table 4 . Reaction to cell phone ban

No	Second survey			
	Category of respondents	Reaction	No	%
		Total responses	7478	

The opinions of all actors influence socialization:

The opinions of students, teachers and parents in this part of the research also have almost the same dispersion, which is presented in the graphic. But unlike the previous research, we see a significant shift in the number of those who see positive effects in this ban, which are reflected in socialization and mutual activities. Analyzing the surveys, we get the following statistical picture: Banning the use will have a positive effect (number 1) on socialization, socializing and increasing empathy, said 58.02%, i.e. 4339 respondents. That the ban will have a negative impact (number 2) was said by 23.04% or 1723 respondents, 1052 respondents declared that this ban will not affect the current scope of socialization (number 3), which represents 14.07% of the sample, while 364 respondents did not answer to this question (number 4).

Reactions of respondents - October



5 CONCLUSION

This research provided a brief comparative analysis of students' attitudes about the use of mobile phones at school and the impact of the ban on personal needs for socialization and socializing. Positive influences can be seen on the basis of the fourth question, and negative on the basis of the answers of the teachers, who are not slightly biased towards the decision. From this it can be concluded that the mobile phone was still one of the tools in the teaching process, and almost certainly a good teaching tool for certain teaching units. In addition, when we compare this research with earlier researches, we come to another conclusion, namely that banning mobile phones improves the concentration and attention of students in class, significantly improves socialization and interactions among students during vacations, improves their navigation in space and creativity, in addition to of this, students are directed to look for information in other places than the Internet, and in general to point out that without a mobile phone you can "get through" the school day in learning, playing and socializing.

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Performance Metrics for Object-Oriented Programming Languages and Python used for Embedded Systems Programming

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Abstract. In this work, a brief overview on the performances and execution speed of C++, C#, Java and Python were made for bubble sort algorithm, selection sort algorithm and insertion sort algorithm. For each of the said programming languages, five iterations of the same implemented algorithm were executed, and each iteration execution time, as well as average execution time in milliseconds is noted. Goal and purpose of this paper was to show the most efficient programming language for the execution time, which is crucial for the embedded systems where the matter of execution time is highly important and critical.

Keywords and phrases: embedded, systems, performance, metrics, object-oriented, programming.

1 INTRODUCTION

Besides structural (functional) programming languages, object-oriented programming languages are used in the development of embedded systems due to modularity and features provided by the object-oriented concepts. Rassokhin (2020)

Encapsulation, polymorphism, inheritance and abstraction could be implemented in the embedded systems that are powering Internet of Things (IoT) and systems of similar use. By implementing such concepts, trade-offs between required memory are made. However, by having correct approach on the development of embedded systems, optimizing source code could eliminate overhead of the execution speed.

2 EVALUATION OF OBJECT-ORIENTED PROGRAMMING LANGUAGES AND PYTHON

Object oriented programming languages were selected for the study of the execution time performed for five iterations, including average execution time. Each programming language is tested for the bubble sort algorithm, selection sort algorithm and insertion sort algorithm.

2.1 C++ Programming language

C++ programming language was developed by Bjarne Stroustrup in the Bell laboratories, somewhere between 1983. And 1985. This programming languages was designed as extended version of C programming language. Mainly designed for UNIX based operative systems, it represents upgraded version of C programming language and offers the ability of improved source code quality. (Ogala, 2020)

Before C++ programming language source code could be executed, it is necessary to compile it. That means that compiler will translate source code to machine code and link it with external pre-compiled libraries via linker. Large C++ based software require higher compilation time, because each line of source code is translated, regardless of its execution. This process can impact the development cycle of the software but produces more reliable source code since compiler can discover various errors during the compile-time, unlike the interpreted languages where the error would result into a runtime error. (Rassokin, 2020)

2.2 Java Programming language

Java is object-oriented programming language developed by James Gosling and his team in 1991. Although first intention of Java programming language was development of applications for internet, Java programming language became programming language of general purpose, which could be used independently. (Chen, 2010)

Java environment is based on Java programming language and Java Runtime Environment (JRE), including Java Virtual Machine (JVM). Besides that, foundation of Java is based on various libraries developed from the third party, such as many open-source projects that are continuously contributing to Java programming language and Java features. (Evans, 2023)

Java platform is designed for portability. It offers abstraction over the operative system and allows sequence of byte-code instructions to be executed over different Java platforms. Besides portability, Java programming language includes safety mechanisms that are securing that bytecode is inspected, thus preventing Java environment corruption from malicious software. (Friesen, 2012)

2.3 C# Programming language

C# programming language is simple, modern, object-oriented programming language. Descending from the C-based programming languages, standardized by ECMA-344 and ISO/IEC 23270 standard. Compiling of C# programming language is possible by .NET Framework, which is presented by the overall ECMA-334 and ISO/IEC 23270 standard. Regardless of being object-oriented, C# programming language offers component-based programming as well. (Hejlsberg, 2010)

C# utilizes compiler for translation from source code to set of instructions of the low level. These instructions are commands that are directing the hardware, which executes the software afterwards. For the development of C# programming language source code, Microsoft made Integrated Development Environment called Visual Studio, which offers the features of compiling, debugging and usage of integrated editor. (Miles, 2018)

Main concepts of C# programming languages are concluded in the namespaces, data types, members and assemblies. Variables, methods, properties and events are just some of the examples of members that are contained in the C# programming language. After compiling, source code and its components are physically compressed to assemblies, whose extensions are usually .exe or .dll, depending on the case of software application executable file or dynamically linked library. (Hejlsberg, 2010)

2.4 Python

Python is developed in the 1991. By the Guido van Rossum. Based on object-oriented approach, Python is an interpreted language of high level. It offers various data structures such as lists, sets and arrays. Unlike other statically typed languages, Python is dynamically typed language. It offers the usability of many developed libraries that are lowering the size of the source code. (Dhruv, 2021)

Development of efficient software requires experience in the performance engineering field, computational modelling and capability of optimizing the algorithms as well as the software itself. During the software development, common choice is made between the software eco-system that offers rapid development (speaking of Python and R languages), and software eco-system that offers high performances and scalability (such as C, C++ and Rust). (Shajii, 2021)

While not demanding, Python is suitable for rapid development of various software prototypes. It is portable and based on the open-source principle. By using appropriate libraries such as Cpython, it is possible to integrate it with C/C++ programming languages in order to achieve better performances during computation and data analysis. (Aziz, 2021)

3 METHODOLOGY

Methods used for this research are based on the three different sorting algorithms which are bubble sort algorithm, selection sort algorithm and insertion sort algorithm. These algorithms are executed by C++, Java, C# and Python to gather information on the execution speed of instructions during the sorting mechanism. Numbers from 0 and 100000 are used for samples. After random selection, 10000 samples are put in array which holds 10000 integer values. After arrays are filled, they are sorted and execution time for sorting is

noted. The cycle of sampling, storing and executing sorting algorithm is done for five iterations where each execution time is noted, and after that, the average execution time is calculated.

In the table 1. Sorting algorithm metric results for C++ programming language, table 2. Sorting algorithm metric results for Java programming language, table 3. Sorting algorithm metric results for C# programming language and table 4. Sorting algorithm metric results for Python, first column (sorting algorithm) shows the sorting algorithms performed. Bubble sort, selection sort and insertion sort are different methods of sorting the data of the array. Second, third, fourth, fifth and sixth columns of table1, table 2, table 3 and table 4 present the iteration of the measurement performed for the sorting algorithms, and the results are shown as execution time in milliseconds, required for the iteration to complete (from start to end). Column for the average execution time shows the average results (in milliseconds) of the previous execution times (iterations).

Table 5. Average execution time of sorting algorithms for C++, Java, C# and Python shows the average execution time in milliseconds for bubble sort, selection sort and insertion sort algorithms, for C++, Java, C# and Python.

Table 1. Sorting algorithm metric results for C++ programming language

Sorting algorithm	First iteration (ms)	Second iteration (ms)	Third iteration (ms)	Fourth iteration (ms)	Fifth iteration(ms)	Average execution time (ms)
Bubble sort	33	33	32	33	34	33
Selection sort	8	8	8	8	8	8
Insertion sort	6	6	6	6	6	6

Table 2. Sorting algorithm metric results for Java programming language

Sorting algorithm	First iteration (ms)	Second iteration (ms)	Third iteration (ms)	Fourth iteration (ms)	Fifth iteration(ms)	Average execution time (ms)
Bubble sort	35	36	38	35	35.8	35.8
Selection sort	18	19	18	18	18	18.2
Insertion sort	6	6	6	6	6	20

Table 3. Sorting algorithm metric results for C# programming language

Sorting algorithm	First iteration (ms)	Second iteration (ms)	Third iteration (ms)	Fourth iteration (ms)	Fifth iteration(ms)	Average execution time (ms)
Bubble sort	40	39	42	39	39	39.8
Selection sort	22	22	21	24	22	22.2
Insertion sort	11	11	10	11	11	10.8

Table 4. Sorting algorithm metric results for Python

Sorting algorithm	First iteration (ms)	Second iteration (ms)	Third iteration (ms)	Fourth iteration (ms)	Fifth iteration(ms)	Average execution time (ms)
Bubble sort	5722	5652	5806	5672	5701	5710.6
Selection sort	2581	2586	2577	2589	2595	2585.6
Insertion sort	2720	2697	2623	2633	2693	2673.2

Table 5. Average execution time of sorting algorithms for C++, Java, C# and Python

Programing / script language	Bubble sort algorithm – average execution time (ms)	Selection sort algorithm – average execution time (ms)	Insertion sort algorithm – average execution time (ms)
C++	33	8	6
Java	35.8	18.2	20
C#	39.8	22.2	10.8
Python	5710.6	2585.6	2673.2

4 CONCLUSION

Based on the research of execution time in C++, Java and C# programming languages as well as Python, it can be noted that C++ is the most efficient in execution time speed. By being low level programming language, offering high speeds and efficient execution time, C++ is suitable for development of embedded systems that require critical execution time, where matter of milliseconds is the most important – factories, industrial systems, military equipment and similar. By performing various types of code optimization, both on the compiler level, and source code level, overall size of the source code can be significantly decreased, while maintaining fast execution speed, which can be very suitable for the embedded systems that have limited space, but require fast operations.

Followed by the Java and C#, higher level languages of general purpose, execution time is notably higher, and they may not be suitable for the development of embedded systems that require very fast time of response. Dependencies and libraries of these languages can have impact on the size of the source code, while maintaining decent execution time.

However, by observing results from Python, much higher execution time can be noted due to nature of Python being an interpreted language. Conclusion can be made that Python could be used for making prototypes of embedded systems as well as performing test for environment behavior and development of software for Internet of Things, where execution time in some cases is not of great importance.

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Building Everyday and Basic Learning Skills through Play: Educational Robots as a Tool for the Improvement of the Learning of Students with Special Educational Needs

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Abstract. Educational robotics is used worldwide as a learning tool in education, but surprisingly rarely in special education. Education in the perspective of new technologies has opened new directions and orientations in the instructive-educational process.

Educational robotic tools, which can also be referred to as "robotic partners", are designed with the ability to adapt to different contexts depending on the circumstances. This is an important factor that makes robotic tools effective mediators for the inclusion of children with special educational needs (SEN) in educational programmes. Another important factor that supports this claim is the fact that educational robotics can promote learning through collaborative play with peers.

In this paper we will present part of our educational robot prototype and our expectations for its use in working with SEN students, also we will see the opinion of teachers for implementing robotics in their classes. The research for the teachers' opinion is done in Latvia, in one of our partner schools of the project.

This work is part of the research activities within the Robotics and Inclusion Erasmus + project.

Keywords and phrases: Educational robots, skills, interactive learning, progress, motivation

1 INTRODUCTION

Educational robots provide an individualised and interactive approach, creating a pleasant learning environment that motivates SEN students to develop their skills. Robots that incorporate educational activities in the area of basic learning skills, such as counting, drawing shapes, painting, directions and orientation, speed and spatial prepositions, help to improve the cognitive abilities of SEN students. In addition, activities that focus on the development of basic daily tasks, such as washing hands, going to the toilet, brushing teeth and tying up clothes, help to strengthen students' independence and autonomy in their daily lives. Educational robots also play an important role in developing emotional awareness through activities such as recognising emotions through colours and smiles, and helping students to understand and regulate their emotional states. This approach enhances both academic and life skills for students, allowing for better integration and progress in their school and social environments. In addition, the use of educational robots creates an opportunity to systematically measure student progress. By monitoring their learning and interactions with the robots, teachers can gather important data about students' skill development and progress, allowing them to tailor

instruction and provide additional support according to each student's individual needs. This analytical component of educational robots is crucial for optimising learning and achieving positive educational outcomes.

2 METODOLOGY

This study employed a quantitative research approach using a structured questionnaire to collect data on the perceptions, experiences, and practices of educators and specialists regarding the use of educational robots in special education settings. The survey was designed to gain insight into the effectiveness of robotics in supporting students with special educational needs (SEN), the types of robots used, and the frequency of use in various subjects.

The target population for this study consisted of educators and specialists working with SEN students in Latvia. Participants were recruited from four types of institutions:

- Special education schools - development centers
- Special education schools
- General Education Schools providing inclusive education for students with special needs
- Pre- schools providing education for students with special needs

The data were collected through an online questionnaire that included of both closed and open-ended questions. The questionnaire was designed to gather information on:

- The type of institution in which the respondent worked in.
- The types of SEN students they worked with (e.g., intellectual impairments, autism, etc.).
- Their experience with using educational robots in the classroom.
- Their perceptions of the effectiveness of educational robots for SEN students.
- The types of robots used and the subjects in which these robots were incorporated.
- The frequency of robot use in different educational settings.

3 TEACHERS OPINION FOR USING ROBOTICS IN CLASROOM

A questionnaire to get some information about the use of educational robots in the special education in Latvia was created. The target audience of the survey was educators and other specialists who work with students with special needs. A total of 41 educators answers the question about using robotics in classroom.

The educators are teaching in Special education school-development center, Special education school, General education school providing inclusive education for students with special needs and Preschool providing education for students with special needs. In figure 1, a portions of working institution involved in the research are represented. The most of the answer of the questioner are from people that are working in special education school-development center. Most of the responders work with the students with mild and moderate intellectual impairments or severe or multiple impairments. The 49 % of the specialists work with the autistic students.

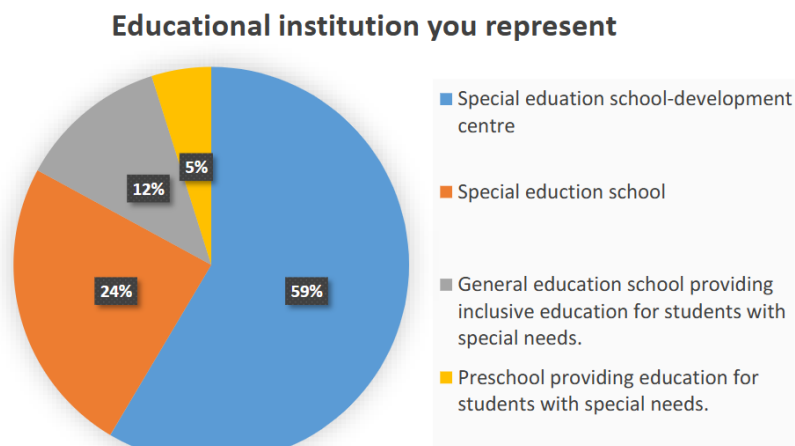


Figure 1. Involved educational institutions

What is your position?

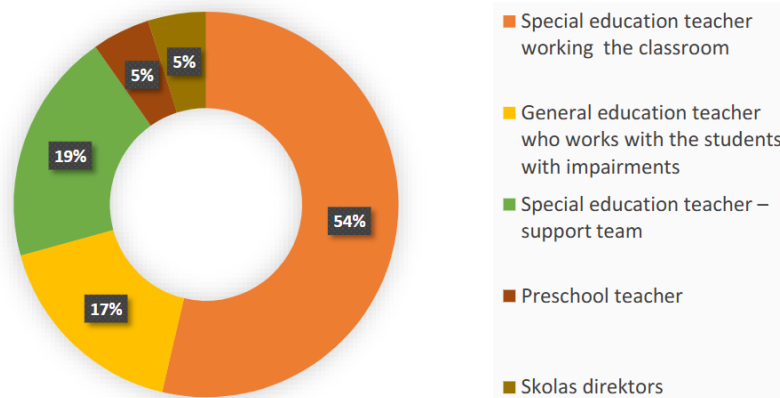


Figure 2. Job position

DO YOU USE EDUCATIONAL ROBOTS WHILE TEACHING THE STUDENTS WITH INTELLECTUAL IMPAIRMENTS?

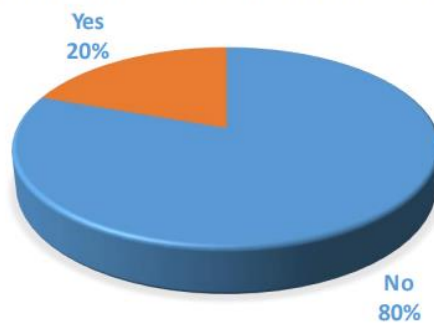


Figure 3. Usage of educational robotics for students with intellectual impairments

The 66 % of the surveyed specialists believe that the use of educational robots is useful and effective for students with special needs. The 10 % believe that the use of educational robots is not efficient and effective, the 24 % of specialists do not know or doubt this issue as is showed on figure 4.

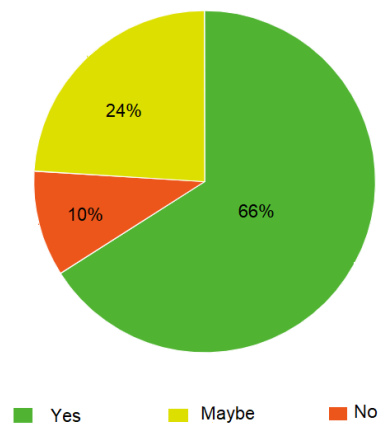


Figure 4. Impact of using education robots for students with special needs

Those specialists who work with educational robots use them more in design and technology, science, social studies, computing classes once a week or once per month. Most of the experts surveyed work with LEGO Education sets and TTS Bee-Bot robots.

The Bee-Bot is a programmable floor robot that looks like a bee and is designed for children ages three and up, to teach control, directional language and programming. The robot is colorful and easy to operate. The Bee-Bot moves in 15 cm increments and can store up to 200 directional commands at once. The Bee-Bot's movement can be programmed by pressing the directional arrows (forward, back, turn right 90 degrees, and turn left 90 degrees) in a sequence matching the desired movement and then pressing the green Go button. The robot blinks at the conclusion of each command to allow children to follow its progress through the program that they have entered. When the entire program is completed the robot confirms it with light and sound. This robot can be used in individual or collaborative settings (Bhattacharya, P. 2020).

LEGO® is a line of construction toys. They consist of different colored interlocking plastic bricks, accompanied by a whole range of different figurines, gears, and miscellaneous other elements. LEGO® has been used in various educational and therapeutic settings, mostly to foster social skills in children with autism (e.g., Huskens et al., 2015; Narzisi et al., 2021; Owens et al., 2008; Ramalho & Sarmento, 2019).

Special education and teaching tactics are necessary for children with special needs (SEN) due to their physical, mental, or social difficulties. In terms of behavioural, sociocognitive, and neurofunctional characteristics, they constitute a very diverse group. Sensory or motor impairments, autism spectrum disorders, mild to severe intellectual disabilities, specific neurodevelopmental disorders, such as attention deficit hyperactivity disorder (ADHD), specific learning disorders, specific language disorders, or other unidentified difficulties, are all possible diagnoses for children with special education needs (SEN). In order to address the deficiencies, social isolation, discrimination, and learning discrepancies of SEN learners, our initiative intends to incorporate robots into schools and centres.

In order to enable teachers working with kids who have special education needs in creating, implementing, and overseeing different techniques to promote robotics abilities in schools, the project intends to produce a comprehensive collection of tools and an instructional package. One effective, engaging, and inspiring approach to expose children incorporates subjects through robotics. Promotes other recruiting qualities at the same time, such initiative, creativity, teamwork, leadership, and problem-solving. Teachers and students will have international collaboration, cooperation, and communication options thanks to Educational Robots.

4 PROTOTYPE OF ROBOT WITH ARDUINO MICROCONTROLLER

The prototype robot is built using Arduino microcontrollers and has a 3D-printed body. Arduino acts as the 'brain' of the robot, controlling its functions and responses based on input from sensors.

The goal of the open-source Arduino microcontroller platform is to make the process of creating electronics projects easier. Its popularity in robotics is due to its ease of use, wealth of libraries, and large developer community that shares resources. Controlling robotic systems is made easy with Arduino boards, such as the Arduino Uno, which include multiple digital and analogue connectors to connect various sensors, motors, and components.

Arduino microcontrollers have inputs and outputs that can be used to obtain information, and based on the data received, Arduino can send output. Arduino microcontrollers can also send and receive data over the internet using HTTP requests. A simple microcontroller that can be connected to the internet is the Esp board. Esp microcontrollers can be connected to a Wi-Fi server or they can act as a Wi-Fi server (A.S. Ismailov, Z. B. Jo'rayev, 2022).

A common term for Arduino is the "brain" of the robot. This is so that the outputs to motors, lights, and other components can be controlled after the Arduino microcontrollers have processed the incoming signals from various sensors. The code - the "instructions" for the robot - determines how the device should respond to various inputs and perform tasks.

There are many different components involved in building a robot, but designing and building the robot's body is one of the most interesting. A 3D printer can be used to create a unique, robust, and useful structure for the body of the robot. In the robot that we will build at the end of the project, the body will be created using a 3D printer.

3D printing is an additive manufacturing (AM) process defined as "the process of joining materials to create objects from 3D model data, usually layer by layer, as opposed to subtractive manufacturing methods such as traditional machining" (Duda T & Raghavan, 2016;). 3D printing can deliver parts with very sophisticated

and complex geometries without the need for post-processing, built from custom materials and composites with almost no material waste, while being applicable to a variety of materials, including smart materials such as shape memory polymers and other stimulus-responsive materials. Therefore, 3D printing is a technology that offers increased "design freedom," allowing designers and engineers to create unique products that can be manufactured in low volumes in a cost-effective manner. One of the main examples of the design freedom offered is the ability to reassemble conventional assemblies into a single complex structure that could not be produced using current manufacturing processes (Gul, Jahan & Sajid, Memoon & Rehman, Muhammad & Siddiqui, Ghayas & Shah, Imran & Kim, Kyung-Hwan & Lee, Jae-Wook & Choi, Kyung, 2018).

On the front of the robot there will be a screen on which the students and teachers can select the functionality of the robot. The idea of the robot functionality is that the robot will have 3 different tasks. The first one will be to help the SEN students in basic daily activities. In this part, the robot will play an animation on the screen how the students can do certain activity. For example, the robot will play an animation how the students can wash their hands properly or put on clothes and some other daily activates.

In the second part of the functionality, the robot will teach the SEN students some basic mathematical concepts. For example, the robot will go on the road where there will be trees on both sides of the road, the task for the students will be to count how many trees the robot will pass. In this way, the SEN students will learn counting by trying the game with the robot.

Also the color sensor will be integrated in the robot, so when the robot sees a defined color it will make a torture. On this way the SEN students can learn the colors and also the orientation in the space left and right. Also with the orientation with the robot in the space, the SEN students will learn the basic geometric figure. For example, the robot will move and with the movement will draw a circle, on this way the students will know what movement with their hands they need to do to draw a circle.

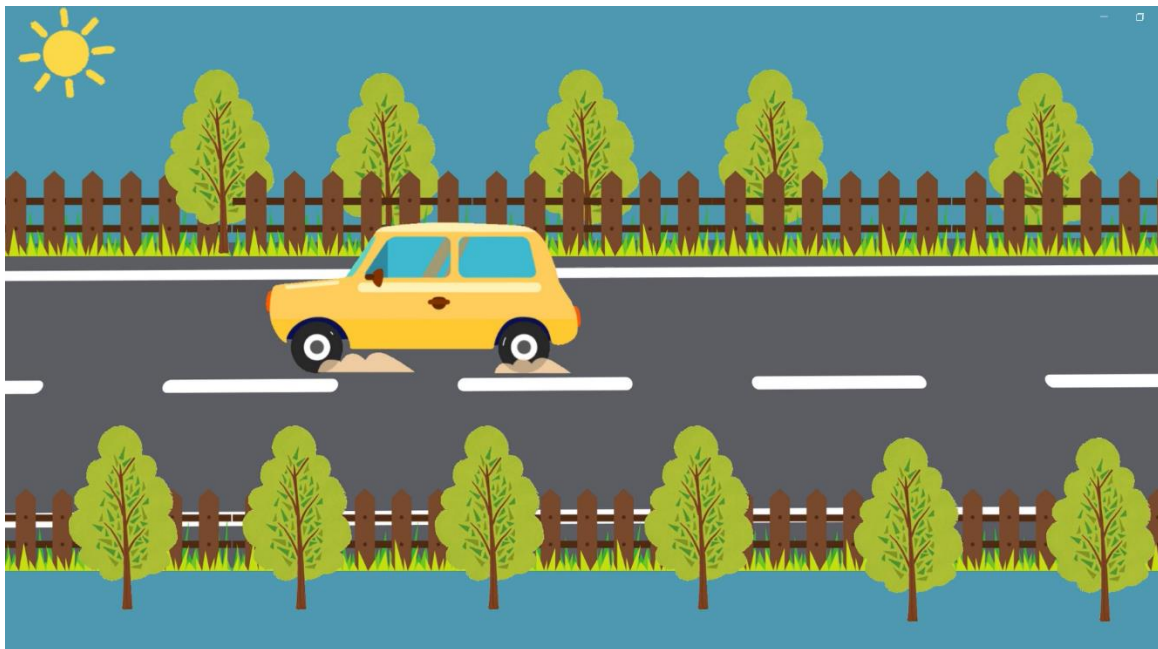


Figure 4. Animation for learn counting

For teachers working with SEN students, it is really important to know how they feel at a certain moment. So, in the third functionality of our robot, we are going to implement a question to the students about how you are feeling today. Students will be able to choose from pictures with emoji's that will be present on the screen. In this way, the teacher will always know the feeling of the students even if the student is not communicating with the teacher.

5 CONCLUSION

Educational robots play an important role in enhancing the learning experience of students, especially those with special educational needs (SEN). By providing interactive and hands-on activities, these robots encourage engagement with STEM subjects, while promoting essential life skills and emotional awareness. Feedback from educators in Latvia demonstrates a strong belief in the effectiveness of using robotics in the classroom, particularly for students with diverse learning needs. The prototype of the robot developed through the Erasmus project features innovative functionalities that support daily living skills, basic mathematical concepts and emotional expression, thus addressing the holistic development of SEN students. As the integration of technology in education continues to evolve, the implementation of such educational robots is poised to have a significant impact on student learning and progression.

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Communicative Language Teaching: Enhancing Speaking Skills in Non-native Learners with Specific Reference to SEE University Students of BES

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Abstract. The CLT approach is based on the idea that learning a language successfully comes through having to communicate real meaning. When learners are involved in real communication, their natural strategies for language acquisition will be used, and this will allow them to learn to use the language. Here the focus is not on the language forms but more on how to use the language to increase the students' fluency and accuracy so that they would be able to communicate with other people in real-life contexts. CLT involves knowledge of the language itself, its social rules, and how language changes depending on the context it is in. When we want to build accuracy in language use, CLT activities can be more controlled, and when we want to improve fluency, they can be less controlled. Learners achieve fluency and self-confidence when they engage in interviews, strip stories, and problem-solving exercises. This study will discuss the key principles, methods, and gains of CLT, what challenges are faced during the implementation of CLT, and the role of CLT in enhancing the speaking skills of SEE University students of BES.

Keywords and phrases: CLT, speaking, methodology

1. INTRODUCTION

The field of language teaching has evolved through the development and advancement of various approaches throughout its history. Researchers and scholars have thoroughly examined and studied these approaches or methods of teaching. The global demand for English has led to a surge in the demand for quality language teaching, making it an international language with immense importance. As a result, language teachers use a variety of approaches to help students learn and communicate in their target language, with the goal of improving their subject knowledge.

The European Council established CLT in the 1970s, based on the work of language specialists such as Wilkins, who studied communicative meanings that a learner must convey and comprehend. He emphasised meaning over the usual grammar-teaching technique. For example, the core notion underpinning CLT is that language training should not only teach grammar and vocabulary but also the meanings and purpose of utterances in a range of authentic circumstances.

According to Larsen-Freeman and Anderson (2013), communication is a must in language learning, and language is for communication, and in a communicative course; everything is done with a communicative concentration. By the same token, speaking activities are an inseparable part of daily life activities that cannot be underestimated (Clampitt, 2016; Coombs, 2014). Furthermore, A. Reza, S. Beniss, and V. Edalati support this by stating: "Speaking is one of four language skills that are very important to be mastered by students to be good communicators, and the ability to speak English fluently and accurately opens up wider opportunities to achieve success in life because speaking is the most important thing in communicating with other people." After all, because of the importance of speaking skills in the context of work, academic life, and social life in society and the state, every actor must understand and be able to apply thoughtful and

skilled ways of speaking so that they are easy to communicate with and can achieve the goal of communicating well and pleasantly (Fauria, R. M., & Zellner, L. J. 2015).

2. LITERATURE REVIEW

Communicative Language Teaching (CLT) is a teaching method that focuses on improving students' capacity to speak effectively and meaningfully in real-world circumstances. In addition, CLT is one of method which is designed to help the English learners to use the target language for daily communication that can improve the student's knowledge and skill especially in speaking skill. Communicative competence, on the other hand, is described as the expression, interpretation, and negotiation of meaning. Richards (2006) defines language proficiency as the ability to use a language for various purposes, adapt it to different contexts, create and comprehend various types of texts, and communicate effectively even with limited proficiency. Subsequently, Savignon (2002) states that "these respectively correspond to the four components of communicative competence: grammatical competence, discourse competence, socio-cultural competence, and strategic competence." The objectives and tenets of CLT modify the content, tactics, and methodologies of language instruction and shift the roles of both educators and learners. By creating a learner-centered and non-threatening environment, CLT encourages students to express their opinions, engage in spontaneous conversations, and become comfortable speaking English in various social settings.

According to Richards and Rodger (2016, p. 153-155), the communicative language teaching (CLT) approach is usually considered as a comprehensive approach to teaching, rather than as a teaching method with a clearly defined set of classroom practices. In speaking, the aspect of fluency, accuracy, clarity, intonation, content, and volume can be learned in this approach.

Richards and Rogers (2001, 161) offered several concepts concerning language acquisition:

"Communication principle: Activities that involve real communication promote learning...task principle: Activities in which language is used for carrying out meaningful tasks promote learning...meaningfulness principle: Language that is meaningful to the learner supports the learning process."

Communicating in a foreign language depends upon being proficient and having linguistic skills and awareness to ensure the material is accessible to the person you are talking to. Given the significance of oral proficiency in English, students must acquire these foreign language abilities to attain high competency in verbal communication, enabling them to utilize English effectively in academic and professional contexts.

Students who learn a second language generally gain extensive knowledge, including grammatical rules and vocabulary lists. However, they discover that they are unable to converse in this language when they want to. Learning a foreign language requires a proper methodology, and CLT has proven to be effective for language instruction and acquisition. This is supported by Haryani and Ainur (2020), who assert that the CLT approach lets students achieve better achievement in speaking English. It fosters interaction and is the most endorsed approach in EFL classrooms globally. Effective implementation of CLT requires that schools and educators provide suitable teaching and learning resources. Schools can assist teachers in facilitating English communication opportunities by developing appropriate lessons tailored to the conditions of the educational system.

A 2013 study conducted by Mennaai examined the efficacy of the communicative language teaching approach (CLT) in enhancing students' spoken communication abilities. To determine participants' attitudes towards this skill and the CLT methodology, two questionnaires were administered amongst faculty members and students at the University of Biskra's Department of English. The findings of this investigation revealed that the CLT approach yielded a positive impact on students' spoken language proficiency.

To enhance students' communicative efficiency in speaking, the teacher may apply a balanced activity strategy that integrates language input, organized output, and communicative output. Many linguists and EFL teachers concur that students acquire proficiency in a foreign language through interaction. For this purpose, the CLT approach works the best. Through communicative student-student activities and by regularly exposing students to the target language, they participate in formal and informal tasks such as interviews, strip stories, and problem-solving exercises.

The proficiency in spoken language is an essential aspect of human interaction, imperative for navigating various realms of life, including daily activities, professional environments and academic settings. As posited by Moss and Ross-Feldman (2000), any activity which requires the learner to speak and listen to others includes the use of communication. Activities with communicative purposes are helpful for breaking down barriers, finding information, expressing ideas about oneself and learning about culture.

Interviews are a great way for students to improve their speaking abilities for a variety of reasons, the main among them being that they force them to participate fully in group and pair discussions. At a basic level, interviews can be structured, but at a higher level, they can be more intricate, incorporating facts, opinions, thoughts, and feelings. According to Steward (2006), interviewing is an interactional communication process between two parties, at least one of who has a predetermined and serious purpose, that involves asking and answering questions. By the same token, Kessler (1992, 7) states there are three main advantages to interviewing as a form of cooperative learning. These include:

1. Providing a richness of alternatives to structure interactions between students;
2. Addressing content area learning and language development needs within the same organizational framework; and
3. The variety of ways to structure student practice with lesson material increases opportunities for individualized instruction, such as peer-provided clarifications.

Strip stories, on the other hand, are narratives segmented into strips in which each student is given some sentences of a story at random. The sentences then must be reorganized through verbal collaboration to construct a coherent plot. When a teacher uses a strip narrative to teach speaking, it will help students enhance their speaking skills through comfortable English language learning while also assisting students in strengthening their speaking skills through authentic communication activities. Richards (2006, 20) supports this by stating that “when using the Picture Strip Stories for CLT, the teacher plans and delivers an oral presentation in a manner that allows much participation from the students and helps direct them towards the desired learning outcomes.”

Vernon, Gerlach, and Donald (1980, p. 277) list the advantages of using strip stories in classes as follows:

- They are inexpensive and widely available.
- They provide common experiences for an entire group;
- The visual details make it possible to study the subject clearly;
- They offer a stimulus for further study because research shows that visual evidence is a powerful tool.
- They help to focus attention to develop critical judgment; and
- They are easily manipulated.

Problem-solving-orientated materials give students more chances to collaborate in pairs or small groups and exchange ideas and knowledge on subjects that are important to them. This approach provides involvement of students in groups of any size. As stated by Ormond (2006, 111), “problem solving is using existing knowledge and skills to address an unanswered question or troubling situation, while problem-based learning is an approach to instruction in which students acquire new knowledge and skills while working on a complex problem similar to those in the outside world.” This is supported by Sanjaya (2014), who states that “the main advantages of problem-solving include: 1) giving opportunities for students to think actively and creatively in expressing opinions, ideas, or ideas; 2) fostering courage and confidence and developing social attitudes and tolerance, cooperation, respect for the opinions of others, and democratically; 3) developing students' ability to think critically”.

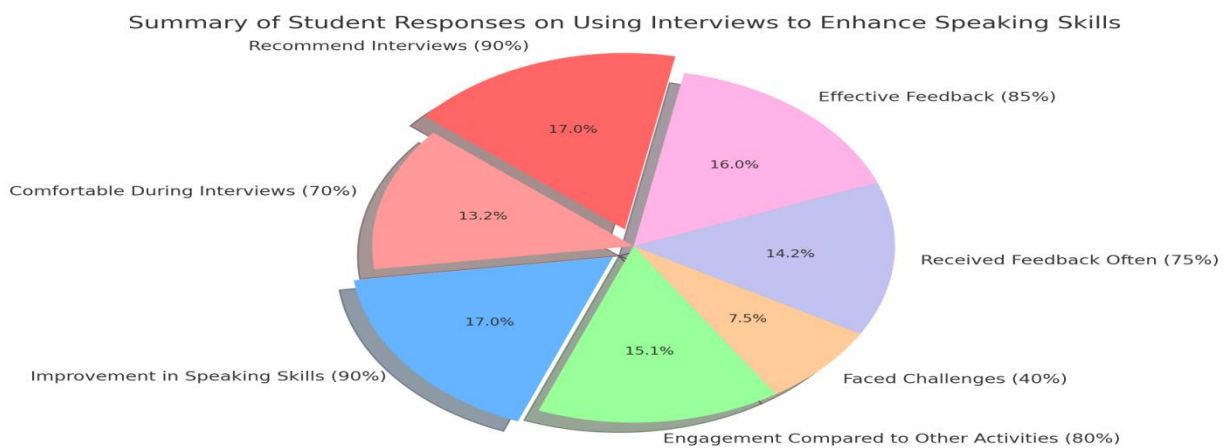
3. METHODOLOGY

We conducted this research at South East European University in Tetovo, Republic of North Macedonia, during the academic year 2023-24. To collect data on the problems encountered during CLT implementation and the impact of CLT in improving the speaking abilities of SEE University BES students, a survey was delivered to students, which included questions about interviews, strip stories, and problem-solving exercises and how these types of exercises affect their speaking performance. Closed questions with predefined

answers were delivered to respondents, who were asked to choose one of the options provided. The participants for the focus group were students of Basic English Skills aged 18–21, both genders, and studying at different study programs such as Business and Economics, Public Administration, Legal Studies, Architecture and Design, Computer Sciences, and Nursing Studies. This group was thought to have relevant opinions and insights on the topic of my survey, and a qualitative method with structured interviews was used.

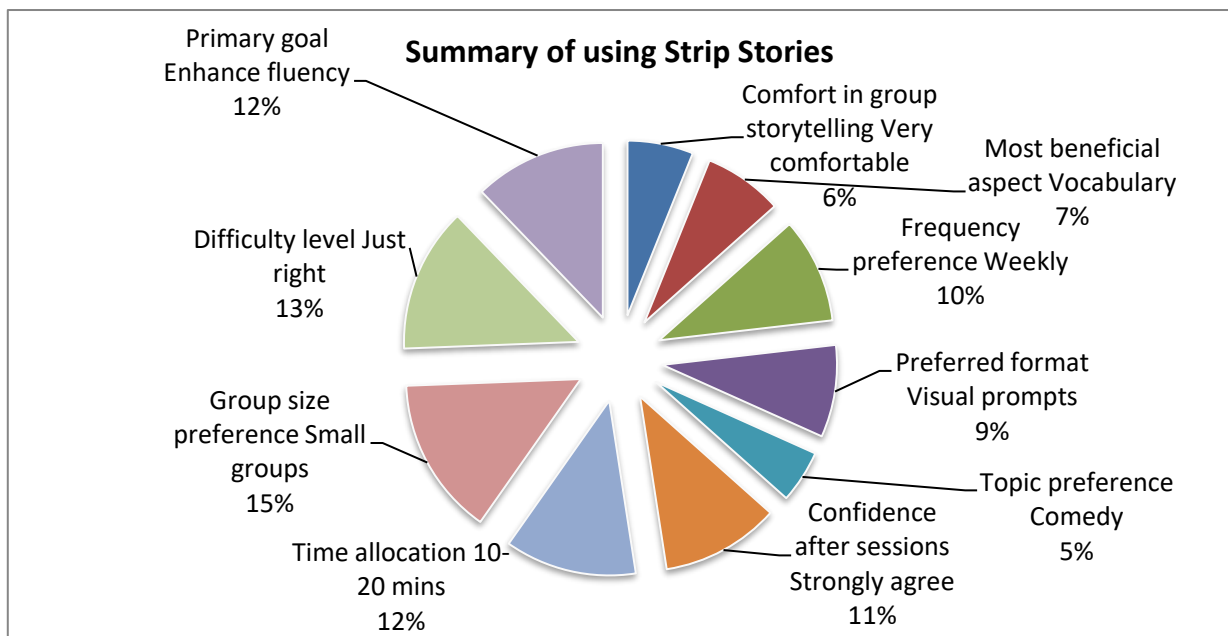
RESULTS

This study included 33 participants from two groups, with most saying interview activities boosted their speaking skills. Students liked doing interviews more than other speaking activities because they saw them as less formal and more like a chat. Here's a chart of our results showing what students found most helpful about these speaking exercises.



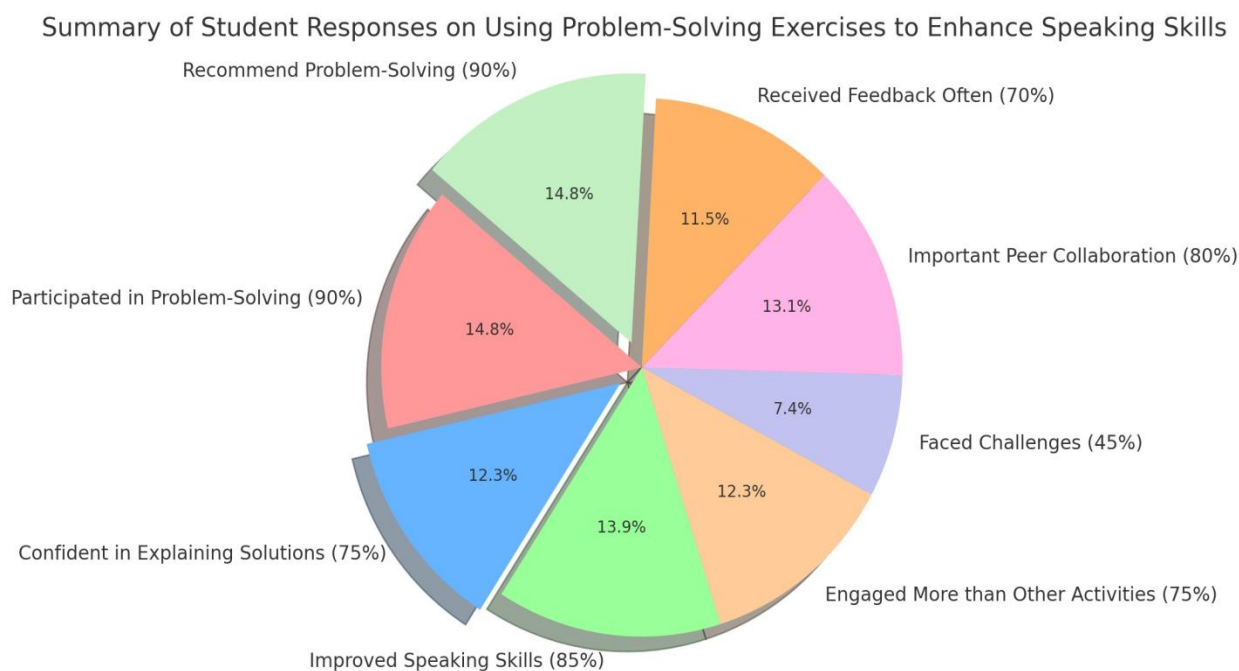
Graph 1. Using Interviews to Enhance Speaking Skills

The second questionnaire was about using strip stories and the summary of results based on the responses of 33 students is as follow:



Graph 2. Using strip stories to enhance students' speaking skills

The third questionnaire was about problem-solving activities and following is the respondents' answers illustrated with a graph.



Graph 3. Using Problem-solving Exercises to Enhance Speaking Skills

4. CONCLUSION

It can be concluded that the data obtained from this study, composed of 33 participants, demonstrated that interview exercises and problem-solving activities are significantly productive in improving speaking. Strip stories highlighted a moderate enthusiasm for group storytelling, and most students indicated regular but not daily activities with strip stories. However, this type of activity built up their confidence, showing that they have a positive impact on students. Interview exercises were particularly highly praised by learners because they lead the learners to interact with people in a more realistic setting since they involve natural interaction as well as authentic language use. The reason behind this was that learners need much confidence and practice to speak even a simple sentence in L1 countries. Likewise, strip stories were also regarded as contributing to developing fluency, creativity, and imagination, but there were diverse views on whether they should be done much or not since some learners thought that they did not contribute to enhancing their speaking ability, while most liked them for improving their communication skills, so they could not be used too much or prohibited. Problem-solving exercises enabled students to work together better; they helped them give explanations and organize ideas while managing the subject matter, which was facilitated through some of the above-mentioned—that is, deepening the context might have a negative effect on accuracy. They all reported it as enjoyable, beneficial, and productive.

Nevertheless, due to their language proficiency and their lack of time, they found the questionnaires engaging, and some answers were socially desirable rather than honest. In addition, some students did not participate in all activities consistently; therefore, their responses may not be reflective of the activities. Finally, due to the low number of respondents, a more in-depth analysis should be carried out with a larger number of students, with more time disposal, so that the results are more reliable. For the reason that Basic English Skills students were involved in this study, we could investigate how this method applies to ESP students.

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The Role of Organizational Learning in Higher Education

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Abstract. Organizational learning plays a key role in strengthening the ability of educational institutions to meet the needs of society and the market, thereby enhancing the overall education system. This paper explores the significance and application of organizational learning in higher education institutions, focusing on improving performance, fostering innovation, and enhancing the organizational climate. Organizational learning is defined as a process in which an organization not only acquires but also applies new knowledge to improve its performance. In higher education, it enables efficient adaptation to changes in educational policy, labor market needs, and the application of new technologies in teaching. Through the analysis of theoretical frameworks and existing research, the paper identifies key mechanisms of organizational learning, such as organizational learning mechanisms and inter-organizational networks. It examines how higher education institutions can become learning organizations, empowering employees, improving teaching methods, and fostering innovations that enhance global competitiveness. The findings indicate that organizational learning, supported by technologies such as artificial intelligence and digital tools, plays a crucial role in transforming educational models and preparing institutions for future challenges.

Keywords and phrases: Organizational learning, higher education, innovation, employee empowerment.

1 INTRODUCTION

Organizational learning has become a key concept in modern organizations, particularly in educational institutions, where rapid changes and the need for continuous adaptation are driven by technological innovations, globalization, and evolving labor market demands. Significant challenges exist in the field of organizational science, as yesterday's organizational knowledge and strategies no longer guarantee future success (Senge, 1990). Therefore, organizational learning is essential for both organizational efficiency and success (Inthavong et al., 2023), with its primary goal being the development of new capabilities that the organization previously lacked (Lojić, 2010). Over the past few decades, the importance of learning organizations has been emphasized not only for improving their own performance but also for enhancing the ability of individuals and teams to respond to dynamic environments and various challenges (Antunes & Pinheiro, 2020). It is now evident that society requires more adaptable and resilient education systems to face an uncertain future (Wahab, 2020). Investment in knowledge not only increases its value but also improves the overall value of society, resulting in a higher quality of life (Grujić, 2012). Consequently, organizations that efficiently manage learning processes can innovate more quickly, solve problems effectively, and maintain long-term competitiveness. In the educational context, organizational learning often remains an uncertain and difficult concept to implement. While schools are inherently places of learning, their institutional frameworks sometimes disrupt the transformation of learning into practical, operational processes. Internationally, there is an increasing need for schools to become organizations that not only transmit knowledge but also continuously learn and develop their practices. In recent years, educational programs, technologies, learning processes, and the roles of teachers and students have undergone significant changes.

To address these changes, higher education institutions must create an effective learning environment that focuses on students' needs, promotes the generation of knowledge and skills, and develops strategies that foster individual development and the sustainability of social life (Vidaković, 2018). Therefore, the strategic development of educational institutions in the future must focus on strengthening knowledge resources, particularly among professors, creating opportunities for innovation and growth (Asbari, 2024).

This paper analyzes how organizational learning functions within educational institutions to improve performance and enhance the organizational climate. The focus is on conceptual frameworks such as learning mechanisms, inter-organizational networks, and other practices that facilitate the processes of learning and adaptation in various environments.

2 METHODOLOGICAL FRAMEWORK

The subject of this paper is organizational learning in higher education institutions, focusing on its role in improving academic programs and organizational climate, empowering faculty members, and supporting innovation.

The aim of the paper is to analyze the significance of organizational learning in higher education, identify the key aspects of this process, and demonstrate how universities can implement organizational learning models to enhance their educational and research activities. The research questions derived from the objective are:

RQ1: How does the effective implementation of organizational learning mechanisms in higher education institutions affect the improvement of academic programs, organizational climate, and employee empowerment?

RQ2: In what way does organizational learning in educational institutions influence innovation and enhance university performance?

RQ3: How does the use of information and communication technologies in educational processes improve learning experiences and increase the efficiency of organizational learning?

The research was conducted through a literature review to establish a theoretical foundation and identify the key aspects of organizational learning, innovation, and performance in higher education institutions. This methodological framework provides a basis for a deeper understanding of the significance of organizational learning in educational institutions and the identification of factors that contribute to the improvement of organizational climate and employee empowerment. The results will be valuable for decision-making regarding strategies to enhance efficiency within educational systems.

3 THE CONCEPT AND ROLE OF ORGANIZATIONAL LEARNING IN HIGHER EDUCATION

Organizational learning is defined as a process through which an organization not only acquires and develops new knowledge but also applies that knowledge to enhance its performance. Its role in higher education is of crucial importance, as higher education institutions function as centers for the creation and dissemination of knowledge. Organizational learning mechanisms in schools represent institutionalized structures for collecting, analyzing, and disseminating information essential for improving school performance. Schools that implement these mechanisms can become learning communities, fostering the growth of both students and faculty (Schechter, Qadach & Da'as, 2022). Organizational learning differs from individual learning, as it involves social interaction among members of the organization, enabling the creation of collective knowledge that individuals cannot achieve on their own (Lojić, 2010). Higher education institutions, as complex organizations, play a key role in educating new generations of professionals, researchers, and leaders. Therefore, the idea of schools as continuously learning organizations is essential. This theory of educational change emphasizes the importance of adapting to changes and restructuring the organization's purpose in dynamic environments (Mulford, 1998). Organizational learning allows universities to: 1. Implement new teaching methods and technologies more quickly and efficiently; 2. Respond to changes in educational policy and labor market needs; 3. Increase productivity by improving academic processes; 4. Promote continuous development and innovation.

Universities that become learning organizations have the ability to quickly identify new trends and opportunities, recognize their own weaknesses, and develop strategies to improve their performance globally.

The concept of lifelong learning is becoming increasingly relevant, and by establishing a learning-focused society, progress is made toward a knowledge-based society (Grujić, 2012).

Organizational learning in higher education requires a combination of knowledge management, leadership, technology, and employee empowerment to create a sustainable system that fosters development and innovation. It relies on several key elements, including a learning priority, consistency and wideness of information distribution, unpredictability, ease of learning new routines, and the challenge of adopting new conceptual frameworks (Fauske & Raybould, 2005).

Higher education institutions must establish deep organizational learning to develop and implement long-term strategies that enable them to adapt effectively to change (Washington-Ottombre, 2024). Organizational learning is essential for renewing school systems to improve learning, teaching, and leadership processes (Collinson et al., 2006) and plays a significant role in challenging environments (Austin & Harkins, 2008).

Thus, the role of organizational learning in higher education is comprehensive, encompassing several aspects: improving the quality of teaching and learning, adapting to change, empowering employees, fostering a culture of collaboration, developing innovations, enhancing the organizational climate, and ensuring long-term sustainability.

4 THE IMPACT OF ORGANIZATIONAL LEARNING ON IMPROVING INNOVATION AND PERFORMANCE IN HIGHER EDUCATION

Academic climate, leadership, and trust among colleagues play a key role in higher education institutions as they directly influence the willingness of academics to share knowledge and improve curricula. A positive organizational climate fosters knowledge exchange, which reflects in the quality of teaching and research (Al-Kurdi, El-Haddadeh & Eldabi, 2020). Similarly, a work environment that promotes learning and learning agility enables organizations to effectively respond to changes and improve organizational performance.

Organizations that adopt organizational learning and supportive leadership experience reduced employee turnover and improved organizational climate (Austin & Harkins, 2008). Internal collaboration among organizational members is essential for creating organizational knowledge, as interaction integrates individual insights into collective knowledge (Antunes & Pinheiro, 2020). Educational institutions should promote learning support and agility, as organizational learning and innovation are key factors for performance improvement (Tripathia & Kalia, 2024). Additionally, trust and a positive organizational climate play a crucial role in knowledge management processes (Sahibzada et al., 2023), further emphasizing the importance of creating a favorable work environment to enhance collective knowledge and performance.

Organizational learning is a dynamic, knowledge-based process carried out through employee activities, with human resources playing a key role. Individuals create, share, and apply knowledge, allowing organizations to gain new insights through the experiences and actions of their employees (Antunes & Pinheiro, 2020). Empowering academic staff significantly impacts their competence and commitment, while an organizational learning culture acts as a moderator, fostering a favorable climate for organizational development (Udin, 2023). Flexibility and synergy between faculty and a supportive environment enable higher education institutions to adapt more easily to changes (Djunaedi et al., 2023).

Key attributes required for professors to successfully implement organizational learning can be divided into two groups: seven adaptive attributes, such as understanding pedagogical needs and creatively using technology, and four non-adaptive attributes, including the need for a clear understanding of blended learning and concerns about technology (Bruggeman et al., 2021). Additionally, during the adoption of organizational learning, factors such as anxiety, lack of information, and avoidance of responsibility can slow learning processes and organizational adaptation (Senge, 1990).

Organizational learning significantly contributes to the development of both soft and hard skills among educators. Higher education institutions that support the continuous development of their employees' knowledge and competencies are better equipped to respond to rapid changes in economic and social environments, ensuring long-term success. Knowledge management and employee empowerment in educational institutions are critical factors for enhancing innovation and organizational efficiency (Asbari, 2024).

Mulford emphasizes that universities must develop as learning organizations, drawing from experience, interaction, and adaptation to environmental changes. He argues that organizational learning offers more opportunities for understanding and implementing educational reforms than existing models of change management in education (Mulford, 1998). This is particularly important given the role of technology in modern education, enabling the exchange of information and the dissemination of organizational knowledge.

The transition to online and blended learning has become essential, with the integration of information and communication technologies necessary for transforming educational models, especially after the COVID-19 pandemic (Wahab, 2020). Digital technologies offer a range of tools that enrich formal learning processes and empower students to actively engage in their education. Furthermore, digital learning is becoming an integral part of modern higher education, requiring a revision and reorganization of educational structures (Alenezi, 2023). These changes accelerate the digitization process, making educational institutions more flexible and resilient to external challenges.

Artificial intelligence (AI) is also becoming increasingly important in education, transforming learning processes and opening new possibilities for personalized learning and collaboration. The integration of AI into educational processes enhances individual and team learning, as well as knowledge dissemination within institutions (Gibson et al., 2023). Digital technologies such as the Internet, virtual reality, and big data are shaping a new educational paradigm, facilitating the transition to smart learning systems (Radun, 2020). In this context, organizational learning is increasingly supported by technology, enabling institutions to respond more rapidly to changes and improve their innovative capacities.

Open innovation and organizational learning in higher education institutions help achieve sustainable competitive advantage by balancing exploratory and exploitative learning (Rafiki et al., 2021). Learning networks between different schools can contribute to the exchange of new ideas and school development. They facilitate deeper collaboration among schools, positively impacting innovation and the adoption of new practices (Schulz & Geithner, 2010).

It is also important to note that school leadership has emerged as a crucial explanation for variations in organizational learning among schools (Leithwood et al., 2021). This highlights the essential role of effective leadership in shaping and enhancing an organizational climate that supports learning and collaboration within educational institutions.

Organizational learning holds great potential for improving higher education institutions, providing tools for continuous development and adaptation to new demands and environments.

5 CONCLUSION

Based on the consideration of the importance of organizational learning in higher education, it is evident that this process not only improves the performance of educational institutions but also empowers individuals and teams to successfully face the challenges of modern society. This paper shows that organizations that recognize the value of continuous learning and implement organizational learning mechanisms become more resilient and better equipped to adapt to change.

Through the analysis of existing research and theoretical frameworks, it has been highlighted that effective organizational learning contributes to the creation of a positive organizational climate, which is essential for fostering innovation and improving the quality of education. Higher education institutions that actively invest in the development of their employees and utilize modern technologies gain a competitive advantage, enabling them to respond rapidly to changes in educational policies and labor market needs.

The findings address **RQ1** by demonstrating how the effective implementation of organizational learning mechanisms improves academic programs, enhances the organizational climate, and empowers employees. This creates a foundation for continuous improvement and professional growth within institutions. Moreover, **RQ2** is answered through evidence that organizational learning fosters innovation, leading to enhanced university performance and an improved ability to compete in the rapidly evolving educational landscape.

Additionally, **RQ3** is addressed by showcasing the transformative impact of information and communication technologies (ICT) on learning experiences and the efficiency of organizational learning. The integration of digital tools and artificial intelligence opens new horizons for personalized learning, collaboration, and the dissemination of knowledge within institutions, further strengthening the organizational learning process.

In the context of globalization and future challenges, it becomes clear that the ability of institutions to learn, adapt, and innovate is crucial for their survival and growth. Higher education must become a space for continuous learning and innovation, where knowledge is not only transmitted but actively created. Institutions that effectively establish a culture of organizational learning will be better prepared to face future challenges, supporting the development of a knowledge-based society and improving the quality of life for all community members. By addressing these research questions, this paper highlights the critical pathways through which organizational learning can drive progress in higher education and beyond.

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Machine Learning in Educational Methods for Improving Learning Outcomes

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Abstract. This paper explores the integration of Machine Learning (ML) technologies in educational methodologies to improve learning outcomes. The focus is on adaptive learning systems and predictive analytics, which enable personalized education and timely interventions based on student performance data. By leveraging these technologies, educational environments can become more dynamic, offering customized learning paths and real-time feedback. Automated assessment tools and intelligent tutoring systems further augment this approach by providing unbiased grading and personalized instructional support. The study presents a theoretical model that outlines the role of ML in educational systems, emphasizing key strategies such as investing in advanced educational technologies, supporting continuous teacher training, and implementing robust data privacy measures. The challenges include technical complexities, data privacy concerns, and the need for policy support. Recommendations are provided for governments, enterprises, and individuals to collaboratively improve educational outcomes through effective use of ML technologies. This research offers a framework for future advancements in educational methodologies utilizing ML.

Keywords and phrases: machine learning, education methods, improving learning, learning outcomes.

1 INTRODUCTION

Machine learning has significantly impacted educational methods, offering innovative approaches to improve learning outcomes. One such approach is adaptive learning systems, which tailor educational content to meet the individual needs of students. These systems leverage machine learning algorithms to analyze student performance data, allowing the creation of personalized learning experiences. As a result, tasks can be adjusted in difficulty, feedback can be targeted, and learning paths can be customized to ensure that each student can progress at their own pace. This personalized approach helps in addressing diverse learning styles and abilities, ultimately supporting a more effective educational experience (Costa et al., 2021). Predictive analytics represents another application of machine learning in education, providing valuable insights into student performance and potential outcomes. Through the analysis of various data points, such as attendance, participation, and academic history, predictive models can identify students who may be at risk of underperforming. This early identification allows educators to implement timely interventions, offering additional support and resources to those who need it most. Predictive analytics not only helps in improving individual student outcomes but also aids in overall classroom management and strategic planning for educational institutions (Adnan et al., 2021). Automated assessment tools have transformed the way educators evaluate student work. Utilizing machine learning algorithms, these tools can efficiently grade assignments, quizzes, and exams, providing instant feedback to students. Automated assessments can analyze written content, detect patterns, and assess understanding with a high degree of accuracy. This automation not only reduces the workload for educators but also ensures a consistent and

unbiased evaluation process. Furthermore, the immediate feedback provided by these tools helps students to quickly identify areas for improvement and adjust their learning strategies accordingly (Hahn et al., 2021).

Intelligent tutoring systems (ITS) are designed to simulate the benefits of one-on-one tutoring through interactive and adaptive learning environments. Powered by machine learning, ITS can offer personalized hints, ask guiding questions, and maintain student engagement through adaptive content and gamified elements. These systems continuously monitor student interactions, adjusting the level of difficulty and type of support based on real-time performance data. By providing a responsive and engaging learning experience, ITS can significantly improve student motivation and learning outcomes (Akyuz, 2020). Machine learning-driven educational methods, including adaptive learning systems, predictive analytics, automated assessment tools, and intelligent tutoring systems, hold great promise for improving educational outcomes. These technologies offer personalized and efficient solutions, enabling educators to better meet the diverse needs of their students and supporting a more effective and inclusive learning environment (Taylor et al., 2024).

The existing body of literature does not comprehensively address the application of Machine Learning in educational methodologies to this extent. This paper aims to fill this gap by providing a theoretical model that integrates various ML technologies into the educational framework. The paper is structured into five sections: Introduction, Adaptive Learning Systems and Predictive Analytics in Education, Challenges of Implementing ML in Education, Suggestions and Guidelines, and Conclusion.

2 ADAPTIVE LEARNING SYSTEMS AND PREDICTIVE ANALYTICS IN EDUCATION

Machine learning has revolutionized educational methods, and one prominent innovation is adaptive learning systems. These systems leverage sophisticated algorithms to tailor educational content to meet the unique needs of each student. Through continuous analysis of student performance data, adaptive learning systems can dynamically adjust the difficulty level of tasks, provide targeted feedback, and create individualized learning paths. This personalized approach addresses the diverse learning styles and abilities found within any classroom, ensuring that each student can progress at their own pace (Essa et al., 2023). The use of adaptive learning systems involves collecting and analyzing various data points, including students' past performance, learning habits, and even engagement levels. This data-driven approach enables the system to make real-time adjustments to the curriculum. For instance, if a student consistently struggles with a particular type of problem, the system can present additional practice problems and instructional materials specifically designed to address that weakness. Conversely, if a student excels, the system can introduce more challenging material to keep them engaged and motivated (Gligorea et al., 2023). Adaptive learning systems also offer the potential to identify and address specific learning gaps more efficiently than traditional methods. Teachers often face the challenge of differentiating instruction for a diverse group of learners, which can be time-consuming and difficult to manage. Adaptive systems alleviate some of this burden by automatically adjusting to each student's needs, allowing teachers to focus their attention on facilitating learning and providing support where it's most needed. This level of personalization not only improves student engagement but also supports a deeper understanding of the subject matter, as students are more likely to grasp concepts when the instruction is tailored to their specific learning needs (Er-radi et al., 2024). Adaptive learning systems can provide valuable insights to educators and administrators. The data collected by these systems can be analyzed to identify trends and patterns in student learning, informing instructional practices and curriculum development. For example, if a significant number of students struggle with a particular concept, educators can re-evaluate the instructional approach and make necessary adjustments. This continuous feedback loop ensures that the educational content remains relevant and effective, ultimately leading to improved learning outcomes (Liu et al., 2017).

Predictive analytics in education is another significant application of machine learning, offering profound insights into student performance and future outcomes. By analyzing a multitude of data points, such as attendance records, participation levels, grades, and socio-economic factors, predictive models can forecast which students are at risk of underperforming. These models provide educators with early warnings, enabling timely interventions to support struggling students before their difficulties become insurmountable (Zeineddine et al., 2021). Predictive analytics utilizes complex algorithms to sift through large datasets, identifying subtle patterns and correlations that may not be immediately apparent to educators. For example, a combination of frequent absences and declining participation might indicate a student is at risk of

falling behind. Once identified, educators can investigate further to understand the underlying causes and provide the necessary support, whether it be academic assistance, counseling, or other resources(Adnan et al., 2021; Zhang et al., 2022).

Predictive analytics can help in identifying patterns and trends within the educational process, allowing educators to refine their teaching strategies and improve overall classroom management. This proactive approach can lead to more effective allocation of resources, ensuring that support is directed where it is needed most. For instance, if predictive models indicate that a particular group of students is likely to struggle with an upcoming unit, teachers can allocate additional resources, such as tutoring sessions or supplementary materials, to help these students succeed(Macfadyen et al., 2014).

Both adaptive learning systems and predictive analytics illustrate the transformative potential of machine learning in education. These technologies offer innovative solutions for personalizing learning experiences and proactively addressing educational challenges, ultimately enhancing learning outcomes and supporting a more inclusive and effective educational environment. By integrating these advanced tools into the educational landscape, educators can better meet the diverse needs of their students, promote equitable access to quality education, and support the continuous improvement of teaching and learning practices(Messer et al., 2024).

3 AUTOMATED ASSESSMENT TOOLS AND INTELLIGENT TUTORING SYSTEMS

Automated assessment tools represent a significant advancement in the application of machine learning within education. These tools are designed to streamline the evaluation process by utilizing algorithms to grade assignments, quizzes, and exams efficiently. One of the primary benefits of automated assessment tools is their ability to provide instant feedback to students. When a student submits an assignment, the tool can immediately analyze the work, compare it against predefined criteria or rubrics, and deliver results without the delay inherent in traditional grading methods. This immediacy helps students understand their performance quickly, allowing them to identify areas for improvement and adjust their learning strategies accordingly(Messer et al., 2024).These tools are not limited to simple multiple-choice questions but are increasingly capable of evaluating more complex responses, such as essays and short answers. Through natural language processing (NLP) and other advanced machine learning techniques, automated assessment tools can analyze written content, detect patterns, assess coherence and argument strength, and even check for originality and adherence to academic standards. This capability significantly reduces the workload for educators, who can then allocate more time to personalized instruction and other pedagogical activities(Hahn et al., 2021).

Furthermore, automated assessment tools ensure a consistent and unbiased evaluation process. Human graders can inadvertently introduce bias or inconsistency, especially when assessing large volumes of work. Automated tools apply the same standards uniformly, enhancing fairness in the grading process. This consistency is important for maintaining academic integrity and ensuring that all students are evaluated on an equal footing. Additionally, the data generated from these assessments can be used to track student progress over time, providing valuable insights into learning trends and areas that may require curricular adjustments(Akyuz, 2020).Intelligent tutoring systems (ITS) are another innovative application of machine learning in education, designed to replicate the benefits of one-on-one tutoring through interactive and adaptive learning environments. ITS can offer personalized hints, ask guiding questions, and maintain student engagement through adaptive content and gamified elements. These systems continuously monitor student interactions, adjusting the level of difficulty and type of support based on real-time performance data. By providing a responsive and engaging learning experience, ITS can significantly improve student motivation and learning outcomes(Troussas et al., 2020).Intelligent tutoring systems work by collecting and analyzing data on student behavior, including response times, error patterns, and engagement levels. This information is used to build a detailed profile of each student's strengths and weaknesses. Based on this profile, the ITS can tailor its responses to meet the specific needs of the student, offering targeted support and challenges. For instance, if a student is struggling with a particular concept, the system can provide additional explanations, practice problems, and hints to help the student overcome the difficulty. Conversely, if a student is performing well, the system can introduce more complex problems to keep the student engaged and challenged(González et al., 2014).

These systems also incorporate elements of gamification to make learning more engaging and enjoyable. Features such as badges, leaderboards, and interactive simulations can motivate students to persevere through challenging material and achieve their learning goals. The use of gamification in ITS helps to sustain student interest and encourage active participation, which are important factors in effective learning (Troussas et al., 2020). Intelligent tutoring systems can provide valuable data to educators about student performance and engagement. This data can inform instructional decisions, allowing teachers to identify students who may need additional support or enrichment. It also helps in evaluating the effectiveness of instructional materials and strategies, guiding continuous improvement in teaching practices. The integration of ITS in the classroom can thus improve the overall quality of education, making it more personalized, interactive, and data-driven (Messer et al., 2024). Automated assessment tools and intelligent tutoring systems exemplify the transformative potential of machine learning in education. These technologies provide efficient, personalized, and engaging solutions for evaluating student performance and supporting individualized learning. As these tools continue to evolve, they hold the promise of significantly enhancing educational outcomes and supporting a more inclusive and effective learning environment (Messer et al., 2024). A model for improving educational outcomes through the integration of adaptive learning systems and predictive analytics is presented in Figure 1.

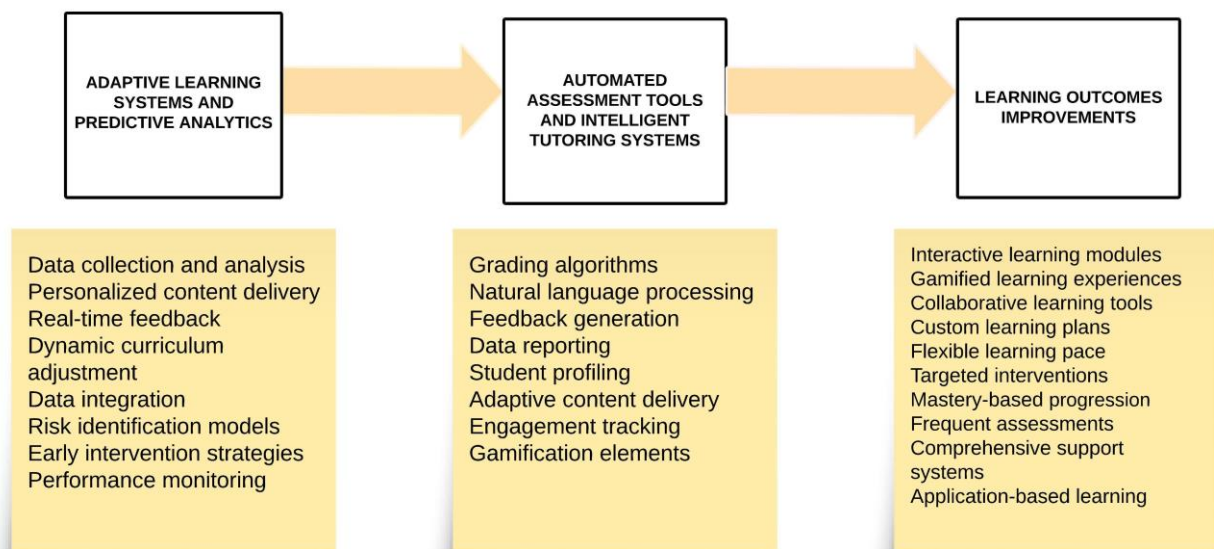


Figure 1. Model for improving educational learning outcomes

The model for personalized education consists of three main elements: adaptive learning systems, automated assessment tools, and learning outcome improvements. Adaptive learning systems use data collection and analysis to tailor educational content based on each student's performance, preferences, and learning styles. Real-time feedback and dynamic curriculum adjustments ensure a responsive and effective learning experience. Predictive analytics complements this by integrating data like grades and attendance to identify at-risk students and enable early interventions, providing targeted support. Automated assessment tools streamline grading with consistent algorithms, improved by natural language processing for complex responses like essays. These tools offer instant feedback to students and inform further personalization of learning materials. Intelligent tutoring systems (ITS) improve engagement by using real-time performance data to provide personalized hints and instructional materials. Gamification and engagement tracking within ITS maintain student interest and motivation. The final element, learning outcome improvements, is achieved through personalized learning paths informed by adaptive learning systems and frequent assessments. Predictive analytics guide interventions to address learning gaps, while mastery-based progression ensures students advance only after demonstrating competence. Support systems like tutoring and counseling offer

holistic assistance. Long-term retention is strengthened through spaced repetition, concept reinforcement, and real-world applications. Together, these elements create an adaptive educational ecosystem that continually improves learning outcomes by integrating feedback, data analysis, and personalization.

4 SUGGESTIONS AND GUIDELINES

Based on the theoretical model in Figure 1 and the reviewed literature, the following guidelines and suggestions are proposed for enhancing educational outcomes through ML:

- Allocate resources for the integration of adaptive learning systems in schools to personalize education. Ensure continuous monitoring and evaluation to measure effectiveness and make necessary adjustments.
- Create robust regulations to protect student data used in adaptive learning and predictive analytics. Provide clear guidelines to educational institutions on data handling and storage.
- Offer professional development opportunities focusing on the use of automated assessment tools and intelligent tutoring systems. Ensure teachers are equipped with the skills to integrate these technologies effectively in their classrooms.
- Focus on creating adaptive learning systems and intelligent tutoring platforms that cater to diverse learning needs. Conduct user research to ensure these technologies are user-friendly and effective.
- Partner with governments and non-profits to deploy educational technologies in low-income and rural areas. Offer scalable solutions that can be easily integrated into existing educational frameworks.
- Develop comprehensive training programs for educators on the use of new technologies. Provide ongoing technical support to ensure seamless implementation and use.
- Invest in research to understand the impact of educational technologies on learning outcomes. Share findings with educational stakeholders to promote evidence-based practices.

These strategies and actions can collectively contribute to the improvement of educational learning outcomes by leveraging technology, supporting collaboration, and promoting continuous development and innovation in the educational sector.

5 CONCLUSION

The integration of machine learning technologies in education offers substantial opportunities for enhancing learning outcomes. Adaptive learning systems and predictive analytics provide a robust foundation for personalizing education, allowing for real-time adjustments based on individual student performance. These systems not only tailor content to meet diverse learning needs but also identify students at risk, enabling timely interventions. The use of data-driven insights ensures that educational strategies are continuously refined, contributing to more effective teaching and improved student success. Future research should focus on empirical studies that evaluate the impact of ML technologies on educational outcomes. This could involve case studies of educational institutions that have implemented adaptive learning systems and predictive analytics. Such research would provide valuable insights into the effectiveness of these technologies and help refine the theoretical model proposed in this study.

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Students' Attitudes Towards the Importance of Using AutoCAD Tools in Teaching

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Abstract. Knowledge of tools for technical drawing and project engineering is essential for modern engineering, where a high level of technical skills is necessary. AutoCAD stands out as one of the most powerful tools in technical disciplines, enabling efficient and precise modelling of complex projects. Therefore, AutoCAD plays a key role in the education of future engineers, providing them with the opportunity to develop the skills required for success in the dynamic field of engineering. The aim of this research is to investigate the importance of using AutoCAD in education through the attitudes of students. The results obtained may serve as a foundation for further considerations regarding the enhancement of curricula.

Keywords and phrases: AutoCAD, education, students'attitudes

1 INTRODUCTION

Technical drawing and project engineering have long served as the foundation of engineering education, enabling future professionals to develop the necessary precision and skill in their work. However, with the rapid advancement of technology, traditional paper-based drawing methods have been replaced by digital platforms, significantly altering how these activities are conducted. In this context, AutoCAD stands out as an essential tool that allows engineers to quickly and efficiently create complex technical drawings and models, contributing to their productivity and innovation.

In addition to being widely adopted in the industry, AutoCAD has become an integral part of educational programs at technical faculties, helping students develop the key skills required for the modern engineering world. Its integration into the educational process raises questions about the impact of this software on the learning process and the acquisition of technical knowledge by students.

This paper examines the influence of AutoCAD on engineering education, with a special emphasis on the development of key skills among students. The focus is on analyzing the experiences of students who used AutoCAD during their studies, exploring their prior knowledge of the program before entering university, as well as assessing the progress achieved through working with this tool in their coursework, particularly highlighting the specific skills that students have most improved. The study also explores students' perceptions of the usefulness of AutoCAD for understanding technical drawing and design, as well as their views on the need for increasing practical lessons involving this software. This analysis will provide insights into guidelines for improving curricula, ensuring that students are better prepared for the modern challenges of engineering practice. Through this research, the paper will offer a comprehensive view of the role of AutoCAD in the education of future engineers.

2 THEORETICAL FRAMEWORK AND RELATIONSHIP WITH THE CURRICULUM

AutoCAD is the oldest drafting program, developed by Autodesk, which has positioned itself as a leading CAD company in the world (Oyebode, Adebayo, & Olowe, 2015; Radonjić, Baralić, & Dučić, 2010). This software, first released in 1982, has become the industry standard for technical drawing and project

engineering (Bojanić Šejat, Nikačević, Knežević, & Čavić; „Upoznavanje sa AutoCAD-om”). AutoCAD is used in various technical disciplines, from architecture and engineering to industrial design and surveying, allowing for the creation of precise 2D and 3D drawings (Bojanić Šejat et al.; Extreme; PMO; TeamCAD). Its comprehensive functionalities include tools for 3D freeform design, project visualization, as well as support for Point Cloud technology, making it an invaluable resource for professionals in different fields (TeamCAD). In addition, AutoCAD has the ability to automate many tasks, such as comparing drawings and creating technical documentation, while also providing users with the opportunity to easily modify and share projects through connected platforms and mobile solutions, significantly improving efficiency in the workflow (Bojanić Šejat et al.; GeoINOVA; PMO; Prior).

AutoCAD, in addition to providing opportunities for acquiring technical drawing and project engineering skills, enables students to enhance their motivation and recognize the importance of learning through the development of creative and critical abilities (Celik, Ertas, & Ilhan, 2018). As a result of this, AutoCAD is extensively utilized as a software tool in educational institutions, particularly within faculties of technical sciences. At the Technical Faculty "Mihajlo Pupin" in Zrenjanin, there are several study programs that address this topic. According to the accreditation documents, these include programs in information technology, informatics and technique in education, mechanical engineering, industrial engineering in oil and gas exploitation, and clothing engineering (Univerzitet u Novom Sadu, Tehnički fakultet "Mihajlo Pupin" Zrenjanin, 2013, 2014, 2021, 2023, 2024).

Based on the available accreditations, the objectives of the courses that study the issues of technical drawing and project engineering using AutoCAD tools in the specified programs are grounded in the importance of acquiring modern technological skills that align with the current needs of the industry (Univerzitet u Novom Sadu, Tehnički fakultet "Mihajlo Pupin" Zrenjanin, 2013, 2014, 2021, 2023, 2024). According to Yuen, this is crucial, as adapting educational programs to current standards related to CAD technology is essential for preparing students for the challenges posed by modern industry (Adnan, Daud, & Saud, 2013). Additionally, the purpose of the curriculum is to develop skills that will enable students to successfully enter the job market and confront the challenges of contemporary business environments (Kwok, 2004). Consequently, aligning students' educational achievements with industry needs increases their employability in the fields of technical drawing and project engineering. (Robertson, Walther, & Radcliffe, 2010). Accordingly, it is clear that AutoCAD not only enriches the educational process but also contributes to the formation of professionals who are capable of responding to the challenges of modern engineering and technology, thereby ensuring their competitiveness in the job market.

3 RESEARCH METHODOLOGY

3.1 *Research sample*

The research includes 100 students from the Technical Faculty "Mihajlo Pupin" in Zrenjanin who have attended classes related to the subject taught in the AutoCAD program. The sample consists of students from the programs in information technology, informatics and technique in education, mechanical engineering, industrial engineering in oil and gas exploitation, and clothing engineering, who are studying or have studied under accreditation from 2014 and onwards.

3.2 *Research instrument*

The conducted research is based on a short questionnaire consisting of six questions, which allows students to express their opinions on the importance of using the AutoCAD software tool in teaching.

3.3 *Time and place of the research*

The research location is the Republic of Serbia. The research was conducted from October 18 to October 22, 2024.

3.4 *Objective of the research*

The aim of this research is to examine students' attitudes towards the importance of using AutoCAD tools in teaching.

3.5 Hypothesis

In accordance with the aim of the research, the main hypothesis of the study is defined as follows: According to students' attitudes, AutoCAD is an important tool in teaching and contributes to the quality of education in the field of technical drawing and project engineering.

4 RESEARCH RESULTS AND DISCUSSION

In the following chapter, the answers to the survey questions will be presented in tabular form, along with accompanying comments.

Table 1 shows the number of surveyed students by study programs. Therefore, the survey included 25 students from the information technology study program, 12 students from the informatics and technique in education study program, 24 students from the mechanical engineering study program, 21 students from the industrial engineering in oil and gas exploitation study program, and 18 students from the clothing engineering study program.

Table 1. Number of Surveyed Students by Study Program

Study program	Number of students
Information technology	25
Informatics and technique in education	12
Mechanical engineering	24
Industrial engineering in oil and gas exploitation	21
Clothing engineering	18

Given the differences between study programs, it is important to distinguish students' opinions based on their respective programs. Therefore, the obtained responses will be analyzed not only as a whole, but also individually for each program in the continuation of the research.

In Table 2 can be seen the responses of the participants to the question "Did you have the opportunity to work in AutoCAD before starting your studies, and if so, for what purpose?". It is evident that the majority of respondents from all programs first encountered the AutoCAD program during their studies, with the exception of students from the mechanical engineering program, who predominantly reported having received instruction related to this software tool in high school. In AutoCAD, in high school, a significant portion of the surveyed students from the industrial engineering program in oil and gas exploitation, as well as students from the information technology program, also reported having experience with the software. A slightly smaller percentage of respondents who used AutoCAD in high school came from the clothing technology program, while no students from the informatics and education technology program had used the AutoCAD tool prior to their studies. In elementary school, only one student had worked in AutoCAD, and that student is enrolled in the information technology program. On the other hand, among the surveyed students, only certain students from the mechanical engineering program indicated that they had worked in AutoCAD for job-related purposes before their studies.

Table 2. Experience of surveyed students with AutoCAD before studying

Did you have the opportunity to work in AutoCAD before starting your studies, and if so, for what purpose?	Percentage of surveyed students from the information technology	Percentage of surveyed students from the informatics and technique in education	Percentage of surveyed students from the mechanical engineering	Percentage of surveyed students from the industrial engineering in oil and gas exploitation	Percentage of surveyed students from the clothing engineering	Percentage of all surveyed students
I worked in AutoCAD in high school.	24%	0%	41,67%	33,33%	16,67%	28%
I worked in AutoCAD at work.	0%	0%	20,83%	0%	0%	5%
I did not work in AutoCAD before my studies.	72%	100%	37,5%	66,67%	83,33%	66%
I worked in AutoCAD in elementary school.	4%	0%	0%	0%	0%	1%

Table 3 shows the responses of the participants to the question "Do you think AutoCAD is useful for understanding technical drawing and project engineering, and to what extent?". The analysis of responses shows that the vast majority of students across all study programs rate AutoCAD as very useful for understanding technical drawing and project engineering. Only a small number of respondents consider AutoCAD to be partially useful, while no student expressed the opinion that AutoCAD is not useful.

Table 3. Perceptions of surveyed students on the usefulness of AutoCAD for understanding technical drawing and project engineering

Do you think AutoCAD is useful for understanding technical drawing and project engineering, and to what extent?	Percentage of surveyed students from the information technology	Percentage of surveyed students from the informatics and technique in education	Percentage of surveyed students from the mechanical engineering	Percentage of surveyed students from the industrial engineering in oil and gas exploitation	Percentage of surveyed students from the clothing engineering	Percentage of all surveyed students
It is very useful.	84%	91,67%	75%	90,48%	72,22%	83%
It is somewhat useful.	16%	8,33%	25%	9,52%	27,78%	17%
It is not useful.	0%	0%	0%	0%	0%	0%

Table 4 presents the responses of students to the question "Has working in AutoCAD at the faculty helped you improve and develop skills in technical drawing and project engineering?". The majority of students across all study programs reported that they have made significant progress in the field of technical drawing and project engineering thanks to the knowledge acquired through working with AutoCAD during their studies at the faculty. It is particularly significant that all respondents from the mechanical engineering and information technology and technical education programs unanimously confirmed the improvement and development of their skills in technical drawing and project engineering. This correlation can be further explained by the fact that, within the mechanical engineering program, according to the curriculum, AutoCAD is used very frequently and extensively in teaching. Consequently, the practical application of this tool has greatly contributed to the development of technical drawing and project engineering skills for students in this program. On the other hand, surveyed students from the information technology and technical education program indicated in previous responses that they had not encountered AutoCAD software before their studies. Therefore, thanks to faculty instruction involving work in this program, they have achieved significant progress in technical drawing and project engineering skills. Only a smaller portion of respondents felt that they did not make progress in this area through AutoCAD courses at the faculty.

Table 4. Impact of working in AutoCAD at the faculty on the development of skills in technical drawing and project engineering

Has working in AutoCAD at the faculty helped you improve and develop skills in technical drawing and project engineering?	Percentage of surveyed students from the information technology	Percentage of surveyed students from the informatics and technique in education	Percentage of surveyed students from the mechanical engineering	Percentage of surveyed students from the industrial engineering in oil and gas exploitation	Percentage of surveyed students from the clothing engineering	Percentage of all surveyed students
Yes, I believe I have advanced in technical drawing and project engineering.	84%	100%	100%	90,48%	77,78%	90%
No, I believe I have not advanced in technical drawing and project engineering.	16%	0%	0%	9,52%	22,22%	10%

To the question "Which specific skills have you improved the most through the use of AutoCAD at the university, if you believe you have progressed?" respondents had the option to select multiple answers. Their responses are presented in Table 5. The overall results indicate that students of all study programs believe

they have most improved their drawing precision in the program, along with creating 2D and 3D models. Optimizing the organization and structure of drawings, as well as the forming technical documentation, are skills that students generally identified as ones they have mastered to a lesser extent, with certain exceptions. Students from the mechanical engineering program noted a slightly higher confidence in their abilities to optimize and organize the structure of drawings compared to students from other programs. Also, regarding the skills of forming technical documentation, subjective assessments from respondents indicate that students from the clothing engineering, mechanical engineering, and informatics and techniques in education programs have mastered these skills better than those surveyed from the information technology and industrial engineering in oil and gas exploitation programs. Students who answered the previous question that they believe they have not made progress in the field of technical drawing and project engineering with the help of faculty instruction that includes working in AutoCAD reaffirmed this stance in their response to this question.

Table 5. Skills improved through AutoCAD usage at faculty

Which specific skills have you improved the most through the use of AutoCAD at the university, if you believe you have progressed?	Percentage of surveyed students from the information technology	Percentage of surveyed students from the informatics and technique in education	Percentage of surveyed students from the mechanical engineering	Percentage of surveyed students from the industrial engineering in oil and gas exploitation	Percentage of surveyed students from the clothing engineering	Percentage of all surveyed students
Improving drawing precision	56%	100%	75%	47,62%	44,44%	62%
Optimizing the organization and structure of drawings	32%	33,33%	58,33%	28,57%	22,22%	36%
Creating two-dimensional models	68%	58,33%	91,67%	47,62%	38,89%	63%
Creating three-dimensional models	64%	66,67%	58,33%	57,14%	44,44%	58%
Forming technical documentation	32%	41,67%	41,67%	28,57%	44,44%	37%
I do not believe I have progressed	16%	0%	0%	9,52%	22,22%	10%

The responses to the question "Do you think it would be useful to increase the amount of practical teaching at the faculty that involves working with AutoCAD?" are presented in Table 6. A significant majority of respondents of all study programs expressed the opinion that it would be important to increase AutoCAD instruction at the faculty, while a smaller portion of respondents indicated that they believe the current AutoCAD teaching is sufficient. None of the respondents stated that the instruction involving AutoCAD should be reduced.

Table 6. Perceptions of the Need for Increased Practical Teaching of AutoCAD at the Faculty

Do you think it would be useful to increase the amount of practical teaching at the faculty that involves working with AutoCAD?	Percentage of surveyed students from the information technology	Percentage of surveyed students from the informatics and technique in education	Percentage of surveyed students from the mechanical engineering	Percentage of surveyed students from the industrial engineering in oil and gas exploitation	Percentage of surveyed students from the clothing engineering	Percentage of all surveyed students
Yes, I believe it would be of great significance.	76%	75%	87,5%	90,48%	88,89%	84%
No, the current level of teaching is sufficient.	24%	25%	12,5%	9,52%	11,11%	16%
No, the amount of teaching involving AutoCAD should be reduced.	0%	0%	0%	0%	0%	0%

5 CONCLUSION

This research emphasized the impact of using the AutoCAD tool in the educational process of technical faculty students. It was shown that students from all study programs accredited to work with the AutoCAD software tool consider this tool very useful in the fields of technical drawing and project engineering and think that they have significantly advanced thanks to faculty instruction that includes its practical application, regardless of their prior experience with the tool. Although certain educational profiles, such as the study program in mechanical engineering, are closer to the field of technical drawing and project engineering and use AutoCAD much more frequently and extensively, students from other study programs also recognize the importance of the AutoCAD software tool. Based on the respondents' answers, the initial hypothesis, which states that according to students' attitudes, AutoCAD is an important tool in teaching and contributes to the quality of education in the field of technical drawing and project engineering, was confirmed.

Moreover, students pointed out that increasing the amount of practical teaching involving AutoCAD would be beneficial. Introducing more practical classes in the future could enhance students' skills in technical drawing and project engineering, making them even more competent and proficient in using AutoCAD and applying technical knowledge in real engineering situations. Additionally, since students highlighted less progress in skills such as optimizing the organization and structure of drawings and creating technical documentation compared to skills like creating 2D and 3D models and drawing precision, it would be effective to focus additional attention on mastering areas where students are less proficient, taking into account the dynamic market demands that are continuously evolving.

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Adapting School Curriculums for 21st Century Skills: A Teacher's Perspective on Educational Transformation

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Abstract. The demands of the 21st century require a change in education to prepare students with skills essential for a rapidly growing society. This paper explores the adaptation of school curriculum to better align with 21st-century skills focusing on teachers' perspectives as crucial stakeholders in the educational process. Drawing on recent studies, it examines how curriculum reforms incorporate cultural thinking, creativity, collaboration, and digital literacy to meet modern challenges. As a part of the paper the benefits and challenges associated with these changes including teachers' preparedness, professional development needs, and the resources to implement these skills in the classrooms effectively. By synthesizing diverse viewpoints, the paper aims to provide practical insights about required changes in the curriculum that emphasize the role of educators. The paper elaborates on many aspects that should be considered when planning and incorporating changes in the curriculum. The challenges should not be understood as the reasons to stop with the change, instead, it is important to conduct research that can provide solutions for successfully responding to these challenges.

Keywords and phrases: 21st-century skills, curriculum reform, teacher perspectives, educational transformation, problem-solving skills.

1 INTRODUCTION

A more complex society and a quickly changing technology-based economy have presented new and difficult challenges to schools and communities alike. Schools worldwide are being urged to create frameworks that emphasize the skills, knowledge, and attitudes required for success in the twenty-first century. In the 21st century, satisfying the demands of school, employment, and business requires additional layers of communication skills, technology savvy, global perspective, collaborative practices, digital abilities, and imaginative applications, rather than just memorization. Communication abilities have evolved. The curricula of the previous century could not have predicted the rapid growth of technology, capacity, and proliferation throughout the world community, or that the internet would enable global communications nearly instantaneous and inexpensive (Geisinger, 2016).

Educational innovations set high criteria for student learning. Preparing students to deal with the complexities of modern societies, policy documents, and educational developments around the world calls for 21st-century competencies (Haug & Mork, 2021).

Traditional curricula, which are primarily focused on rote learning and standardized testing, are widely viewed as insufficient for developing critical thinking, creativity, digital literacy, and collaborative skills required in today's society. Teachers, as the major agents of curriculum delivery, have a significant impact on how these modern skills are implemented in the classroom. However, aligning school curricula with these objectives necessitates overcoming considerable hurdles, such as limited resources, different levels of teacher

preparedness, and the need for ongoing professional development. Understanding teachers' perspectives on curricular adaptation can provide useful insights into the efficacy of existing educational changes and the resources needed to achieve long-term change.

2 ANALYSIS OF THE TOPIC

2.1 Importance of 21st century skills

In the twenty-first century, the quick speed of technological innovation, globalization, and altering economic demands have fundamentally altered the skills required for personal, academic, and professional success. Traditional educational approaches, which frequently emphasize memorization and standardized testing, are widely viewed as insufficient in educating pupils for these contemporary challenges. Instead, critical thinking, problem-solving, cooperation, creativity, adaptability, and digital literacy have emerged as necessary abilities. These qualities, often referred to as "21st-century skills," are critical not only for workforce preparedness but also for lifelong learning and active citizenship.

Critical thinking, problem solving, creativity, meta-cognition, communication, digital and technology literacy, civic responsibility, and global awareness are some of the competencies commonly associated with the 21st-century skill set (Kim et al., 2019). Organizations require a diverse set of 21st-century talents, including critical thinking, interpersonal relationships, technological proficiency, and personal attributes. Teamwork, integrity, adaptability, initiative, and motivation are other qualities that an employee requires in a business. Educational institutions, such as schools, are the most effective organizations for creating new abilities in students to fulfill market demands. As a result, instructors' competencies are highly valued in translating 21st-century skills to students via a more organized teaching approach (Sulaiman & Ismail, 2020).

21st-century talents have been divided into three broad categories. The cognitive domain encompasses competencies linked to cognitive processes and techniques, knowledge, and creativity, such as critical thinking, reasoning, and argumentation. The intrapersonal domain includes beliefs and motivation for learning, as well as metacognition and self-regulated learning. The interpersonal domain comprises qualities associated with collaboration and leadership, such as effective communication and accountability. Such skills are not new; they have been widely recognized for millennia. However, the emergence of advanced modern societies creates a necessity for all students to acquire these competencies and be able to use them in many fields irrespective of future careers (Haug & Mork, 2021).

An increasingly globalized and complicated world has fueled a trend for a diverse set of abilities dubbed "21st century." The majority of frameworks focus on a variety of higher-order skills, including sophisticated thinking, communication, teamwork, and creativity. These talents are rapidly becoming acknowledged as the gold standard for student abilities, as well as necessary for professional and personal success (Kim et al., 2019). However, the practice of giving knowledge to students through a transmission method (e.g., lecture, dictation) is still prevalent in many parts of the world. As a result, if what kids learn must go beyond rote, teacher methodology must alter accordingly. Teachers should enhance and apply 21st-century skill implementation strategies to improve their competency. This scenario has a significant impact on the teaching and learning processes. The ability of teachers to apply 21st-century skill-based teaching has successfully enhanced student motivation and engagement in gaining these skills (Kim et al., 2019). 21st century learning and assessment prioritizes more than only reading, writing, interpretation, and synthesis skills. One method for arranging 21st-century talents focuses on cognitive, intrapersonal, interpersonal, and technical abilities (Geisinger, 2016).

The value of 21st-century talents stems from their ability to provide individuals with the tools they need to flourish in a complex, rapidly changing world. By providing children with these skills, schooling may foster adaptation and resilience, allowing them to meet new difficulties confidently and creatively. Furthermore, focusing on these abilities alters the educational model to a more student-centered approach that emphasizes active participation, personal growth, and the ability to innovate. Recognizing the importance of 21st-century skills and incorporating them into curriculums is critical for developing a future-ready generation capable of making meaningful contributions to society and the global economy.

2.2 Changes in curriculums

Implementing 21st-century skills in the curriculum demands teachers to be prepared. Research shows that teachers prioritize 21st-century skills such as creativity, innovation, critical thinking, collaboration, and

communication, but their teaching practices vary (Haryani et al., 2021). However, teachers do not necessarily feel prepared for implementation, even if research supports the importance of teacher preparation to effectively implement curriculum reform (Haryani et al., 2021). Factors impacting curriculum reform implementation include teacher professional development, teamwork, and belief in its benefits for students. To effectively execute curriculum reform, it's important to give resources and structured supervision to guarantee that the new curriculum and teaching practices are integrated into classroom activities. To become active members of 21st-century society, students need an education that equips them to think critically, analyze multiple sources of information, connect diverse subjects, and actively participate in the learning process. This does not imply that we should completely forsake teacher-directed lessons. On the contrary, listening is a crucial component of active learning (OECD, 2018). The changing needs of society, climate change, and the demands of modern labor have all resulted in substantial changes in educational approaches. As the world faces difficult environmental and economic concerns, curriculum reform has become a main area of scholarly debate. Climate literacy, sustainability, and workforce readiness must be integrated into school curricula to ensure that students have the information and skills required for a fast-changing world (Qureshi, 2024).

2.3 Teachers' perspective

Teacher effectiveness in implementing curriculum change has been demonstrated to be highly influenced by school leadership, teacher connections with leaders and colleagues, school operational methods and culture, as well as individual motivation (Jenkins, 2019). Curriculum implementation involves teachers using curriculum-specific materials to offer instruction and assessments. Curriculum designs typically include instructional suggestions, scripts, lesson plans, and assessment alternatives based on a set of objectives. Such designs emphasize uniformity to enable teachers to successfully implement and maintain the curriculum structure to accomplish diverse objectives (Nevenglosky et al., 2019). Teachers need to know how to meet the objectives of the curriculum, which indicates that even if the curriculum changes are introduced without teachers to fulfill the goals in practice the change will not happen. Because of that teachers have the core role in this process and should be involved in the development of the curriculum (Nevenglosky et al., 2019).

Nevenglosky et al. (2019) also emphasize that it is of great importance to include teachers so that issues that are noted as problematic for teachers can be addressed before the curriculum is applied in classes. Tangney et al. (2023) underline that it is important to take into account the beliefs of teachers about the changes in curriculum taking into account that they are those who implement the change in the classes. It is further emphasized by Tangney et al. (2023) that to a certain extent, it can be perceived that introducing these changes is an additional burden for teachers.

Boredom and lack of engagement are two of the most significant barriers to maintaining student attention in classrooms. To pique the interest of 21st-century learners, teachers must progressively ensure that their coursework is practical and interesting. One method to accomplish this is to explore pertinent societal problems and provide students with the skills they need to address them. The concept of "radical relevance" relates to the ability of instruction to enable students to discover, discuss, and recognize potential solutions to the world's current social concerns (OECD, 2018).

2.3.1 Strategies to support teachers

As educational systems attempt to incorporate 21st-century skills into curriculums, the role of teachers becomes increasingly important to the success of this transformation. Teachers are not only responsible for implementing curriculum changes, but also for fostering student-centered learning environments in which skills like critical thinking, cooperation, and creativity can thrive. However, adapting to a curriculum that emphasizes these abilities frequently necessitates a transition from traditional instructional methods to more innovative, adaptable ones. This transition can be difficult, especially when teachers confront gaps in training, insufficient resources, or a lack of institutional support.

Research from the OECD Teaching and Learning International Survey (TALIS) and Programme for International Student Assessment (PISA) indicates that student-centered teaching strategies, where students take an active role in lessons, are more effective in improving student learning and motivation than traditional teacher-directed approaches (OECD, 2018). Furthermore, student-centered learning prepares students for the ever-changing demands of the modern world. In the twenty-first century, information and abilities are becoming obsolete at a faster rate than previously. Student-centered approaches help students develop lifetime

learning skills, adaptability, and the ability to traverse complicated information environments. They learn how to successfully search for information, analyze sources, and synthesize knowledge from diverse fields, preparing them to meet obstacles in higher education (Eslit, 2023). As a result, incorporating twenty-first-century learning abilities into the classroom has become an increasingly crucial component of curriculum development and implementation. Educators must educate in a forward-thinking manner, integrating ICT into the modern curriculum. Nonetheless, it is more than only teaching certain technologies and the capacity to use them, but rather transferring the abilities to relevant real-world applications (Kooi & Annamalai, 2023). The effective implementation of an ICT-based curriculum remains a challenge for many teachers. Furthermore, many teacher educators believe that their knowledge and skills are inadequate for the new learning environment which represents a huge problem in changing the curriculum (Kooi & Annamalai, 2023).

Collaborating and sharing experiences with others can help you identify obstacles, best practices, and solutions. Access to others' knowledge might provide teachers with the opportunity to reflect on and improve their practices. The panelists explored various methods of professional development that promote teamwork. All panelists agreed that a collaborative approach in which teachers and students discuss the future of their school and the education system as a whole can be very beneficial in developing a shared vision among the major stakeholders (OECD, 2018).

To introduce these changes, and adapt the classes to the requirements of 21st skills teachers need to have more autonomy and to be able to apply the most adequate strategies that may help to desired goals in education are achieved. To do so, it is important to create a network of teachers that can exchange experience and discuss potential barriers as this change is radical when it comes to the adaptation of curriculum (OECD, 2018).

Supporting teachers during this transition is critical to accomplishing real, long-term curriculum improvement. Targeted professional development, collaborative learning opportunities, and practical techniques for increasing confidence and capacities in facilitating student-centered learning are all examples of effective support. By providing educators with the necessary skills and resources, schools can build a learning culture that prepares students for the demands of the twenty-first century.

3 CONCLUSION

To summarize, adjusting school curricula to acquire 21st-century skills is critical to educating kids in an increasingly complicated and linked world. However, this research review demonstrates that many teachers are unprepared to adopt these changes because they lack specialized skills and tactics for supporting student-centered learning. Teachers' opinions emphasize the importance of complete professional development that prepares them to promote critical thinking, creativity, digital literacy, and teamwork. Addressing these gaps requires focused resources and training to assist instructors in effectively transitioning from traditional to more student-centered approaches. Supporting educators with these tactics is critical for implementing long-term curriculum modifications that truly engage children and prepare them for future problems.

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Multimedia Dynamics in Responsive Web Portal with The Use Of Presentation Models: Preschool Institution Zrenjanin Case Study

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Abstract. This paper presents results of a project that had a main goal to improve user experience (UX) aspect of official web portal of Preschool institution Zrenjanin, Serbia. The user experience aspect was enhanced with adding multimedia types, dynamics in multimedia elements presentation, as well as adjustment of web portal to have both desktop and mobile version, i.e. to be responsive to device display characteristics. Particular emphasis of this paper is to describe implementation details of the developed solution. The software solution includes new Content Management System that enables texts and multimedia to be included in the main web portal. Presentation of multimedia at the main web portal is implemented with the utilization of object-oriented and Model-View-Controller (MVC) approach. This solution includes presentation models, which are related to View component of MVC. For the same data there could be many views, i.e. presentation models that include different elements organization at the page display. This approach of dynamic use of different presentation models enable better software maintenance and user experience.

Keywords and phrases: responsive web portal, Model-view-controller, object-oriented programming, multimedia, dynamic aspect.

1 INTRODUCTION

In the modern world, everyday activities are related to the use of Internet. Web and mobile applications use is integrated in processes of work, education, health, entertainment and other areas. It is particularly important to create such software that could easily be used and integrated within diversity of user profiles, working environments and devices. Contemporary web sites align their functions and graphical design with the purpose and the expected user profiles expectations, habits, knowledge and skills. Different application areas require appropriate graphical and functional design, as well as underlying data presentation and flow. Therefore, it is very important to gain appropriate attention from users and retention of their use of web sites, based on their satisfaction. Particularly, in the case of preschool institutions, it is very important for a web site or a web portal to have cheerful and dynamic multimedia, to represent positive and developing working environment for children. Therefore, multimedia dynamics and diversity of their representation are essential approaches for this particular case.

User experience of web sites, as a term, belongs to a broader category of human-computer interaction. According to (Garrett, 2011), there are five key aspects of user experience of web applications: a) Strategy – product objectives (business goals, brand identity) and user needs (user segmentation, usability); b) Scope – functional specifications and content requirement; c) Structure – interaction design and information architecture; d) Skeleton – interface design, navigation design, information design; e) Surface – sensory

design (vision, hearing, touch, contrast, uniformity, internal and external consistency, color palettes and typography).

Aim of this paper is to presents results of the project “*Improvement of graphical and functional aspect of user experience of Preschool institution Zrenjanin official web site (www.predskolskazr.edu.rs)*”, conducted from July 2023 to October 2024. This project targeted user experience improvement, comparing to previous web portal solutions. These enhancements are made at main web site (presentation part) in particular areas of: a) broadening multimedia types that will be presented (by adding mp4video and youtube video to be presented at website), b) making responsive solution (mobile friendly to align with different mobile devices), c) enhancing visual representation with colors, fonts, better presentation of images etc. d) establishing dynamics with animations and transitions, e) broadening functionality (search, users count etc.), f) broadening data with new sections available at website (documents of different kinds, projects, archive etc.). Second area of improvements were related to CMS (Content Management System) module that enable complete control of all elements of main web site, with possibilities of editing data and adding, changing and removing data and multimedia elements, with additional feature of “work in progress” status of the publication of text and other multimedia. Particular emphasis in this paper is to describe presentation models that are developed to enable different types of visual organization of elements at web pages. This way, it is possible to have diversity of presentations - dynamic integration of data from database, multimedia and presentation models improves user experience by gaining dynamic diversity.

The rest of the paper is organized as follows: second section presents background about user experience basic approaches and modern standards in this field, third section provides short review of results in previously published papers, fourth section provides results of initial analysis of similar solutions, fifth section describes the developed web portal for both modules and multimedia dynamics, sixth section emphasizes the proposed approach of presentation models applied in this particular software and the final section brings conclusions and future work directions.

2 RELATED WORK

Appropriate organization of code is crucial for better development management and overall product quality. Kadri, Tibermacine, & Le Gloahec, (2007) emphasize the role of modularization and hierarchical organization of modules within web application, particularly for presentation layer. Shuling N (2002) emphasizes the need for enhancement in separation of data and presentation and proposes extension of Model-View-Controller approach with enabling web presentation templates be used as abstract models that in runtime integrate with data. According to study of Offut and Wu (2010), web applications are complex software solutions and should be organized modularly, with awareness of software coupling and dynamic data flow, to enable better testing. Automated analysis of web application code in aim to dynamically track and evaluate impact of changes in user interface was proposed in (Wang, Zhang, Xie, Xiong, & Mei, 2012), with main focus on generated HTML code and analysis of bug reports.

Design of web applications with model-driven development gain particular attention in professional and scientific work. Kozaczynski & Tharion (2002) discuss about user experience modeling with UX UML metamodels and possible automated implementation based on previously created models. Ceri, Fraternali, & Bongio (2000) propose Web modeling language to help in better design of web applications. In the area of conceptual modeling of web applications user interfaces, Cachero, Gómez, & Pastor (2000) propose template-based approach with the use of Abstract Presentation Diagram and Navigation Access Diagram. These authors propose a catalog of templates, i.e. information patterns, interaction patterns and navigation patterns. These patterns are used within the proposed diagrams. Khasawneh, Samarah, Al-Omari, & Conrad, (2012) propose a reverse engineering approach to analysis of existing solutions of web applications, with particular focus on user interfaces (HTML layout) and representation with UML diagrams, to enable their transformations and enhancements.

Adaptivity and adaptability of web applications is particularly important regarding users (Tvarožek, Barla, Bieliková, 2007) and regarding display environments (devices). To enable better user experience, web applications need to adapt to users and their preferences with personalization, as well as to different devices (Garrigós, I., Meliá, S., & Casteleyn, S., 2009). Adaptivity is possible via dynamic creation of user interfaces or changes of their characteristics. Yu et al (2007) propose dynamic creation of web user interface, based on components. Fogli, D., Gelfi, N., Giacomini, M., & Guida, G. (2010) presented their approach to dynamic adaptation of information presentation, based on interactive assessment and selection of best content-presentation pairs, with utilization of fuzzy approach to select best alternative, but with the special attention to

user interface principles to be satisfied. Engineering the presentation layer of web applications was particularly addressed in (Fiala et al, 2004). Authors make distinction between conceptual, navigational and presentational design of web information systems. They present modeling for personalized web information systems (HERA methodology) with RDFS schema output that could be integrated with automated generation (in AMACONT project) of different presentation layouts ready for diversity of presentation environments (end devices and output formats).

3 DIRECTIONS FOR NEW SOLUTION BASED ON INITIAL ANALYSIS OF SIMILAR SOLUTIONS

During specification, several existing web portals were appointed as an example that should provide directions for visual design and content selection and organization. Before detailed design of new solution, the proposed examples (www.nasvrtic.rs, www.mojvrtic.rs = automatically redirects to www.zdravodetepozarevac.rs and www.predskolska.rs) were analyzed on 27 July 2023. Some of their web pages are presented at Figure 3.



Figure 2. User interface of 3 examples of preschool institutions websites (obtained 27 July 2023)

Descriptively, results of this comparative analysis will be presented as summary conclusions. First two web sites (mojvrtic.rs and nasvrtic.rs) are web sites of particular kindergardens, while the third (predskolska.rs) is the web site of an institution that gathers work of multiple kindergardens in the city of Novi Sad. In this context, the closest to the target institution (Preschool institution Zrenjanin) should be the third web site, since they both are institutions of the same kind. Because of the limited space to present detailed results of this comparative analysis, here will be presented only directions for development of new solution for Preschool institution Zrenjanin that were collected as summary of ideas from these three examples:

1. Technical aspect = to use light and cheerful colors for text, background and font, to use cheerful font (for example Sans type), font to be large and bold, different types of menu (horizontal, dropdown) and sticky, home link in Breadcrumb, Cyrillic letters, animations, transitions, statistics animated counter, images slider, video and youtube, diversity of text and images layout (left-right, top - bottom), images gallery, illustrations and drawings, dark color footer, responsive, no cookies, alt for images, number of news per page
2. Content – first page with minimal data, menu containing items related to institution, enrollment, kindergardens, projects, specific informations and advices for parents, image gallery, news regarding events and projects, contact for all services, social networks icons, documents, useful links, google maps with kindergardens.

4 DEVELOPED SOLUTION OF RESPONSIVE WEB PORTAL WITH MULTIMEDIA DYNAMICS

The developed solution consists of two modules – main web site and Content Management System (CMS). Both modules were developed as completely new solutions, based on the data structure and essential functions from previous version of web portal. The implementation of the whole web portal is based on the use of HTML, CSS, Java Script and PHP programming language – both old and new versions. Comparing to old solution that was object oriented, but multipage by architecture, the new solution is based on principles of single page and Model-View-Controller (MVC) web application architecture and object oriented programming.

OLD WEB PORTAL – first page



Only desktop version

NEW WEB PORTAL – first page



Desktop version



Mobile version

Figure 3. Old and new web portal www.predskolskazr.edu.rs

Multimedia dynamics has been included in new version of web portal with:

- Introductory slider of images at first page (four drawings that are presented in the loop with 6 seconds delay between)
- Animated counter at the first page for number of enrolled children
- Animation of fade effect in easy delayed display of title and text of every news
- Presentation of mp4 and youtube video as additional multimedia material attached with news
- Animation of title and icon next to the title appearance (moving title effect)
- Transition when user moves mouse above icons next to the title and icons to start search or contact functions.
- Random selection of icons to decorate title of news (each time the page loads it is different icon displayed)
- Responsiveness of the layout – desktop version has flex presentation with row layout of elements, while mobile version has flex column layout, fonts and dimensions of all multimedia are resized.
- Different positions of images/video/YouTube/maps in the layout with text – left/right, top/bottom by using presentation models and dynamic computation of each news layout at a page.

Some of previously mentioned solutions were presented for desktop and mobile version of the new web portal at Figure 3.



You Tube presentation

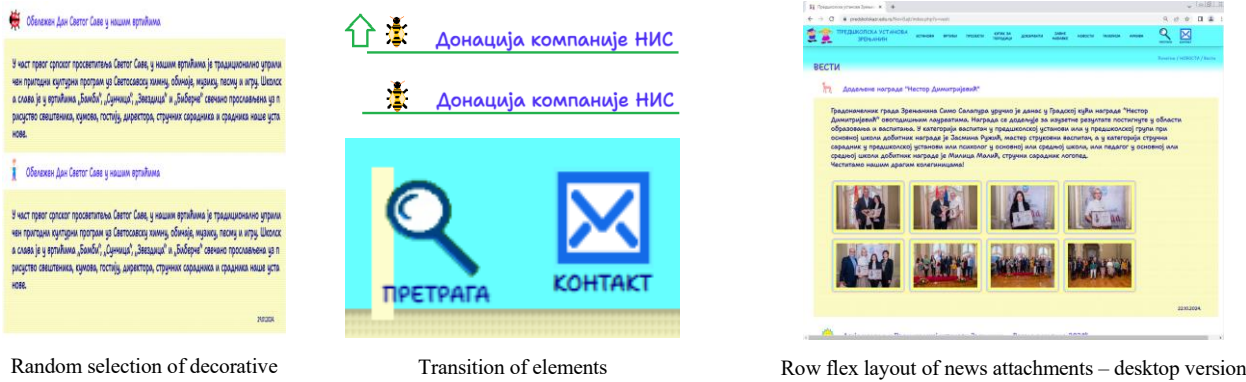


Column flex layout of news attachments



Drawings slider at first page

Figure 3.a – presentation of some multimedia dynamics at new web portal solution



Random selection of decorative icons next to the news title

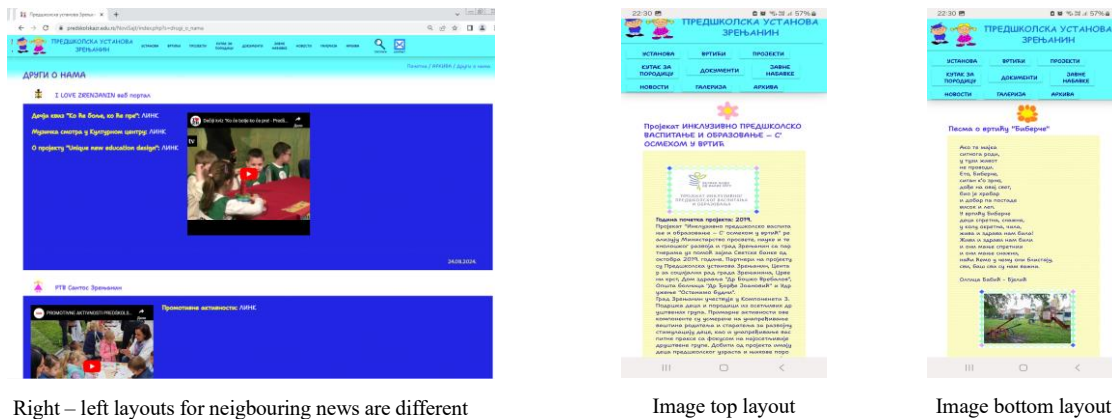
Transition of elements

Row flex layout of news attachments – desktop version

Figure 3.b – presentation of some multimedia dynamics at new web portal solution

5 THE PROPOSED APPROACH AND IMPLEMENTATION

The proposed approach is related to dynamic integration of presentation model and data, for the benefit of presentation diversity and better user experience, as well as better extendibility and maintainability of solution. The proposed presentation model is a PHP class that enables View component to be presented differently, according to setting appropriate presentation parameters.



Right – left layouts for neighbouring news are different

Image top layout

Image bottom layout

Figure 4. Different layouts of elements are based on the use of presentation model

In the Listing 1 there is presentation of a part of the presentation model class source code, to represent the essence of the proposed solution. According to layout type parameter, there will be echo command presenting elements in certain order. In desktop version they will be left-right, but in mobile version - top-bottom directed, according to css flex settings regarding presentation classes in media query.

```

if ($SpozicijaPriloga=="PrilogLevo"){
    echo "<div class=\"$sklasaPrikaza\">";
    if (isset($this->slika)){
        echo "<div class=\"$KontejnerObjavaSlika\">";
        echo "<a href=\"$this->slika.\"><img src=\"$this->slika.\" width=\"100%\" loading=\"lazy\" class=\"slikaObjava\" alt=\"\".$this->opisPriloga.\"\" title=\"\".$this->opisPriloga.\"\"></a>";
        echo "</div>"; // kraj div slika
    }
    if (isset($this->videoMP4)){
        echo "<div class=\"$ObjavaVideoMP4\">";
        echo "<video class=\"$ObjavaVideoMP4\" src=\"$this->videoMP4.\" loop autoplay muted></video>";
        echo "</div>";
    }
    if (isset($this->videoYouTube)){
        echo "<div class=\"$ObjavaVideoYouTube\">";
        echo "<iframe class=\"$frameObjavaVideoYouTube\" src=\"https://www.youtube.com/embed/\".$this->videoYouTube.\"\" title=\"$YouTube video player\" frameborder=\"0\" allow=\"accelerometer;
autoplay; clipboard-write; encrypted-media; gyroscope; picture-in-picture; web-share\" allowfullscreen></iframe>";
        echo "</div>"; // kraj div video youtube
    }
    if (isset($this->mapaGugl)){
        echo "<div class=\"$ObjavaVideoYouTube\">";
        echo "<div class=\"$ObjavaVideoYouTube\">";
        echo "<div class=\"$ObjavaVideoYouTube\">";
        echo "</div>"; // kraj div video youtube
    }
    echo "<div class=\"$sklasaStilBojeTekstObjave\">";
    echo "<div class=\"$sklasaStilBojeTekstObjave\">";
    echo "<div class=\"$sklasaStilBojeTekstObjave\">";
    echo "</div>";
    echo "</div>";
} // kraj prikaza na prilog levo
    
```

Listing 1. Key elements of source code for Presentation model class

6 CONCLUSION

This paper presents the essence of results of a project that has a goal to enhance user experience aspect of web portal www.predskolskazr.edu.rs. Particular contribution of this paper is presented with the multimedia dynamics and the use of presentation model, as a specific class within PHP object-oriented solution.

Future work on this web portal has several directions:

1. Personalization - to enable parents to log-in and get particular data regarding their specific kindergarden or child activities,
2. Accessibility – gained via features that are related to different languages support and features to adjust graphical elements, such as colors and font sizes,
3. Development of different presentation models – for example, news can have different layouts,
4. Development of additional standard elements – modal presentation of multiple images etc.

Future scientific work could be directed towards development of metrics systems to evaluate different aspects of web sites quality.

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A Holistic Analysis of Education, Insights from International Project to Advance Academic and Research Integrity

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Abstract. The paper aims to provide a comparative analysis on the content of reports which focus on policies, practices, rules, and guidelines on a national and institutional level in North Macedonia, Sweden, Czechia, and Lithuania, all while drawing parallels between the countries, their similarities, and their differences. The paper aims to highlight the best practices as well as lessons learned about how to improve the Academic Integrity (hereafter AI) and Research integrity (hereafter RI) infrastructure on the country level and encourage academic integrity and research integrity on a national and institutional level in the BRIDGE partner countries, as well as in other countries.

This paper uses the insights from the BRIDGE project partners and focuses on the reports produced by project partners on the connection between academic integrity and research integrity in the respective countries. While conducting desk research, the partners encountered some commonalities and differences in the connection and application of AI and RI concepts in project partner countries.

A two-step process is utilized, to 1. collect data and 2. to draw conclusions from the same. In the first step, in order to collect data, a holistic approach was implemented in order to generate data from all project partners on the state of AI and RI in their countries. In the second step, a method of metasynthesis is used to generate conclusions based on the data on the best practices in each country. Metasynthesis enables the use of different qualitative or quantitative data to draw conclusions by identifying commonalities or difference in particular society, entity or institution.

Keywords and phrases: Academic integrity, research integrity, BRIDGE Project, good practices in AI and RI

1 INTRODUCTION

Despite the current fast-paced, technology-driven changes in society, education maintains its relevance and increases in value by relying on knowledge production and knowledge dissemination. Currently, 220 million students worldwide are engaged at tertiary education institutions, making education one of the largest sectors in one country. Universities, in particular, are liable to respond to the most difficult challenges in current societies, including responsibilities of knowledge production, training a skilled workforce ready to work in the market, upgrading economic development, and being self-sustainable. Sustainability here refers not only in economic terms but also in qualitative terms, despite both being interrelated to the overall success of the sector. Quality here is more specifically related to the core values of higher education institutions which are based on accessibility, knowledge, merit, fair competition, and innovation. These values play a crucial role in shaping the profile of an “ideal citizen”, a future generation of citizens who are highly skilled, reliable, hard-working, responsible, and accountable. The institutional supremacy of educational institutions is far away from ideal. To name a few, public funding for universities. Altbach, P. G., & de Wit, H. (2020) mention that higher education institutions across the globe are under financial constraints where funding is less accessible and other sectors such as infrastructure and economy are given priority. This certainly comes with the cost of affecting the quality of educational outputs. Education being one of the largest public sectors in one country, in North Macedonia, the second largest sector, makes it vulnerable to external influence by political parties or political developments. To illustrate the way political developments can influence the funding of educational institutions, Post Brexit, UK universities were denied access to major European educational funding programs such as Horizon and

Erasmus+, a loss reported to have reached 2 billion annually. Funding aside, on the subject of quality, in the upcoming years, as was the case in the past, higher education will face the biggest challenge yet—the challenge of maintaining the quality and relevance of education. The quality and relevance of higher education are interrelated in a way that institutional success is dependent on the degree to which the universities can successfully respond to the needs of the job market by delivering high-quality education and research (Marginson, 2016). Universities apply various formal methods to ensure high-quality education and research. Those methods vary from faculty qualifications, accreditation, curricular development, technology, and student feedback to research, international collaboration, and ethics.

This study aims to explore the ways in which universities can improve the quality of educational outcomes by intertwining qualitative methods of international collaboration, research, and ethics, with a particular focus on the BRIDGE project as a way to improve the institutional capacity to deal with issues related to integrity.

Multidisciplinary research requires a multidisciplinary approach and analysis of data. For the purpose of this research, maintaining such an approach underscores the importance of the inclusion of methodologies adopted from the field covered in the study. For that purpose, in this study, the authors implement theories from academic integrity(AI) and research integrity(RI), in a multinational educational setting, by means of international assistance.

2 INTEGRITY INFRASTRUCTURE AND BRIDGE PROJECT

Academic integrity and research integrity have a common denominator, the root of which lies in establishing and maintaining integrity in society. While academic integrity encompasses promoting values such as truth, honesty, respect, responsibility, courage, and fairness within higher education institutions (International Center for Academic Integrity (ICAI), 2021), research integrity encompasses how practitioners in higher education institutions adhere to these values in their everyday professional life (ALLEA - All European Academies, 2017). Current local, and global contexts in the higher education sector (introduction of AI, brain drain, financial constraints, and institutional support) present a serious threat to the quality of educational outcomes. Such circumstances often become a Breeding Ground for unethical practices such as cheating, plagiarism, and contract cheating. Students and staff hardly resist the temptation of easily accessible tools (advanced language models) to achieve their academic goals, starting from the publication of an article, the next academic promotion, writing a dissertation, or simply doing homework. Since the introduction of AI, the number of academic misconduct has increased significantly in recent years. (Fowler, 2023), (Buchanan, 2023).

The incorporation of additional tools to combat academic misconduct to maintain qualitative output among students and staff often requires universities to allocate additional funds. This also means that educational institutions are caught in a vicious cycle of constantly upgrading their technological infrastructure to detect plagiarism and other form of misconduct on one side, and the market offering new applications to avoid detection of plagiarism on the other. Such applications for institutional use come with massive price tags. Developed countries may not have the difficulty of affording these applications, however, the expenses to purchase and maintain such technological infrastructure in countries in development it is more likely to spend the yearly budget for research. Such comparisons are relevant because higher education is more connected than ever in human history and student and staff mobility has become a key agenda as they rely on student and staff mobility to foster innovation, knowledge, and competition, a good example of that is the Bologna Process. Increased exchange among staff and students from developed countries and countries in development also implies experiential exchange of knowledge, values, and practices where students exhibit academic practices that intentionally or unintentionally adhere to or are in opposition to the existing policies and regulations of the host university. A study across 6 countries, including developed and in development found a positive correlation between socio-economic status and ethical behavior in a higher education setting. Due to economic hardship, students from countries with low GDP per capita are more likely to engage in academic misconduct.

(Králiková et al. 2019).

The BRIDGE project is aiming at narrowing the gap in integrity across tertiary education by offering pedagogical solutions to real-world problems. Including students and staff from the EU and non-EU countries is crucial in this aspect because these students, post-graduation, while entering the job market are expected to demonstrate and maintain the same integrity values across all countries. To address all these issues from a pedagogical standpoint, the main objective of the BRIDGE project consists of the following:

1. Compiling checklists and the guidelines for bridging academic integrity in research, business, and society.
2. Developing educational materials including innovative gamified cases based on the checklists and the guidelines representing real-life situations;
3. Developing open educational resources in the form of innovative customized modules based on gamified cases that can be adapted to different disciplines or subject areas, and can be the means of linking academic integrity to research, business, and society. The modules can be used to educate master and PhD students and improve the knowledge and skills of their supervisors. The project consists of 5 different intellectual outputs, as follows:

O1 Analysis of bridging integrity in higher education, business, and society,

O2 Bridging academic and research integrity

O3 Bridging academic integrity and integrity in business

O4 Bridging Academic Integrity and Citizen Science

O5 Training and guidelines as building stones in bridging academic integrity in research, business, and society

For the purpose of this research, the emphasis will be on the first intellectual output and its sub-outputs as the same is directly related to the research and development of the results of this paper. The first suboutput of output #1 is the desk research on the connection between academic and research integrity. The desk research implies compiling a synthesized report identifying good practices about academic integrity and research integrity in each partner country.

3 METHODOLOGY

This paper uses the insights from the BRIDGE project partners and focuses on the reports produced by project partners on the connection between academic integrity and research integrity in the respective countries. While conducting desk research, the partners encountered some commonalities and differences in the connection and application of AI and RI concepts in project partner countries.

A two-step process is utilized. Step 1, collect data from partner countries such as Sweden, Lithuania, Czechia, Ukraine and North Macedonia. Step 2, draw conclusions from the collected data. In the initial phase, of collecting data, a holistic approach (Frodeman, 2010) was implemented in order to generate data from all project partners on the state of AI and RI in their countries. In the second step, a meta-synthesis method is used to create conclusions based on the data on the best practices in each partner country, and the synthesized report was produced from all the data. Meta-synthesis as a research method enables the use of different qualitative or quantitative data to draw conclusions by identifying commonalities or difference in a particular society, entity, or institution. (Erwin, 2011).

Data was collected from laws, policies, guidelines, regulations, institutional codes of conduct, internal and external evaluation reports, and institutional rulebooks.

During the data collection phase, the task for each project partner includes answering the following questions:

1. How are AI and RI defined at the national and institutional levels?
2. How AI and RI practices are integrated within institutional and practical level?
3. What are the best practices in addressing AI and RI in BRIDGE project partner countries?

More specifically, the data were collected by filtering words that are considered crucial in addressing academic and research integrity on a national level.

1. Filtering of words includes words such as ethics/al, integrity, research integrity, academic integrity, misconduct, plagiarism, fabrication, falsification
2. Definition of AI and RI
3. Positive/ negative dimensions of AI/RI
4. Courses, projects, workshops, and lectures dedicated to AI and RI in higher education institutions

The analysis of the desk research includes master and PhD levels, however, other practices from the undergraduate level were not completely omitted, should the same demonstrate a good academic practice relevant to the analysis, including policies, codes of conduct, rules, guidelines, and other additional awareness raising events or activities related to AI and RI infrastructure at higher education institutions and beyond.

The key aspect of the search for good practices in AI and RI includes specific examples, such as mechanisms applied by higher education institutions in respective countries which deal with the detection, reaction, and prevention of AI and RI related misconduct.

The approach to the analysis of AI and RI policies and practices is in line with (Lorenzetti, 2009) and (Parther, 2020) who highlight the relevance of implementing the framework of prevention, detection, and reaction in issues related to AI and RI. The time frame for this research is September 2020 to February 2021.

4 FINDINGS

In this section, the authors have compiled the main results from the national reports of the partner countries participating in the Erasmus+ project titled Bridge project (Bridging integrity in higher education, business, and society). After the careful revision of national, and European laws, policies, rulebooks, and other regulations related to artificial integrity and research integrity, we came to the following findings.

Academic integrity

In the context of academic integrity, one of the most compelling results in all partner countries is the fact that on a national level, there are definitions encompassing issues related to academic integrity. Though with different terms, it is worth pointing out the vastness and the variety of terms used to refer to integrity in the academic setting. In many of the partner countries, the word *ethics* stands out as a word that is most frequently used to describe issues related to integrity in documents, policies, rulebooks, and other administrative and academic documents. *Ethical conduct or code of conduct* is the second most used term in regard to academic integrity, as well as, plagiarism and cheating procedures, pointing to the fact that issues of integrity are used only in the negative sense of the word, as ways to describe, procedures, policies and regulations which have been breached in the case of misconduct. However, a positive context of academic integrity needs to be included, in particular, the examples of fostering trust and credibility among students and staff (McCabe and Treviño, 1997), instilling values of building ethical leadership (Fishman, 2016), and encouraging intellectual growth through genuinely upgrading the existing academic knowledge and skills (Bretag, 2013). *Code for administrators* is another term used for the administrative staff employed in higher education institutions which refers to the administrative staff of higher education institutions,

In addition, there is no single definition/inclusion of academic integrity stipulated in the national laws. Project partner country reports lead to a lack of use of academic integrity in any form or in any law. Especially surprising is that the term(AI) is not included in the national laws in higher education.

In the context of positive dimensions related to academic integrity, variations in preventive dimensions are reported. Some countries focus on preventive measures, some focus on reactive measures, and some on detection. Some countries exemplify a more determined approach to tackling issues related to academic integrity by including the prevention, detection, and reaction in their national legislation.

Principles of academic integrity reflected in the national legislature are also reflected on an institutional level and sometimes overlap with institutional documents.

Other positive dimensions of AI in project partner countries include signing inter-institutional initiatives to uphold academic integrity values, signed by different universities to promote the values of integrity among students and staff. Moreover, on a national level, Lithuania presents a unique example of dealing with issues of AI by establishing the office of Ombudsperson.

In terms of the negative dimension of AI in project partner countries, few aspects appear to remain a challenge on all levels. The lack of institutional transparency in cases of negative detection remains to be a serious indicator of a lack of commitment to academic excellence. Followed by Inconsistency in the accessibility of institutional documents related to breaches of academic integrity. Lack of academic integrity centers to help students and staff in the writing process and ways they can avoid plagiarism, essay mills, and other forms of academic dishonesty. In terms of academic staff, a serious challenge for most institutions within the partnership remains mandatory academic integrity coursework for staff. With the exception of Sweden, no other country had mandatory coursework on academic integrity for staff.

Research integrity

In regards to positive dimensions of research integrity, with a particular focus on the applicability of the prevention, detection, and reaction framework, universities acquire courses in research ethics and research integrity and in some institutions, these courses are mandatory for students and staff. This, unfortunately, is not the case with all the countries from the partnering institutions in the Bridge project.

Other positive aspects of incorporating research integrity on the institutional level are the identified values and principles, and responsible bodies for supervision of integrity on both institutional and national levels. These values of ethical supervision in research are particularly developed within the field of biomedical sciences.

In regards to the negative dimensions of research integrity, with a particular focus on the applicability of the prevention, detection, and reaction framework. The responsibility for following the good practices in research falls within the responsibility of the researcher whereas the responsibility lies with the university. In addition, regulation appear to focus only on one field, in this case, biomedicine. Other fields are excluded from a wider strategy on a national level for ethical supervision.

5 LIMITATIONS

DRP framework(detection, reaction, prevention) Bridge Project contributes to the development of a prevention segment from the DRP framework. Detection and reaction are equally important constituents of the overall efforts to combat corruption in education, academic dishonesty, or other forms of academic misconduct, (McCabe, Treviño, & Butterfield, 2001). However, this paper does not provide an overall solution to the problem of integrity in academia. For best results, the issue of integrity in one education system remains to be addressed by means of economic, cultural, and educational terms.

6 CONCLUSION

As academic integrity and research integrity become increasingly important for higher education institutions it is important to understand the differences and similarities between educational institutions on the ways they deal with issues arising from deviant phenomena such as plagiarism, cheating, fraud, essay mills, and other forms of academic and research misconduct. The partner universities in the BRIDGE project have displayed a good academic integrity infrastructure, in other words, policies, practices, and procedures are accessible.

The evidence shows that regardless of the level of development in one country, academic integrity, and research integrity remain a crucial challenge in need of a permanent and urgent solution on the national and institutional level in all partner countries. In order to solve issues related to integrity, universities need to increase their efforts in applying the framework of detection, reaction, and prevention equally. Good examples can be drawn from project partners, which in terms of academic integrity and research integrity, have expanded their services with Bioethics centers for staff and students to engage. In addition, offering classes for staff and students on writing, such as the Swedish example, where staff members, in order to be promoted to the next academic position, need to undertake courses that include integrity and writing skills. Another good example is the case of Lithuania where they have established the Office of the Ombudsperson for academic ethics and procedures.

Moreover, higher education institutions must remain transparent about the number of cases related to breaching academic integrity, as well as the measures taken against the perpetrators. In addition, universities need to report on preventative measures to minimize the risks to staff and students engaging in such deviant phenomena in the future by proposing and implementing policies, and measures to minimize the breaches of AI and RI. Universities need to improve their integrity infrastructure(policies, regulations, action plans) on an institutional level by comparing their experience with integrity to the experience of other countries with longer traditions in dealing with issues of integrity. In this way, the universities will not only protect their students and staff from engaging in deviant phenomena but also fulfill their primary goal of securing the sustainability of their institution, and the sustainability of knowledge production.

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The Digitalisation of Education: Current Trends, Challenges, and Future Predictions

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Abstract. The digitalization of education, encompassing methods, techniques, and service providers, necessitates a reassessment of its effects to determine whether original educational objectives are being met. This paper explores some key advantages and disadvantages of digitalization, focusing on personalized learning and flexibility while addressing issues such as the digital divide and potential adverse impacts on educational quality. Further analysis examines conflicting findings from previous studies regarding the effectiveness of digitalization, emphasizing challenges in underdeveloped areas, student motivation and engagement, and the development of critical thinking skills in young learners. The study also highlights key areas requiring further research to fully understand the long-term impacts of digitalization on education. The methodology involves a review of contemporary literature, allowing for a synthesis of conclusions on the aforementioned topics. The aim of this study is to emphasize the benefits and drawbacks of the current concept of digitalization and offer insights for future research addressing challenges specific to the technological era.

Keywords and phrases: digitalization of education, advantages and disadvantages of digitalization, digital gap, contraindications of digitalization

1 INTRODUCTION

The modernization of society has introduced transformative changes to all spheres of human life, reshaping perspectives and operations in ways unimaginable to previous generations. Embedded in every aspect of daily existence, these changes may appear gradual, yet their cumulative impact is profound, necessitating systemic adaptation and reform. Digitalization, as a particularly pervasive force of change, increasingly influences workplaces, personal routines, and, notably, educational frameworks. While the process of digitalization may seem intricate and unprecedented, it aligns with education's core mission: to drive progress, foster knowledge, and support human development. Education, as the primary channel to the future, ideally embraces digitalization to promote growth and improvement. A significant body of evidence underscores the potential benefits of digitalization, including its contributions to inclusivity, accessibility in high-risk occupations, opportunities for individuals with disabilities, time efficiency, and cost-effectiveness. The discourse surrounding the digitalization of education reveals two distinct perspectives. Proponents highlight its positive impacts on accessibility and efficiency, arguing that digitalization can create an inclusive, well-organized learning environment. Conversely, critics suggest it might cause more harm than good to certain aspects of the educational process. Central to this debate are issues of student engagement, motivation, and the development of essential skills. For instance, studies on the use of digital resources during the COVID-19 pandemic demonstrated that digitalization ensured sustainable access to learning materials and improved its efficiency. Communication was more effective, resources were better organized, and access to learning platforms was streamlined. On one hand, this learning environment nurtured the development of competitive skills; simultaneously, it optimized working conditions, enhanced decision-making processes, and brought many additional benefits. Considering such findings, advocates believe that with a robust infrastructure supported by legislative frameworks, digitalization holds substantial potential to contribute to the quality of education and learning itself.

2 METHODOLOGY

The literature for this study was identified and collected using the Google Scholar platform, as well as various reports and journals. The selection criteria focused on works published between 2019 and 2024 that explore topics related to the digitalization of education, its progress, advantages, and challenges in its integration into teaching processes. The collected information was synthesized to identify common trends and opposing perspectives within the existing literature. Limitations of this methodology include reliance on available works from the specified platforms and the potential for biased selection due to the exclusive use of studies written in Serbian and English.

3 THE IMPACT AND CONTEXT OF DIGITALISATION IN EDUCATION

Digitalization in education presents challenges, particularly for regions with less advanced digital infrastructure. Many countries are developing frameworks where significant disparities in digital literacy exist among both students and educators. This exacerbates uncertainty and reduces engagement in digital learning environments. Furthermore, students and educators who lack adequate training and access to relevant digital tools struggle to incorporate educational practices into training processes effectively. Consequently, the benefits of digitalization may not be fully realized unless its integration includes the comprehensive training of both students and educators within schools. Digitalization also alters pedagogical dynamics and the social interactions fundamental to the educational process. Theoretical approaches to digital literacy and competencies suggest that beyond technical skills, there is a need for strategies that integrate the socio-cultural dimensions of digitalization. A holistic approach to modern discourses on digital literacy would thus require not only skills for digital engagement but also critical and reflective competencies for using digital resources. Such socio-cultural awareness, combined with practical digital skills, is increasingly crucial to enable students to participate meaningfully in a digitally structured society. In an era of rapid digitalization, early childhood and primary education face unique pedagogical challenges. While the COVID-19 pandemic undoubtedly accelerated the use of digital technologies across educational settings, research suggests that the application of digital tools in early education should be implemented carefully and in developmentally appropriate ways (Ružić, 2021). For instance, setting limits on screen time for younger students could mitigate risks to health and socialization. Poorly tailored digital content, unaligned with the needs and interests of young learners, may hinder rather than enhance their educational experiences (Brkljača et al., 2024). Therefore, early education must strike a balance in its approach to digitalization, maximizing its benefits while safeguarding developmental and social well-being. Strategic implementation of age-appropriate digital technologies can ensure positive educational outcomes without adverse effects on children's cognitive and social development.

At the level of higher education, digitalization unlocks new pathways for enhancing teaching methodologies and research capacities. Students now enjoy unprecedented flexibility with digital tools and resources, enabling more dynamic access to course materials, greater interactivity, and improved organization of learning schedules. Online lectures, databases, and digital research tools accelerate the development of competencies and skills essential for effective performance in today's digital workplaces. This flexibility is particularly valuable in the fast-evolving social and professional environment, allowing students to engage more actively with practical aspects of their studies and refine their individual research skills. Graduates entering the labor market possess enhanced capabilities to thrive in a digitalized economy, with well-developed technical and analytical skills. For educators, the preparation and delivery of courses, as well as interactions with students, are significantly streamlined by digital tools. Platforms enable more efficient organization of group discussions, feedback surveys, and assignments, leading to higher student participation and more engaged learning. Moreover, digital tools allow instructors to tailor content to individual needs, ensuring that learning materials are both relevant and accessible to all students. In research, digitalization facilitates swift access to databases, fosters international collaboration among peers, and enables participation in data-driven projects for developing and disseminating scientific knowledge (Ružić, 2021). These functionalities enhance the benefits of digitalization in higher education, supporting collaborative research efforts and building a more active and informed academic community. Nevertheless, digitalization in higher education also introduces challenges, such as the need for continuous digital training, access to sophisticated technologies, and adherence to security standards. Addressing these issues demands sustained investment in digital infrastructure and in the competencies of both educators and students. Future

advancements must enable the full realization of digitalization's benefits across all levels of education, fostering an innovative learning environment capable of addressing the demands of modern society. The long-term viability of higher education hinges on the integration of digital tools within its institutions.

3.1. Current trends in the digitalisation of education

The transformation of learning through digitalization has been significantly influenced by advancements in technology. Some of the most prominent trends include personalized learning, blended and hybrid learning models, the integration of artificial intelligence (AI), and the use of mobile learning applications. Personalised learning, one of the most notable trends, involves tailoring educational content and pacing to meet individual student needs. Here, AI plays a critical role by personalizing content and assessments. Adaptive learning pathways facilitated by AI enhance student engagement and retention. Additionally, blended and hybrid learning models combine face-to-face instruction with digital components, offering flexibility and improving learning outcomes through a balanced mix of traditional methods and modern technology. These models have proven particularly effective in higher education institutions, where students take a more active role in pacing their learning and remotely accessing course materials. According to Kirkwood & Price (2018), mobile learning, another emerging trend, enhances accessibility and inclusivity, especially in developing regions. Mobile applications allow students to participate in learning activities anytime and anywhere, making education more adaptable to individual schedules and contexts.

3.2. Challenges in the Digitalisation of Education

Despite its advantages, digitalization poses several challenges. One of the most critical is the *digital divide*, where unequal access to technology exacerbates educational disparities, particularly for students in remote or under-resourced areas (Nguyen, 2019). This gap is not solely linked to geographic or economic disparities but also to differences in digital literacy, as students from less privileged backgrounds often lack essential technical skills. Additionally, issues of student engagement and motivation in digital environments have emerged. For example, Chen et al. (2019) argued that while digital tools increase flexibility, they can also lead to greater distractions and reduced motivation due to diminished face-to-face interaction. Moreover, digitalization might hinder the development of critical thinking and problem-solving skills. Students often miss opportunities for in-depth discussions and real-time feedback—two essential components for fostering analytical abilities (Sheninger, 2020).

3.3. Contrasts and Conflicting Views

The impact of digitalization in education is not entirely positive, and its efficiency remains a topic of debate. Some scholars argue that while digital tools improve accessibility, they may simultaneously compromise education quality. For instance, substantial evidence suggests that over-reliance on technology undermines the human aspects of education, such as the teacher-student relationship, which is crucial for students' socio-emotional development (Schleicher, 2019). In less developed regions, digitalization often faces challenges like inadequate infrastructure and a lack of trained staff, further complicating its implementation (Nguyen, 2019). Concerns about data privacy and security also arise, as the extensive use of digital platforms raises ethical questions about student data collection and its potential misuse. Much of this data is managed by private companies, which may prioritize profit over educational outcomes, often at the expense of student privacy (Zuboff, 2019). Researchers have differing views on the benefits of digitalization in education, particularly regarding its impact on underdeveloped areas, student engagement, and critical thinking skill development. While some studies highlight enhanced learning opportunities and increased student engagement, others point to significant barriers, especially in regions with poor technological infrastructure. Students in such areas often lack access to digital tools and resources, reducing motivation and making full learning engagement challenging. Concerns also include the potential decline in critical thinking skills among children who might rely on technology to find information or solve problems instead of developing these skills through traditional means. These inconsistencies in the literature present a nuanced perspective on digitalization's role—one full of promise but also highlighting obstacles that must be overcome to fully realize its potential in improving educational outcomes.

3.4. Future Predictions for Digitalisation in Education

Digitalization in education is poised to grow further with technological advancements and the evolving needs of students. It is anticipated that artificial intelligence (AI) will play a more prominent role in personalizing educational experiences, with intelligent tutoring systems and adaptive learning platforms becoming increasingly prevalent. Moreover, advancements in virtual and augmented reality technologies are expected to create immersive learning environments, allowing students to explore complex ideas and scenarios interactively. As digitalization progresses, the development of digital citizenship skills among students will gain prominence. These skills will equip learners with the knowledge and competencies necessary to navigate a digitally interconnected world responsibly (Hollandsworth et al., 2017). While it is crucial to weigh the benefits and drawbacks of digitalization, the optimal approach lies in embracing its complexity and refocusing on how to best prepare teachers to harness technology effectively. Comprehensive training could empower educators to utilize digital tools efficiently, saving them time for professional development while helping students reach their full potential. This shift is imperative, as technology cannot replace the creativity and intellectual processes that teachers bring to the classroom. Rather than fearing digitalization, educators should view it as a valuable tool to enhance their methods and provide students with more personalized learning experiences. Future research should focus on developing effective teacher training programs, investigating how such initiatives can prepare educators to integrate technology into their teaching strategies. Additionally, attention should be given to designing educational programs tailored to varying levels of digital literacy, ensuring inclusivity and accessibility in the digital learning landscape.

4 CONCLUSION

In summary, the digitalization of education represents a complex landscape filled with remarkable opportunities and significant challenges. Potential benefits, such as improved access, enhanced flexibility, and personalized learning experiences, offer great promise for transforming educational practices. However, it is imperative to weigh these advantages against critical concerns related to equity, student engagement, and the overall quality of education. To navigate this intricate terrain effectively, policymakers, educators, and institutions must take proactive steps to address these challenges. Bridging the digital divide and ensuring comprehensive digital literacy training for both teachers and students should be top priorities. Moreover, as the education paradigm continues to evolve, it is essential to acknowledge the contradictions present in current literature concerning the effectiveness of digitalization. By recognizing and embracing these complexities, we can foster a nuanced understanding that informs future research efforts. Technology should be embraced as a tool that enhances the human aspects of teaching, nurturing genuine connections and collaborative learning experiences fundamental to the educational process. While evaluating the advantages and disadvantages of digitalization is crucial, the most meaningful approach lies in empowering educators with the skills and knowledge needed to use technology effectively. By creating an environment that fosters professional development, teachers can better support their students in realizing their full potential and developing essential critical thinking skills. Ultimately, the success of education digitalization will depend on our collective ability to adapt to rapid technological advancements while remaining committed to the core values of education: equity, inclusivity, and quality. By prioritizing thoughtful integration of digital tools and continuous support for educators, we can ensure that digitalization not only enriches the learning experience but also contributes positively to the holistic development of every student.

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The Impact of the Mentor in the Process of Writing a Final Thesis: Experiences of Students

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Abstract. The mentor has a crucial function in the educational process, especially in the context of students' final thesis work. Through mentorship, students have the opportunity to develop and enhance their critical thinking skills, write quality papers, and conduct their own research. In this way, mentors significantly shape students' professional paths and personal development. This paper investigates the importance of mentorship in the process of writing final theses, with a particular focus on students' attitudes and experiences. The aim of the research is to identify the mentor's impact on the quality of the final thesis from the viewpoint of students.

Keywords and phrases: mentor, final thesis, student

1 INTRODUCTION

In contemporary educational systems, mentorship is becoming an increasingly important factor in achieving academic success for students. Mentors not only provide professional support but also assist in the development of critical thinking, creativity, and independence among students. Interaction with a mentor helps students gain additional knowledge while also shaping their own thinking processes and approaches to problems. As a result, students are encouraged to confront the challenges of academic writing and research, which often require a high level of analytical and organizational skills.

This paper explores the role of mentors in the process of creating a final thesis, focusing on the experiences of students who have successfully completed their studies by defending their theses at their university. The research will identify how and to what extent mentors influence the quality of students' final theses. This analysis will cover various aspects, including the mentor's influence on the development of the idea and concept, improvement of the final work's quality, their readiness to adequately address posed questions and guide the creation process by reviewing drafts, the usefulness of the feedback provided, as well as their impact on the development of critical thinking, research skills, writing skills, and assistance with formalities related to writing a student's final paper.

Based on the results of the research, recommendations will be provided to enhance mentorship and its impact on the quality of final theses. These recommendations aim to create an environment that further fosters the development of skills essential for success in both academic and professional realms.

2 THEORETICAL BACKGROUND

The final thesis is a written document based on a specific field that demonstrates a student's professional competence, independence, and maturity in solving problems and addressing issues relevant to their discipline. Through this work, students illustrate their ability to engage with scientific literature, conduct independent research, analyze collected data, interpret results, and formulate conclusions, all under the guidance of a mentor (Akademija vaspitačko-medicinskih strukovnih studija, 2020; FINra, 2020).

The mentor is a professor who teaches the subject from which the final paper is derived and is responsible for guiding the student through the process of completing the final paper, from topic selection, through draft versions, to final completion (Akademija vaspitačko-medicinskih strukovnih studija, 2020; Cencič; Damjanović, 2008; FINra, 2020; „Uputstvo za izradu završnog rada”). His role is not only to provide

professional support related to the details of thesis writing, but also to guide the student through all stages of the work (Akademija vaspitačko-medicinskih strukovnih studija, 2020; Damnjanović, 2008; FINra, 2020; „Uputstvo za izradu završnog rada”). Collaboration between the mentor and the student takes place through regular consultations, which are crucial for speeding up the process and improving the quality of the work (Akademija vaspitačko-medicinskih strukovnih studija, 2020; Damnjanović, 2008; FINra, 2020; Sholeh, Sutrisno, & Ab Rahman, 2024; „Uputstvo za izradu završnog rada”). The mentor assists the student in developing the idea and concept of the paper, as well as in addressing the chosen topic, while also recommending relevant sources and methods for crafting the work (FINra, 2020; „Uputstvo za izradu završnog rada”). Additionally, the mentor assists in shaping the thesis structure, formulating the title, and resolving potential dilemmas that may arise during research (FINra, 2020; „Uputstvo za izradu završnog rada”).

Thus, mentorship, as a foundation for professional and academic development, represents a process of guidance and support in the writing of final theses, as well as in the broader context of academic writing and research (Bekar, 2022; Hercigonja, 2018; Sarabipour et al., 2022). It not only helps students avoid mistakes during research, writing, and critical thinking but also enables a deeper understanding of specific aspects of the discipline, thereby contributing to the student's overall success (Cutillas et al., 2023; Hercigonja, 2018; Jiao, 2011).

Relying on Wooden's theories of continuous learning and improvement in teaching (Ermeling, 2012), Palmer and Smith emphasize that successful mentorship requires a combination of elements such as pointing out key information and repeating it, being ready to respond quickly and specifically, providing verbal support, as well as correcting mistakes and redirecting for the purpose of improving the quality of work (Palmer & Smith, 1990). This approach to mentorship encourages the student to engage in work while also allowing them to better develop the skills necessary for successful research and academic writing (Kleinbort, 2020; Palmer & Smith, 1990). This dynamic process opens up space for critical discussions between the mentor and the student, further deepening knowledge and understanding of specific topics (Palmer & Smith, 1990). Supporting this fact is the research by Can and Walker, which found that the feedback students receive from mentors plays a crucial role in their progress (Can & Walker, 2011), as well as the research conducted by Rose, which highlighted that students are most satisfied with mentors who provide honest feedback and communicate clearly and openly (Rose, 2003).

3 RESEARCH METHODOLOGY AND RESULTS

The research focuses on the faculties in the Republic of Serbia and was conducted from October 18 to 24 2024 through an online questionnaire containing 10 questions. A total of 300 respondents who completed their studies by defending their final thesis at various faculties participated in the study. The aim was to determine the impact and role of mentors in the thesis writing process based on the respondents' experiences related to their thesis writing.

Of the total number of respondents, 77 graduated from the Faculty of Education, 50 from the Technical Faculty, 47 from the Faculty of Philosophy, 33 from the Faculty of Natural Sciences and Mathematics, 16 from the Faculty of Pedagogy, 15 from the Faculty of Philology, 11 from the Faculty of Economics, 6 from the Faculty of Agriculture, 6 from the Academy of Arts, 4 from the Technological Faculty, 4 from the Faculty of Sports and Physical Education, 4 from the Faculty of Defectology, 3 from the Faculty of Medicine, 3 from the Faculty of Geography, 2 from the Faculty of Organizational Sciences, 2 from the Orthodox Theological Faculty, 2 from the Faculty of Physics, 2 from the Higher School of Professional Studies for Educators, 2 from the Higher Technical School of Professional Studies, 1 from the Faculty of Civil Engineering, 1 from the Faculty of Mining and Geology, 1 from the Faculty of Biology, 1 from the Faculty of Chemistry, 1 from the Faculty of Law, 1 from the Faculty of Political Sciences, 1 from the Faculty of Traffic, 1 from the Faculty of IT, 1 from the Higher Business School of Professional Studies, 1 from the Higher Health School of Professional Studies, and 1 from the Music Academy, as can be seen in Table 1.

Table 1. Number of respondents from the faculties

Number of respondents	Names of faculties
77	Faculty of Education
50	Technical Faculty
47	Faculty of Philosophy
33	Faculty of Natural Sciences and Mathematics
16	Faculty of Pedagogy
15	Faculty of Philology
11	Faculty of Economics
6	Faculty of Agriculture, Academy of Arts
4	Technological Faculty, Faculty of Sports and Physical Education, Faculty of Defectology
3	Faculty of Medicine, Faculty of Geography
2	Faculty of Organizational Sciences, Orthodox Theological Faculty, Faculty of Physics, Higher School of Professional Studies for Educators, Higher Technical School of Professional Studies
1	Faculty of Civil Engineering, Faculty of Mining and Geology, Faculty of Biology, Faculty of Chemistry, Faculty of Law, Faculty of Political Sciences, Faculty of Traffic, Faculty of IT, Higher Business School of Professional Studies, Higher Health School of Professional Studies, Music Academy

In response to the question "Do you believe that the mentor followed the process of completing the final thesis by reviewing working versions, and to what extent?", 34% of respondents indicated that the mentor monitored the process very closely, while 31.3% stated he monitored it partially. Additionally, 23.3% reported that he monitored it exceptionally well, 10% felt he monitored it insufficiently, and 1.3% believed he did not monitor it at all. The results of these responses are presented in Table 2.

Table 2. Monitoring the process of completing the final thesis by the mentor

Responses	Number of respondents	Percentage of respondents
He monitored extremely closely.	70	23.3%
He monitored very closely.	102	34%
He monitored partially.	94	31.3%
He monitored insufficiently.	30	10%
He did not monitor.	4	1.3%

Respondents answered the question "Do you believe that the mentor influenced the development of the idea and the concept of the final thesis, and to what extent?" with the following responses: 33% said the mentor had a significant influence, 31.3% stated he had a partial influence, 26.7% indicated he had an exceptional influence, 6.7% reported he had a slight influence, and 2.3% felt he did not influence at all. The respondents' answers are presented in Table 3.

Table 3. Influence of the mentor on the development of the idea and concept of the final thesis

Responses	Number of respondents	Percentage of respondents
He had an exceptional influence.	80	26.7%
He had a significant influence.	99	33%
He had a partial influence.	94	31.3%
He had a slight influence.	20	6.7%
He did not influence.	7	2.3%

In response to the question, "How useful were the feedback you received from your mentor regarding your final thesis?", 38.3% of respondents said that the feedback from their mentor was very useful, 31.7% stated it was exceptionally useful, 20.7% said it was moderately useful, 7% said it was insufficiently useful, while 2.3% said that the feedback from their mentor was not useful at all. Table 4 presents the respondents' answers to this question.

Table 4. Usefulness of feedback from mentors regarding the final thesis

Responses	Number of respondents	Percentage of respondents
Exceptionally useful	95	31,7%
Very useful	115	38,3%
Moderately useful	62	20.7%
Insufficiently useful	21	7%
Not useful at all	7	2.3%

In Table 5, the responses to the question "Do you believe that the mentor was prepared to adequately respond to your questions related to the completion of the final thesis, and to what extent?" are presented. The majority of respondents indicated that the mentor was exceptionally prepared to answer their questions (39.7% of respondents), 25.3% said the mentor was partially prepared to respond to their questions, 24.3% stated he was very prepared, 7.3% said he was slightly prepared, and 3.3% felt he was not prepared at all.

Table 5. The mentor's preparedness to adequately respond to questions related to the completion of the final thesis

Responses	Number of respondents	Percentage of respondents
Exceptionally prepared	119	39.7%
Very prepared	73	24.3%
Partially prepared	76	25.3%
Slightly prepared	22	7.3%
Not prepared	10	3.3%

In response to the question, "Do you believe that your mentor influenced the development of your critical thinking skills, and to what extent?", the respondents provided answers that are presented in Table 6. Specifically, 32.7% of respondents stated that their mentor had somewhat influenced the development of their critical thinking skills, 21.7% indicated that the influence was significant, 18.3% said there was little influence, 15.3% reported that the influence was exceptional, and 12% felt that there was no influence at all.

Table 6. Influence of mentors on the development of critical thinking skills

Responses	Number of respondents	Percentage of respondents
He influenced exceptionally.	46	15.3%
He influenced very much.	65	21.7%
He influenced partially.	98	32.7%
He influenced a little.	55	18.3%
He did not influence.	36	12%

Table 7 shows the respondents' answers to the question, "Do you believe that your mentor influenced the development of your research skills, and to what extent?" The largest portion of respondents, 31%, believes that the mentor has partially influenced their development of research skills, 24.3% believe that the influence was significant, 17.7% believe it was minimal, 14% believe there was no influence, and 13% believe it was exceptionally influential.

Table 7. Influence of the mentor on the development of research skills

Responses	Number of respondents	Percentage of respondents
He influenced exceptionally.	39	13%
He influenced very much.	73	24.3%
He influenced partially.	93	31%
He influenced a little.	53	17.7%
He did not influence.	42	14%

Table 8 presents the respondents' answers to the question, "Do you believe that your mentor influenced the development of your writing skills, and to what extent?" Of all the respondents, 30.3% believe that the mentor has partially influenced their development of writing skills, 25% believe the influence was significant, 17.3% believe there was no influence, 17% believe it was minimal, and 10.3% believe it was exceptionally influential.

Table 8. Influence of the mentor on the development of writing skills

Responses	Number of respondents	Percentage of respondents
He influenced exceptionally.	31	10.3%
He influenced very much.	75	25%
He influenced partially.	91	30.3%
He influenced a little.	51	17%
He did not influence.	52	17.3%

The question "Do you believe that your mentor helped you with the formalities in completing your final paper (regarding academic standards, citation rules, technical details, etc.) and to what extent?" has the following percentages of respondents' answers: 25% believe that their mentor helped them a lot, 24% that their mentor partially helped them, 20.7% that their mentor helped them very much, 16.7% that their mentor helped them a little, and 13.7% that their mentor did not help them with the mentioned formalities.

Table 9. Help from the mentor with formalities in completing the final paper

Responses	Number of respondents	Percentage of respondents
Helped a lot.	62	20.7%
Helped very much.	75	25%
Partially helped.	72	24%
Helped a little.	50	16.7%
Did not help.	41	13.7%

The concluding question in the survey is, "Do you believe that mentorship has contributed to the quality of your final paper, and to what extent?" The respondents' answers are as follows: 30.7% believe that mentorship has significantly contributed to the quality of their final paper, 24.3% believe it has partially contributed, 20% believe that mentorship has exceptionally contributed, 13% believe it has contributed a little, and 12% believe it has not contributed at all.

Table 10. Contribution of mentorship in the context of the quality of the final paper

Responses	Number of respondents	Percentage of respondents
Contributed exceptionally.	60	20%
Contributed significantly.	92	30.7%
Contributed partially.	73	24.3%
Contributed a little.	39	13%
Did not contribute.	36	12%

In order to gain a closer insight into the research results obtained, the respondents' answers were quantified by assigning numerical values from 1 to 5. Here, 5 represents the designation for the response that expresses the most positive attitude of the respondents toward the question, 4 indicates a positive response, 3 denotes a neutral response, 2 signifies a negative response, and 1 symbolizes the responses that represent the most negative attitude of the respondents. Below is Table 11, which presents the answers to the questions along with their quantitative replacements.

Table 11. Quantification of responses to survey questions

Mentorship aspects / Quantification measure for response	5	4	3	2	1
Monitoring the process of completing the final thesis by the mentor	He monitored extremely closely.	He monitored very closely.	He monitored partially.	He monitored insufficiently.	He did not monitor.
Influence of the mentor on the development of the idea and concept of the final thesis	He had an exceptional influence.	He had a significant influence.	He had a partial influence.	He had a slight influence.	He did not influence.
Usefulness of feedback from mentors regarding the final thesis	Exceptionally useful	Very useful	Moderately useful	Insufficiently useful	Not useful at all
The mentor's preparedness to adequately respond to questions related to the completion of the final thesis	Exceptionally prepared	Very prepared	Partially prepared	Slightly prepared	Not prepared
Influence of mentors on the development of critical thinking skills	He influenced exceptionally.	He influenced very much.	He influenced partially.	He influenced a little.	He did not influence.
Influence of the mentor on the development of research skills	He influenced exceptionally.	He influenced very much.	He influenced partially.	He influenced a little.	He did not influence.
Influence of the mentor on the development of writing skills	He influenced exceptionally.	He influenced very much.	He influenced partially.	He influenced a little.	He did not influence.
Help from the mentor with formalities in completing the final paper	Helped a lot.	Helped very much.	Partially helped.	Helped a little.	Did not help.
Contribution of mentorship in the context of the quality of the final paper	Contributed exceptionally.	Contributed significantly.	Contributed partially.	Contributed a little.	Did not contribute.

After quantifying the respondents' answers, the overall impression is calculated using the arithmetic mean, as shown in Table 12. The arithmetic mean was selected as the basic measure for the statistical analysis of this research because it provides a clear and comprehensive insight into the research results, allowing for their straightforward interpretation and mutual comparison. At the level of the entire study, the average rating of students for monitoring the process of completing the final thesis by the mentor is 3.75. Students rated the influence of the mentor on the development of the idea and concept of the final thesis with an average score of 3.75. Regarding the usefulness of feedback from mentors regarding the final thesis, it received the highest rating from students, which is 3.9. Additionally, students rated the mentor's preparedness to adequately respond to questions related to the completion of the final thesis at 3.9. Significantly lower ratings were given for the influence of mentors on the development of critical thinking skills (3.1), the influence of the

mentor on the development of research skills (3.05), and the influence of the mentor on the development of writing skills (2.94). The help from the mentor with formalities in completing the final paper was rated with an average score of 3.18, while the contribution of mentorship in the context of the quality of the final paper was rated at 3.35.

Table 12. General impressions of students on the role of the mentor in the process of writing a final thesis

Mentorship aspects	Arithmetic mean of the quantified responses
Monitoring the process of completing the final thesis by the mentor	3.68
Influence of the mentor on the development of the idea and concept of the final thesis	3.75
Usefulness of feedback from mentors regarding the final thesis	3.9
The mentor's preparedness to adequately respond to questions related to the completion of the final thesis	3.9
Influence of mentors on the development of critical thinking skills	3.1
Influence of the mentor on the development of research skills	3.05
Influence of the mentor on the development of writing skills	2.94
Help from the mentor with formalities in completing the final paper	3.18
Contribution of mentorship in the context of the quality of the final paper	3.35

4 DISCUSION AND CONCLUSION

This research identifies the impact of mentors on the preparation of students' final theses. Based on the obtained results, it is evident that students recognize the significance of mentorship in the process of developing their final papers, but they also express the need for further improvements in certain aspects of mentorship that could enhance the quality of their work and academic progress. They emphasize that the professional competencies of mentors, which include the ability to provide concrete answers to questions and offer useful feedback, have been extremely helpful during the writing process. Additionally, they expressed great satisfaction with the mentors' influence on shaping the ideas and concepts of their final papers, as well as on overseeing the entire process of preparation. The contribution of mentorship to the quality of the final papers was also rated fairly solidly. However, when it comes to the mentors' assistance regarding writing formalities, such as citation and technical details, students express a slightly lower level of satisfaction. Moreover, the impact of mentors on the development of critical thinking, research skills, and writing abilities was rated as average by the students.

In order to improve this process, it is advisable to consider the introduction of more regular consultations between mentors and students based on the analysis of the obtained data. This way, students would be able to receive timely guidance related to the preparation of their final papers. Additionally, it is recommended to create comprehensive guides and handbooks for students that cover key aspects of academic writing, including citation, technical details, and so forth. These resources should be easily accessible to students, and mentors could organize working sessions to help them understand and apply these guidelines. It would also be significant to introduce a greater number of classes in research methodology, enabling students to gain a deeper understanding of the research process and further enhance their academic skills. Furthermore, to enhance the development of critical thinking, research skills, and writing abilities, it would be beneficial to organize additional forms of extracurricular activities such as various workshops and seminars that would provide students with closer insight into the process of writing a final paper and ensure they have adequate opportunities to develop their academic skills. By implementing these recommendations, mentorship could become even more effective, resulting in higher quality final papers and an improvement in students' academic competencies.

This paper did not include an analysis of the availability of the proposed measures for improving mentoring, so future research could examine whether some of these recommendations are already accessible to students and, if so, how they could be utilized to be more effective. Also, future research could consider the specific challenges students face during the thesis writing process, as well as the long-term impacts of mentorship on

the development of their subsequent academic careers. These insights would be valuable for improving mentoring practices and providing adequate support to students in their academic endeavors.

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InfluxDB as an Educational Example of a Time-Series Database Used in the Industrial Internet of Things System for Dust Monitoring

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Abstract. Implementing IIoT (Industrial Internet of Things) technology in production, which enabled the collection, storage, and analysis of a large amount of data about machines and the industrial environment in real-time, improved industrial production processes. Traditional databases such as Oracle Database, MySQL, and others are, in some cases, not suitable for working with Time Series data characteristic of IIoT systems. Time Series databases are structured for efficient collection, storage, and analysis of large amounts of data and, as such, are suitable for IIoT systems. This paper explores the use of Time Series DBMS in IIoT systems, focusing on InfluxDB, which, according to db-engines.com, is one of the most popular databases in this category. The paper presents a detailed analysis of InfluxDB's characteristics and an example of its application in the IIoT system. Research results show that InfluxDB can meet most of the requirements that IIoT systems expect, such as efficient processing of large amounts of data to improve the performance and accuracy of analytical processes in industrial environments. The example presented in this paper can be used in the educational process as a platform for student projects and prototyping, because of its low cost, availability, and scalability. Benefits, problems, and opportunities for further research are discussed.

Keywords and phrases: IIoT, Time Series DBMS, InfluxDB, Databases.

1 INTRODUCTION

Industry 4.0 is a concept that includes new technological innovations that are applied in industrial processes. By using technology such as IIoT, industries become more efficient, autonomous, and adaptable to change. (Lins, Oliveira, Correia & Silva, 2018) IIoT systems in their environment use many connected devices that produce a large amount of data, which helps improve production processes. The data from each connected device in the system can be viewed as collections of time-series requiring appropriate database features. Databases intended to solve these requirements must be able to ensure efficient data entry and work with them. (Di Martino, Fiadone, Peron, Vitale & Riccabone, 2019)

IIoT systems fundamentally use a large number of devices in combination with various sensors that generate a vast amount of data. These systems impose new requirements for managing Time-Series databases, based on the needs of the IIoT system architecture. (Wang et al., 2023) IoT applications require efficient management of Time-Series data both on the edge computing side and in the cloud environment, providing high throughput data ingestion and advanced analysis. (Wang et al., 2020)

This paper focuses on gathering information about using Time Series DBMS in IIoT systems. InfluxDB, which is the most popular in this category according to db-engines.com, is taken as an example of a Time Series Database. The paper presents a detailed analysis of InfluxDB's characteristics and an example of its application in the IIoT system which can be used in the educational process at universities as a platform for student projects and prototyping, because of its low cost, availability, and scalability. The following sections of the paper will present a literature review related to Time Series DB and InfluxDB. After that, the paper will focus on a case study of implementing InfluxDB in a real IIoT system. Finally, the conclusion will describe the advantages, challenges, and possibilities for future research.

2 LITERATURE REVIEW

Databases represent a crucial element of IIoT systems, enabling the storage and analysis of large amounts of data collected from various devices. This literature review will focus on the role of Time Series DB in IIoT systems, with InfluxDB as an example of such a database. The advantages and challenges of TSDB InfluxDB in various IIoT applications will be examined by analyzing existing papers and research.

For every technological innovation development, multiple solutions can be applied. Choosing a solution to be used in an innovation creates a competitive market where companies with solutions compete, maintaining continuous development of services and products in the same domains. This creates an additional challenge: selecting the most efficient solution for the problem. The paper (Kenitar, Arioua, & Yahyaoui, 2023) addresses the issue of selecting an efficient system for storing and managing large volumes of IIoT data. The study investigates SQL and NoSQL databases to find the most efficient solution. AWS Aurora SQL Database and AWS DynamoDB NoSQL Database were taken as examples, representing SQL and NoSQL databases. Additionally, the MQTT protocol, one of the most popular protocols for communication in IoT systems, was used. The methodology was carefully designed to ensure the study's effectiveness. Data collected during the research experiment showed that the NoSQL database reduces latency. The same experiment was conducted with 1, 10, and 100 units to cross-validate the results. In every case, the results showed that the latency of the SQL database is higher than that of the NoSQL database for the IIoT system. Despite all the limitations during the research, the results presented helpful information related to IIoT and communication with different types of databases. Such systems have the potential to increase efficiency and reduce production costs.

The amount of data sent by industrial machines can be large and often falls into the Big Data category. Such data, coming from different sources and having various characteristics, presents a challenge in selecting a DBMS as the main element of an IIoT system. The paper (Di Martino, Fiadone, Peron, Vitale, & Riccabone, 2019) analyzes three NoSQL DBMSs to find the most efficient solution for ingestion, retrieval and required storage space for IIoT data. The experiment involved measuring the performance of Apache Cassandra, MongoDB, and InfluxDB in managing a dataset of about 600 million records (about 60 GB of data) collected from an instrumented grinding machine. The results showed that MongoDB performed best for queries on non-temporal indexed attributes, while Cassandra was unstable and significantly worse in almost all tests. InfluxDB achieved the best results and proved to be the most stable solution in storage, providing the best performance in ingestion and time-based queries. As a result of the research, InfluxDB emerged as the most recommended solution for a DBMS in IIoT systems.

3 TIME SERIES DBMS

Time-Series represents a data set for a single variable (e.g., temperature) at equal time intervals (e.g., hourly). For example, data combined with time intervals, such as measurements obtained from IoT devices, can be considered Time-Series. A Time-Series Database (TSDB) is a specially optimized database for Time-Series data. TSDB allows users to create, enumerate, update, delete, and organize various Time-Series data more efficiently. (Naqvi, Yfantidou, & Zimanyi, 2018)

Time-Series data are most commonly associated with data obtained from server monitoring, application performance monitoring, network data, sensor data, events, clicks, market transactions, and many other types of analytical data. Time-Series databases used for these purposes are becoming the standard for storing, retrieving, and analyzing these data types in real time. (Dix, 2003)

The main difference between Time-Series databases and regular databases is that with Time-Series data, questions are always asked about them in units of time. To determine whether a dataset is a Time-Series, you need to check if your data are tied to the time they were recorded, i.e., whether the data diagram includes time on its axes. (Dix, 2003)

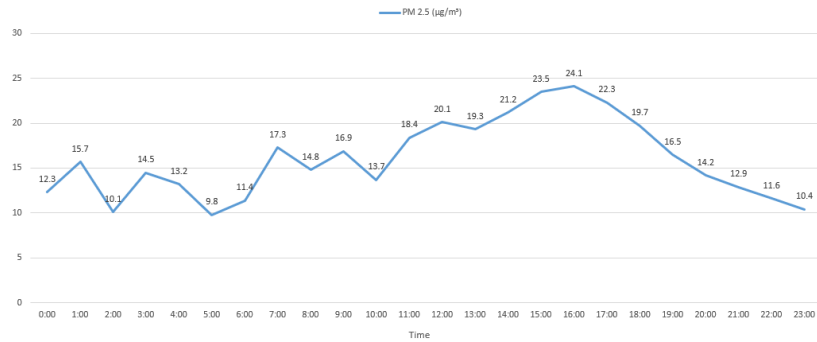


Figure 1: Example of regular Time-Series data

Time-Series data are divided into two categories – regular and irregular. Regular Time-Series data are obtained from measurement sources provided by software or hardware sensors at real-time intervals (for example, every 10 seconds). Irregular Time-Series are data obtained from events created by users. An example of irregular data is summarizing the average response time for application requests at one-minute intervals or displaying the average trading price of Apple stocks every 10 minutes during the day. (Dix, 2003)

There are advantages and disadvantages to using time-series databases compared to relational databases. One advantage of time-series databases is the shorter time needed to execute aggregation functions over data. In the paper "Comparison of Relational and Time-Series Databases for Real-Time Massive Datasets" an experiment was conducted on InfluxDB as a time-series database and PostgreSQL as a relational database, where the advantages of using time-series databases were proven. The research showed that the execution time for the aggregation operation with time interval constraints is 46.87%-77.62% shorter when using InfluxDB compared to PostgreSQL. The experiment results demonstrated that InfluxDB performs aggregations with time interval constraints and groups results by time interval 76.82% - 95.30% faster. Additionally, the execution time for aggregation with time constraints and grouping results by indexed attribute/tag is 24.76%-63.20% shorter than the PostgreSQL database.

Time-Series databases form the foundation of IIoT systems, enabling intelligent control of production processes, data analysis of industrial environments, and many other parameters that can improve production. Traditional databases face challenges in obtaining insights that are not immediately obvious from the data but can be discovered through detailed analysis or by applying advanced methods such as machine learning or deep learning algorithms. (Ren, Jia, Laili, & Huang, 2023)

4 INFLUXDB

Accurate measurement of industrial environment parameters using various sensors is essential to IIoT systems. These sensors collect and transmit a large amount of data that can impact production. Companies must understand this technology and its advantages by analyzing data obtained from the environment and machines in production. (InfluxDB, 2024)

Time-series data are the essence of IIoT systems and the Industrial Revolution 4.0. The characteristics of Time-Series data align with the principles prescribed by Industry 4.0, which are:

- **Connectivity:** The mutual communication of sensors, devices, and machines with people.
- **Information transparency:** This connectivity ensures the system collects large amounts of data, which, after analysis, is easily accessible to all personnel working in production.
- **Technical assistance:** Programs that, in addition to data collection, also perform visualization of analyzed data to help employees make decisions and solve problems on the go.
- **Decentralized decisions:** The inclusion of artificial intelligence, which autonomously decides and takes the following steps based on the collected data, makes production processes more efficient and requires human intervention only in exceptional situations.

InfluxDB, an open-source project created by InfluxData, is a Time-Series database central to many IIoT data storage solutions, enabling high ingestion rates, compression, and real-time querying. The foundation of IIoT systems, on which a stable connection can be scaled, lies in the efficient data storage structure, allowing flexibility and speed in visualization, querying, and alerting. (InfluxDB, 2024)

Here are some advantages of using InfluxDB in IIoT systems:

- **Open technology:** InfluxDB offers flexibility in system development as an open-source project. It allows easy adaptability in development, simple access, and easy availability of information.
- **Query languages:** InfluxDB supports SQL and SQL-like InfluxQL languages. SQL is the universal language. The ability to use multiple query methods provides additional flexibility.
- **Scalability:** Resources and infrastructure are two key features related to the scalability of InfluxDB. InfluxDB is a system capable of managing resources. It can scale to adapt to data input needs. It is optimized to handle large amounts of Time-Series data without affecting performance. It can write large data sets quickly and be available for queries simultaneously.
- **Multiple deployment options:** InfluxDB is cloud-native but offers on-premises implementation for local systems. Besides these two options, it is compatible with edge deployments, allowing organizations to collect and process data closer to the data sources.

By implementing IIoT solutions that include InfluxDB, industries can rely on advanced real-time analytics, using large amounts of data for AI/ML improvements. This database is adaptable to cloud and local systems, ensuring constant and stable data exchange. (InfluxDB, 2024)

5 EXAMPLE OF IIoT SYSTEM BASED ON INFLUXDB – DUST MONITORING SYSTEM IN THE ELECTRONIC PRODUCTION

Dust monitoring in electronics manufacturing is crucial in maintaining product quality, worker health, and machine operation. The presence of dust in electronics manufacturing can significantly impact product quality. Dust falling on PCBs' electronic components can cause corrosion and oxidation. Workers exposed to dust released during electronics production, which may contain harmful particles such as metals, glass, or plastic, can develop respiratory problems. Dust can clog ventilation openings, coolers, and other parts of industrial machines, potentially leading to failures. Regular monitoring enables the detection of potential issues before they result in more severe failures. With an appropriate monitoring system, worker safety is ensured, product quality is improved, and the lifespan of equipment in production is extended.

Dust monitoring can be implemented by developing an IIoT system whose architecture consists of devices for collecting information on the presence of PM particles in the air and a server that collects models and displays the data. The IIoT system for dust monitoring combines hardware (ESP8266 D1 Mini boards and PMS7003 sensor) with a server (Raspberry Pi) on which data storage, processing, and visualization programs are installed.

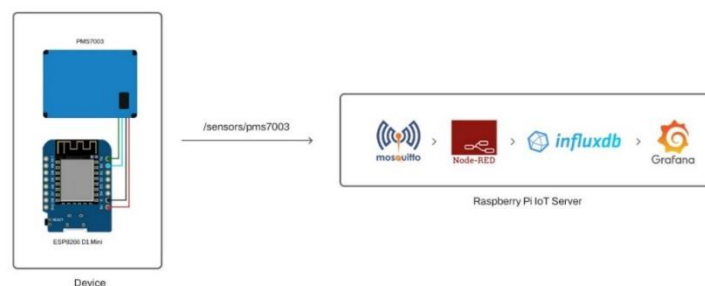


Figure 2: System structure

The criteria for selecting the development board for the device included small size, wireless data transmission capability, low power consumption, serial communication capability, and adequate memory space on the chip. The wide selection of development boards suitable for a device aimed at collecting data from sensors and transmitting it wirelessly was narrowed down to the WeMos D1 Mini board choice with the ESP8266 microcontroller. This development board is very small in size, uses the 802.11b/g/n wireless communication protocol, has 11 Digital IO pins, and all IO pins except D0 are capable of PWM, Interrupt, I2C, and 1-wire interfaces. It also has 4 MB of Flash memory. (Gaikwad, Joshi, Mudaliar, Naik, Gudal & Bhandari, 2020)

The requirements for the air particle detection sensor include a low false reading rate, real-time response, accurate data, minimal detectable particle diameter, high resistance to interference, and optional air input and

output directions. The sensor that is compatible with the development board and meets the system requirements is the PMS7003. The PMS7003 uses the laser scattering method to measure the concentration of particles in the air. The laser emits light beams, and the sensor analyzes the scattered light to determine the number and size of particles. The PMS7003 can measure particles in the ranges of PM1.0, PM2.5, and PM10, which are 10 micrometers in diameter and larger. (Plantower, 2015)

The hardware selected for the IIoT server is the Raspberry Pi 4 with 4GB of RAM. Its performance meets the intended purposes of the system. Four main applications are installed on the server: Mosquitto - MQTT broker, Node-Red, InfluxDB, and Grafana. These applications are run through DOCKER containers.

Communication between the hardware and the server is carried out using the MQTT protocol. The system's combination of the ESP8266 and the PMS7003 sensor represents an MQTT Client, which sends the collected data to the MQTT Broker (Mosquitto) using the MQTT protocol. Relative to the hardware that sends the data, Node-RED acts as an MQTT Client that reads data from the MQTT Broker.

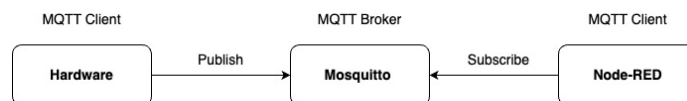


Figure 3: Communication folow

In the Node-Red application, three elements are defined. The first element sets the MQTT topic for data collection, the second defines the method for formatting the message into JSON, and the third element is responsible for writing data into the InfluxDB database.

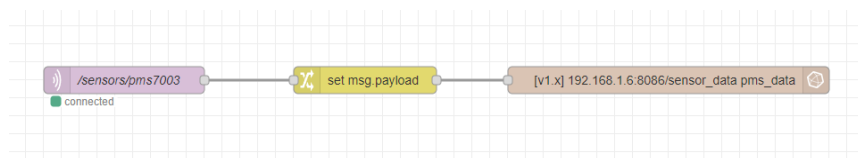


Figure 4: Node-RED System flow

The criteria for selecting the database used in this project are as follows: to be time-series, open-source, easily scalable, with fast response times, and compatible with Raspberry Pi architecture. The InfluxDB OSS database fulfills these requirements and others that meet the system's purpose. InfluxDB OSS is an open-source time series platform for storing, querying, and analyzing time-series data. InfluxDB integrates into Node-RED via node-red-contrib-influxdb. This option allows data collected through Node-RED to be stored in the InfluxDB database.

A database named PMS7003DB has been created, located on port 8086. After creating the database and successfully connecting it with Node-RED, data started to be automatically written to it according to the rule specified in the “Change node” (Figure 5).



Figure 5: Node-RED change node

Values obtained from the PMS7003 sensor, sent to the Node-RED application, are stored in the database using fields named psm_1_0, psm_2_5, and psm_10_0.

Grafana is an open-source web application for data visualization. It is commonly used for displaying and monitoring data in IoT systems. It provides the capability to display data through charts, diagrams, and real-time data output. It easily integrates with various types of databases and supports direct integration with InfluxDB. (Ndukwe, Iqbal, & Khan, 2020)



Figure 6: Node-RED System flow

Connecting Grafana and InfluxDB is done directly in Grafana's settings by defining the address, port, and database name. After establishing communication between Grafana and the database, creating a dashboard with the desired display is necessary. This example required showing measurement history and current states. Based on this, a dashboard was designed to display the history of PM1.0, PM2.5, and PM10 measurement results in charts. In addition to the charts, the dashboard also includes the current measured particle concentrations (Figure 6).

After setting up the system, a multi-day testing phase followed under experimental conditions. The testing required changing the data transmission frequency from the device, physically relocating the device, altering the data refresh rate in Grafana, and exposing the device to more dust. The test results showed that the choice of hardware and database performed very well. Changing the data transmission rate did not affect the data writing speed in the database. Relocating the device and exposing it to a higher amount of dust demonstrated accurate measurement and display of dust levels in Grafana.

6 DISCUSSION

6.1 Advantages and Disadvantages of Using Time-Series Databases

This paper examined the pros and cons of using Time-Series databases, such as InfluxDB, compared to relational databases. Time-series databases allow more efficient data analysis for data recorded at specific time intervals, which is important for applications that monitor and analyze industrial parameters. The advantages include fast data writing and better compression, which is particularly significant for programs that require real-time analysis. However, the challenges include the complexity of setting up and maintaining such databases and the need for additional education and specialized knowledge in the field of Time-Series databases.

Time-series databases, like InfluxDB, are crucial for efficiently collecting, storing, and analyzing continuously generated data in real-time. For IIoT systems, which rely on constant data collection from sensors, these databases provide optimal solutions for managing large volumes of data.

6.2 Results and Analysis

One of the main challenges in using IIoT solutions is collecting and processing large amounts of data in real-time. Time Series databases, such as InfluxDB, can improve the development of IIoT systems. The implementation of the system has shown that the chosen hardware and software, including ESP8266 D1 Mini boards and PMS7003 sensors along with applications on the Raspberry Pi 4, can efficiently collect, process, and visualize data on the presence of dust particles. Testing the system in various conditions, including changing the data transmission frequency, physically moving the devices, altering the data refresh rate in Grafana, and exposing the devices to higher amounts of dust, demonstrated high reliability and

accuracy in measurement and result display.

6.3 Advantages of the Used Solution

1. Flexibility and Scalability:

The selected components of the system, particularly the InfluxDB database, demonstrated high flexibility and scalability. InfluxDB provides high-speed data ingestion, processing, and compression of large volumes of data in real-time, which is a fundamental requirement for IIoT systems. InfluxDB stored data on dust levels collected by the PMS7003 sensors in the analyzed monitoring system, enabling immediate access and analysis of that data. The performance of the InfluxDB database was not compromised even with large volumes of data, which is a significant advantage for industrial applications.

2. Efficient Data Structure:

Time series data are structured to include measurements, tags, fields, and timestamps. This database format enables precise data entry and analysis, a key feature of industry monitoring systems for dust levels. InfluxDB's adaptable structure allows for the easy addition of new sensors. The system's operation demonstrated successful measurement, data storage, and display of dust levels with high accuracy, as confirmed by experimental testing.

3. Simple Integration and Visualization:

Combining tools such as Node-RED for data flow, Grafana for visualization, and InfluxDB enabled the successful collection, processing, and display of data. Node-RED facilitated easy data routing from sensors to InfluxDB, while Grafana provided real-time viewing and analysis of this data through graphical displays and dashboards.

6.4 Challenges and Limitations

InfluxDB enabled fast processing and data accessibility, which was crucial for real-time monitoring and responding to changes in dust levels. The system can be easily expanded by adding new sensors and parameters without significant changes to the database or infrastructure. Integration with Grafana allowed for easy data analysis and display, facilitating decision-making based on accurate information. One of the tasks related to a system of similar purpose is the need for stable network communication to ensure continuous data transmission from sensors to the database. Although InfluxDB is adapted for large volumes of data, constant monitoring and maintenance of the system are required to ensure optimal performance.

7 CONCLUSION

The system for monitoring parameters in an industrial environment based on IIoT technologies offers many benefits. Applying such technology improves production process efficiency and increases the autonomy and adaptability of production to the environment. The use of a combination of devices such as the ESP8266 D1 Mini and PMS7003 sensors, along with applications like Mosquitto, Node-RED, InfluxDB, and Grafana installed on a Raspberry Pi 4, enables the collection, storage, and visualization of dust level data in real-time.

Time Series databases, such as InfluxDB, demonstrate many advantages over traditional relational databases. These databases allow for faster data recording and better compression, which is especially important for IIoT applications that require real-time data analysis. However, challenges include the complexity of setting up and maintaining these databases and the need for additional education and specialized knowledge in this field. InfluxDB provides rapid data entry, processing, and compression, efficiently managing large volumes of data generated in real-time. Testing the system under experimental conditions showed that changes in data transmission frequency, physical relocation of devices, and exposure to higher dust levels do not negatively impact system performance, confirming its reliability and accuracy in measuring dust levels.

This study has shown that using IIoT technologies in the industry helps improve processes and efficiency. Time Series databases, such as InfluxDB, enable rapid data collection and analysis, which is crucial for enhancing the performance and accuracy of analytical processes in industrial environments. The example presented in this paper can be used in the educational process at universities as a platform for student projects and prototyping, because of its low cost, availability, and scalability. Future research can address the

challenges related to integrating such systems in educational process and improving the education of students and professionals working with advanced IIoT technologies.

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Online Exam Proctoring System – Student Perspective

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Abstract. Online proctoring systems have become increasingly prevalent as educational institutions shift towards remote learning and assessments. However, while these systems offer significant benefits in terms of maintaining academic integrity, their impact on students' experiences remains underexplored. This study aims to evaluate an online proctoring system from the student perspective, focusing on factors such as usability, fairness, data privacy, and the psychological impact of surveillance during exams. A survey was conducted with students who experienced the proctoring system during online exams, with questions addressing various aspects of the system's effectiveness, usability, and perceived fairness. Results are discussed and conclusions are drawn.

Keywords and phrases: Proctoring system, online exam, artificial intelligence, Safe Exam Browser.

1 INTRODUCTION

In the rapidly evolving landscape of digital education, online examinations have emerged as a critical component of academic assessment, particularly in the conditions of global disruptions such as the COVID-19 pandemic. The unprecedented shift towards remote learning and digital assessment methodologies has fundamentally transformed traditional educational evaluation paradigms, presenting both unprecedented opportunities and significant challenges. In addition, rapid development of AI and its wide range of application in multiple sectors such as medicine (Chabra et al., 2013), (Stojanov & Koceski, 2014), (Kotevski et al., 2024), healthcare (Devedžić et al., 2021), (Stojanova et al., 2019), social care (Koceski & Koceska, 2016), (Koceska et al., 2019), robotics (Koceska et al., 2013), (Velinov et al., 2024), finance, business (Kirovska & Koceski, 2015), is significantly changing the entire sector of education (Duh et al., 2017), (Koceski & Koceska, 2022), (Koceska et al., 2024). While digital assessment methods offer unprecedented flexibility, accessibility, and potential for innovative evaluation techniques, they simultaneously raise complex questions about academic integrity, student privacy, technological equity, and the psychological well-being of learners.

The global transition to online examinations has been accelerated by technological advancements, institutional adaptability, and external pressures such as global health crises. However, this rapid transformation has not been uniformly smooth or successful across different educational contexts. Varying technological infrastructures, institutional readiness, and student preparedness have created a complex ecosystem of digital assessment practices that demand rigorous scholarly investigation. Research from diverse educational settings has revealed significant disparities in the implementation, effectiveness, and student experience of online examination platforms.

The landscape of academic integrity is increasingly complex, with student cheating behaviors evolving in tandem with technological advancements. Empirical research consistently demonstrates the persistent challenge of academic dishonesty in online examination environments. A study by McCabe et al. (2001) revealed that approximately 64% of undergraduate students engage in some form of academic cheating, a trend that has been exacerbated by digital technologies. More recent investigations suggest that online examination platforms create unique opportunities for academic misconduct, including sophisticated cheating strategies that leverage technological tools.

Contemporary cheating behaviors have become increasingly sophisticated, transcending traditional methods of plagiarism and unauthorized collaboration. Students now employ a range of technological strategies, including:

- Use of hidden communication devices
- Advanced screen-sharing techniques
- AI-powered answer generation
- Collaborative online platforms for real-time problem-solving
- Sophisticated impersonation methods
- Exploitation of proctoring system vulnerabilities

In addition, technological safety emerges as an additional concern in this digital assessment landscape. Cybersecurity threats, potential data breaches, authentication challenges, and the risk of academic misconduct represent critical areas of research. Moreover, the psychological dimensions of online examinations—including student stress, anxiety, technological self-efficacy, and perceived fairness—are equally crucial in understanding the holistic experience of digital assessment. These multifaceted challenges necessitate a comprehensive, student-centered approach to understanding and improving online examination practices.

Existing literature demonstrates varied perspectives on online examination safety. Some studies have emphasized technological solutions, focusing on robust authentication mechanisms, secure browser technologies, and advanced proctoring techniques. Others have explored psychological and pedagogical dimensions, investigating how digital assessment formats impact student performance, stress levels, and learning outcomes. However, a significant research gap persists in synthesizing these perspectives and centering the student voice in understanding what constitutes a "safe" online examination experience.

This research aims to bridge this critical knowledge gap by conducting a comprehensive, mixed-methods investigation into students' perspectives on online examination safety. This seeks to provide a nuanced understanding of the multiple dimensions of safety in digital assessment. In the following the developed system for proctored online examination is described and evaluated. The conclusions are derived and discussed.

2 STATE OF THE ART

Research has consistently highlighted concerns regarding academic integrity in online learning environments. Studies across different academic settings have demonstrated that students perceive online environments as more conducive to academic dishonesty (King et al., 2009). This perception is supported by quantitative data, with Watson and Sottile's (2010) comprehensive study of 635 participants revealing students' self-reported likelihood of engaging in dishonest behavior was approximately four times higher in online settings. These findings align with multiple research efforts documenting elevated rates of academic misconduct in virtual learning environments (Lanier, 2006; Harmon & Lambrinos, 2008; Dietz-Uhler & Hurn, 2011).

Recent research has focused on integrating multiple detection channels to create comprehensive proctoring solutions. A notable advancement in this field employs a cost-effective dual-camera setup combined with audio monitoring. An approach that synthesizes six fundamental detection elements: identity verification, textual content analysis, audio monitoring, browser activity tracking, gaze tracking, and mobile device detection (Atoum et al., 2017). With the development of technology other methodologies are tested. In order to investigate the usage of the 360-degree security camera over the traditional webcam, practical study was conducted (Turani et al., 2020). It claims that this approach can enhance the exam security and minimize the stressful restrictions.

Significant developments have emerged in the application of visual analytics for examination monitoring. Sophisticated algorithms to analyze both head movements and cursor activity patterns were developed (Li et al., 2021). These systems provide educators with intuitive visualization tools that enable efficient monitoring of student behavior during online assessments. The integration of behavioral analysis has proven particularly effective in identifying suspicious patterns that may indicate academic dishonesty.

The shift toward online learning has necessitated innovative approaches to maintaining academic integrity. Holden et al. (2021) emphasize the unique challenges inherent in online education, where student autonomy and physical separation from instructors create verification difficulties. Modern automated proctoring solutions have evolved to incorporate comprehensive monitoring capabilities. Awaghade et al. (2022) introduced a framework providing a versatile, fully computerized system accessible to both administrators and test takers. Current systems feature:

- Real-time screenshot capture
- Environmental audio analysis
- Tab switching detection
- Copy-paste restriction mechanisms
- Advanced head movement tracking
- Facial feature analysis
- Multi-person detection
- Continuous presence verification

The implementation of deep learning techniques has marked a significant advancement in online proctoring systems. Ahmad and Mehmood demonstrated the effectiveness of biometric techniques using OpenCV face recognition and HOG detection (Ahmad et al., 2021). Yadav and Singh (2016) further showed how computer vision techniques could be effectively integrated into proctoring systems incorporating:

- Object framing and recognition
- Image processing algorithms
- Scale-invariant detection methods
- Movement tracking
- Environmental analysis

Research examining the relationship between proctoring methods and academic performance presents varied conclusions. Several studies report significantly higher performance in non-proctored online examinations compared to proctored settings (Schultz et al., 2007; Alessio et al., 2017; Richardson & North, 2013). However, contrasting research has found no significant performance variations between proctored and non-proctored online assessments (Ladyshevsky, 2015; Yates & Beaudrie, 2009; Beck, 2014).

Ingram et al. (2018) identifies three critical selection factors for institutions:

- Financial considerations
- Security requirements
- Technology accessibility for faculty and students

Secreto et al. (2015) emphasized the importance of integrating technological solutions with institutional support structures. Tripathi et al. (2024) further highlighted how remote investigation and monitoring are becoming increasingly crucial for maintaining credibility in MOOCs and credit-based certifications. Daffin & Jones (2018) developed a comprehensive comparison framework examining various aspects of online proctoring services.

3 SYSTEM ARCHITECTURE

Our comprehensive proctoring system for remote examination integrates multiple security layers to enhance assessment validity. The system architecture (Figure 1) combines three primary components: custom made examination system, a specialized secure browser environment based on Safe Exam Browser, and advanced real-time video monitoring and alerting system. The main aim of this system is to help professors to facilitate and automate the process of examination of big groups of students at the Faculty of Computer Science at Goce Delcev University. Moreover, it is aimed at helping students to facilitate the examination process, especially in subjects where coding is needed to solve practical problems. Solving coding problems during

exam using pen and paper is really difficult for students as they are not aware of any bugs and syntax errors. Therefore, we build a custom examination system that includes online compilers and enables real-time preview of the results on various test cases.

The examination platform employs a specialized secure browser Safe Exam Browser that provides comprehensive system control by restricting access to external applications and preventing concurrent browser sessions. This secure environment actively blocks background processes while disabling clipboard functionality to prevent unauthorized data transfer. The system maintains secure communication channels with the examination server via internet or local network connectivity to ensure continuous monitoring integrity. The system supports flexible device configurations while maintaining strict security protocols across various hardware platforms. The primary monitoring interface operates seamlessly across desktop computers, laptops, and mobile devices.

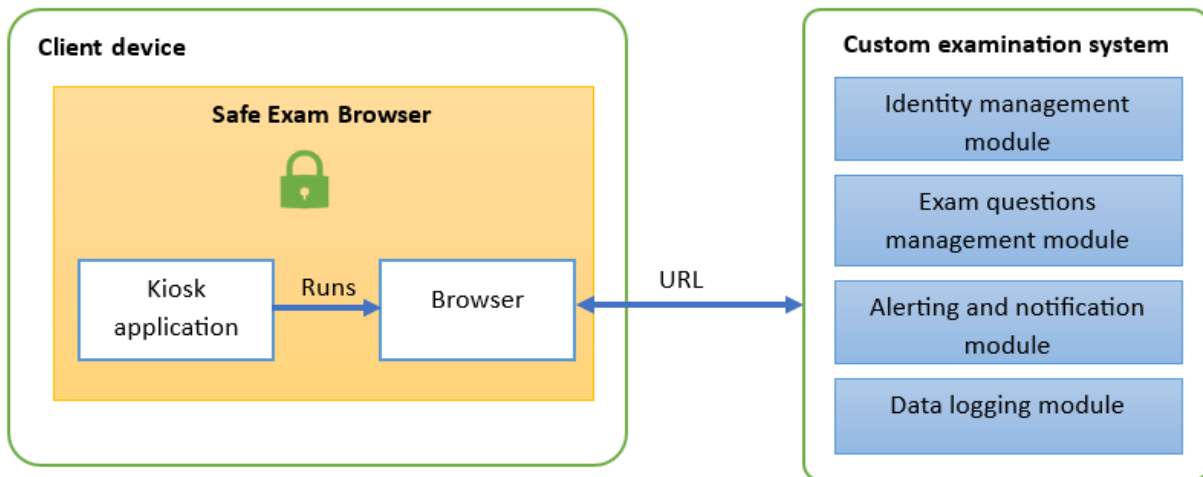


Figure 1. System architecture overview

To provide monitoring coverage, the system enables recording the students with primary web camera that is capturing the student's face. In order to protect students' privacy, the video capture is analyzed on client side and just information about the head pose and sound events are streamed to the server. Moreover, the system is rising alarms directly on client side as well as on the supervisor's side. This kind of alerting system should interrupt an attempt for cheating and should prevent potential academic integrity violations.

Faculty members can conduct real-time monitoring of examination sessions while the system maintains robust authentication protocols throughout the assessment period. This real-time monitoring approach ensures immediate detection of potential integrity concerns while providing a secure and controlled examination environment.

The system employs a sophisticated combination of identity verification and continuous monitoring protocols. The mandatory front-facing camera serves dual purposes, facilitating both initial authentication and ongoing behavioral observation. This integrated approach ensures consistent verification of student identity while maintaining the integrity of the examination process through continuous surveillance.

The platform's design accommodates various educational contexts and technical requirements while maintaining rigorous security standards. This flexibility allows institutions to implement custom monitoring configurations based on specific assessment needs while ensuring consistent security protocols across all examination scenarios.

4 SYSTEM EVALUATION AND DISCUSSION

The system was evaluated on a group of 60 students (28 females and 32 males) attending the course Basics of computer science taught in first year of bachelor studies in both Macedonian and English languages at the Faculty of Computer Science, at Goce Delcev University. All the students were following this course for the first time. The system was tested during mid-term course evaluation related to Web Development Fundamentals. This module forms a core component of the BSc curriculum, introducing students to essential

client-side web technologies. This assessment framework evaluates students' practical understanding of HTML, CSS, and JavaScript while emphasizing industry-relevant application. Before the exam all the students were introduced to the Safe Exam Browser environment and the way it works. They have all logged in to the examination system and tried the system several times before the examination, solving similar practical problems during their laboratory exercises' hours.

All the students were informed that the web cams will be capturing their face, but no recording will be stored on the local devices nor on the server. Instead, just numerical parameters will be calculated and eventually stored during the examination process. Once the Safe Exam Browser loads the web application on the dedicated address, all students were able to authenticate and the examination environment was active. It consists of navigation toolbar with basic commands to contemporary save the answers, to compile and run the solution, as well as to select one of the given problems. The central portion of the application is divided in two main panels: the left one containing basic text editor to write the code, and the right one aimed at previewing the result after compile. The system is auto-saving the current version of the solution each minute. On the top bar a red visual indicator for eventual suspicious behavior of the student is placed. It starts blinking whenever the AI algorithm for head pose estimation combined with sounds analyzer detects potentially irregular behavior (Figure 2). The algorithms are based on MediaPipe and OpenCV and implemented in Javascript.

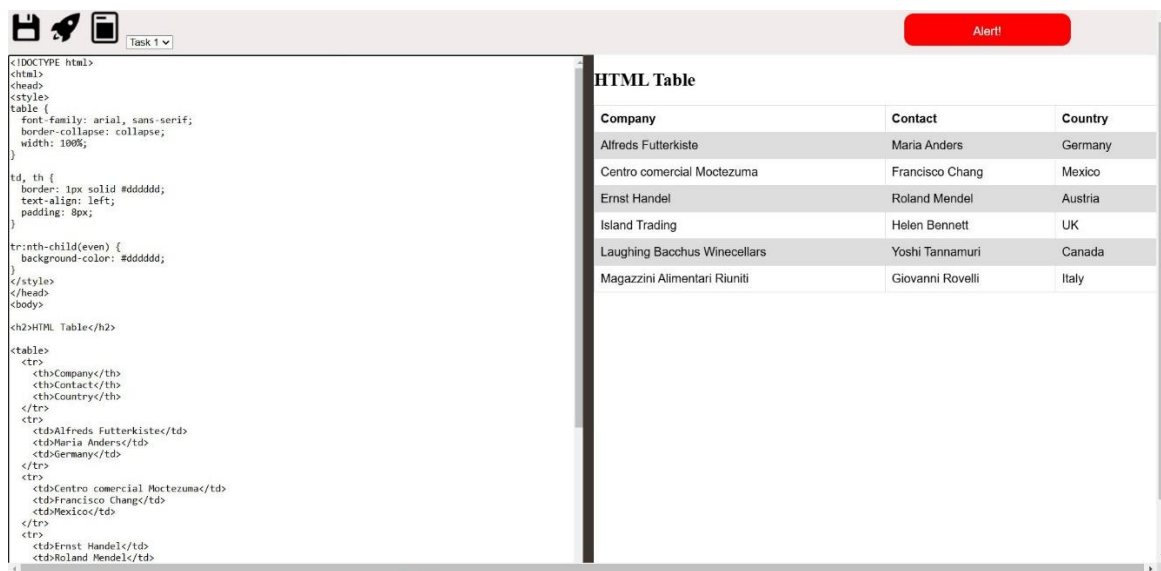


Figure 2. Examination platform screen

The examination session was lasting for 45 minutes and after its end each student was asked to fill in a questionnaire with several questions. All the students without exception have answered all the questions and all of them were taken into consideration for the analysis. The questions (Table 1) were divided in multiple categories each of them aiming at collecting the students' viewpoints on different aspects of the system. Students were asked to answer each question using the Likert scale from 1-5 (1 meaning low and 5 meaning high). Detailed descriptive statistics for the questions 5-13 is presented in Figure 3.

	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13
count	60	60	60	60	60	60	60	60	60
mean	4.2	3.8	4.9	1.8	3.2	3.5	4.6	3.8	4.2
std	0.65871	0.731842	0.354152	1.176032	0.879137	0.624364	0.643086	0.65871	0.65871
min	3	2	3	1	2	2	3	3	3
25%	4	3	5	1	3	3	4	3	4
50%	4	4	5	1	3	3	5	4	4
75%	5	4	5	2	4	4	5	4	5
max	5	5	5	5	5	5	5	5	5

Figure 3. Descriptive statistics for questions 5-13

The distribution of the given responses is given in Figure 4, while the correlation heatmap of the responses given by the students is presented in Figure 5.

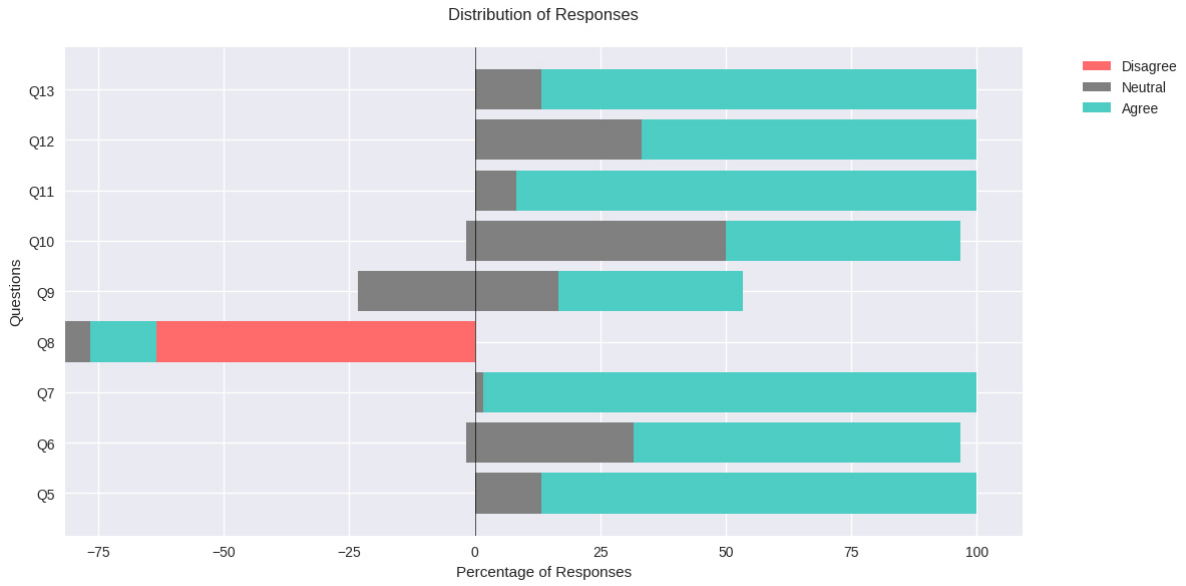


Figure 4. Distribution of responses

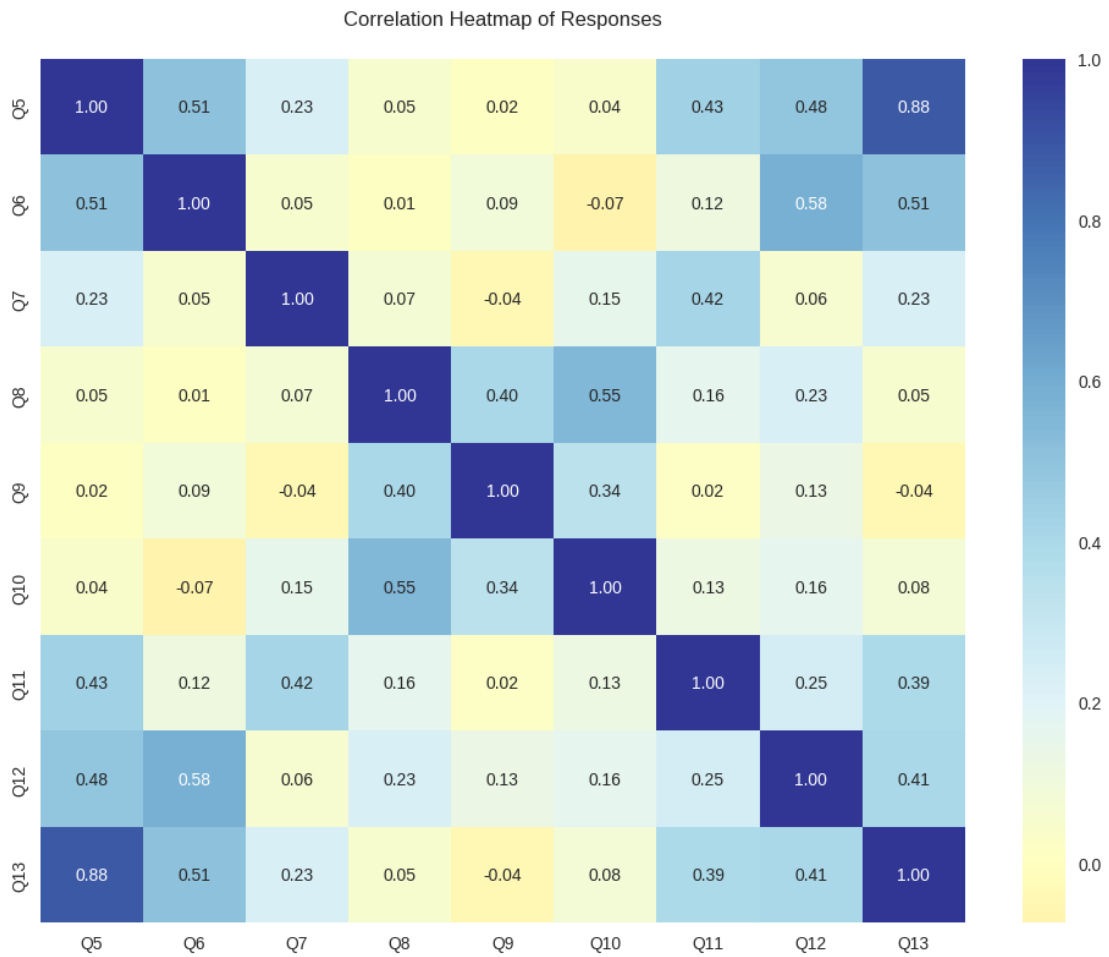


Figure 5. Correlation heatmap of responses

The average grade provided by the students on all the questions from the first group (1-4) was 5. Firstly, this unanimous high rating could indicate that the system is user-friendly and accessible, as students found it easy to set up and operate on their devices without encountering significant technical barriers. This ease of use likely reflects well-designed software and user interfaces, which may have minimized common issues like device compatibility, connectivity disruptions, or complex setup requirements. Additionally, such high ratings suggest that the system's instructions were likely clear and intuitive, empowering students to feel confident in using the proctoring technology during the exam process.

The high usability score also implies a positive overall user experience, as students were able to focus on their exams without unnecessary technical distractions or interruptions. The lack of reported issues during setup and throughout the exam indicates that the system likely maintained a stable connection and functioned reliably under exam conditions, which is crucial for high-stakes testing environments.

Table 1. Evaluation questions

Question No.	Category / Questions	Average score
	Technical usability	
1	How easy was it to set up the proctoring system on your device?	5
2	Did you experience any technical difficulties (e.g., camera or microphone issues, internet connectivity) during the exam?	5
3	How reliable was the system in terms of staying connected throughout the entire exam?	5
4	Were the instructions for using the proctoring system clear and easy to follow?	5
	Privacy and security	
5	How comfortable did you feel with the level of surveillance during the exam?	4.2
6	Do you have any concerns about the data being collected and how it is stored or used?	3.8
7	Were you informed about the data privacy policy of the proctoring system before using it?	4.9
	Exam experience	
8	Did the presence of the proctoring system impact your ability to focus on the exam?	1.8
9	How stressed or anxious did the proctoring system make you feel during the exam?	3.2
10	Did you feel that the proctoring system was fair and unbiased in monitoring your actions?	3.5
11	Was online exam convenient and flexible?	4.6
	System Efficiency and Accuracy	
12	Were there any false alerts or misunderstandings by the proctoring system regarding your behavior?	3.8
13	Did the proctoring system successfully identify and prevent any cheating attempts as far as you know?	4.2

A relatively high score of 4.2 on question 5 indicates that students generally felt comfortable with the level of surveillance during the exam. This comfort level suggests that the proctoring system's design, transparency, or unobtrusive nature likely contributed to a positive perception. Students may have perceived the monitoring as necessary for maintaining integrity, and it appears that this monitoring did not excessively impact their sense of privacy. With a slightly lower score of 3.8 on question 6, some students expressed moderate concerns about data collection and its usage or storage. This score suggests that while students accepted surveillance during the exam, there may still be underlying apprehensions regarding how their data is handled post-exam. Addressing these concerns, such as by reinforcing transparency about data use, could further alleviate student reservations. A near-perfect score of 4.9 on question 7 shows that students felt well-informed about the data privacy policy. This high score reflects that the proctoring system or institution took effective steps to educate students on privacy practices, which likely contributed to their overall comfort. It underscores the importance of clear communication and transparency regarding data handling, a critical factor in fostering trust in proctoring systems.

An average score of 1.6 on the question 8, suggests that the proctoring system had a minimal impact on students' concentration during the exam. This low score implies that most students felt the proctoring system did not distract or hinder their focus, which is a positive indication of the system's unobtrusiveness. A non-intrusive proctoring environment is crucial, as it allows students to remain focused on their tasks without feeling overly monitored or stressed by the system's presence. This minimal perceived impact may indicate that the proctoring system operates quietly in the background and does not involve frequent prompts, notifications, or invasive checks that could otherwise disrupt students' attention.

With a score of 3.2 on question 9, students experienced a moderate level of stress or anxiety due to the proctoring system during the exam. This indicates that, while the system may not have been overwhelmingly anxiety-inducing, it did cause some degree of discomfort. This could be due to factors like the awareness of constant monitoring, which may have heightened students' self-consciousness or concern about being misunderstood by the system. To reduce stress, adjustments like providing familiarization sessions or incorporating a less intrusive setup could be considered. A score of 3.5 on question 10 reflects a moderate level of confidence in the fairness and objectivity of the proctoring system. While some students likely trusted the system to monitor them fairly, others may have been unsure, potentially due to concerns about misinterpretation of actions or potential biases in the technology. This score suggests that while fairness was generally accepted, there is room for improvement. Increased transparency about how the system detects and evaluates student actions, along with safeguards to ensure impartiality, may enhance perceptions of fairness. A score of 4.6 on the question 11 regarding the convenience and flexibility of online exams indicates a very high level of satisfaction among students. This suggests that students greatly appreciate the adaptability and ease that online exams provide, likely valuing the ability to test the codes and preview results and avoid spelling or syntax errors. A score of 3.8 for the question 12 about false alerts or misunderstandings indicates a moderate level of concern among students regarding the accuracy of the proctoring system. While it suggests that the system generally performed well, occasional misinterpretations of student behavior may have occurred, potentially leading to a few unwarranted alerts. On the other hand, a score of 4.2 for the question 13 about the system's ability to identify and prevent cheating attempts reflects a high level of confidence in the effectiveness of the proctoring system. Students generally feel that the system is successful in monitoring exam integrity, which suggests they trust its role in ensuring fairness. This positive response indicates that, despite some minor issues with false alerts, the proctoring system is perceived as effective in fulfilling its main purpose of preventing cheating, contributing to a more secure and trustworthy exam environment.

By centering student experiences and perspectives, this research aspires to contribute to a more holistic, empathetic, and strategically informed approach to digital assessment in contemporary educational landscapes.

5 CONCLUSION

Based on the evaluation of the online proctoring system, several key recommendations can be drawn for the development and enhancement of future proctoring systems, ensuring they are both effective and user-friendly. It is crucial that users are clearly informed about how their data will be collected, stored, and used. Providing transparent privacy policies and clear communication about data handling practices is essential in building trust with users. Systems that offer easy access to privacy-related information and ensure compliance with data protection regulations (e.g., GDPR) will foster a more secure and trustworthy environment for students. Although the system was generally perceived as minimally stressful, it is important to design proctoring systems that limit any potential anxiety associated with surveillance. Offering students reassurance through transparent communication about the purpose and fairness of the monitoring system, as well as providing an option for students to ask questions or seek clarification, can help reduce feelings of unease. False alerts and misunderstandings by the system can cause unnecessary distractions for students. Proctoring systems must be equipped with highly accurate algorithms to differentiate between legitimate behavior and potential violations, ensuring that the monitoring process is as seamless and error-free as possible. Regular updates and training of AI models can help to improve accuracy and reduce false positives. Maintaining fairness in the proctoring process is vital. Students should feel confident that the system is unbiased and equally effective for all exam-takers, regardless of their backgrounds. It is important to implement regular checks and balances to ensure that monitoring does not disproportionately target certain groups of students or introduce any form of bias. Proctoring systems should be designed with flexibility in mind, allowing students to take exams with minimal interference while ensuring integrity. High system availability, low resource usage, and easy integration with existing learning management platforms can enhance the overall user

experience. Additionally, providing users with control over minor preferences and offering support channels for technical issues will further improve satisfaction. It is essential to continuously assess the effectiveness of proctoring systems through user feedback and performance data. Regular monitoring and updates based on real-world user experiences will help to fine-tune the system, address emerging challenges, and improve its overall reliability over time.

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Review on Software Applications for Children with Dyslexia

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Abstract. Dyslexia is a neurodevelopmental disorder affecting reading, spelling, and writing abilities, quite common among 5% to 17% of the general population. Traditional approaches to education often fail to respond to the special needs of dyslexic learners. That is why this scoping review investigated how ICT tools—web applications, desktop software, and mobile apps—may provide support for children with dyslexia. Key features include TTS, STT, dyslexia-friendly fonts, and adaptive learning paths that provide multisensory environments to address phonological processing and memory challenges. These tools have been shown to improve reading comprehension, writing skills, and engagement by providing flexible and interactive learning experiences. However, access to these technologies is not always equitable, especially in low-resource settings, and there is a need for further research on their long-term effects. Finally, emerging technologies such as virtual reality and artificial intelligence are promising avenues toward the further enhancement of interventions for dyslexia. This review points out the transformative role of ICT in supporting dyslexic learners and calls for continuing innovation to ensure that learning environments become increasingly inclusive.

Keywords and phrases : Dyslexia, Information and Communication Technology (ICT), Assistive technology, Reading interventions, Multisensory learning

1 INTRODUCTION

Dyslexia is a neurodevelopmental learning disorder that primarily affects an individual's ability to read, spell, and write, often despite normal intelligence and adequate educational opportunities. Dyslexia is often described as a condition that leads to surprisingly critical problems in school and everyday life due to deficits in phonological processing and decoding skills. Estimates say that dyslexia might affect up to 5% to 17% of the population (Olivier & Nell, 2020), although the exact prevalence is rather difficult to identify due to the variations in diagnostic criteria, assessment procedures, and awareness across countries (Lerga et al., 2021).

Early diagnosis is critical to the effective management of dyslexia, which may cause major effects on academic achievement and general well-being. Dyslexia can be diagnosed through a complete educational and psychological examination that accounts for reading fluency, phonological awareness, and memory skills. These examinations can usually be carried out by educational psychologists or specialists trained in disorders related to learning. In the absence of intervention, dyslexia may progress to long-term school failure, a decrease in self-esteem, and psychological problems such as anxiety and depression (Wilmot et al., 2023).

Early intervention, especially at the primary level, can greatly change the outcome of the dyslexic child. Dyslexia is best managed through a multisensory approach to learning that integrates visual, auditory, and kinesthetic techniques to strengthen reading skills. One of the most widely applied methods is the Orton-Gillingham approach, which aims to be explicit, direct, and individualized in nature for each student. This multi-sensory approach can be extremely helpful in teaching children with dyslexia and other learning

disabilities using contemporary ICT devices like touch-screens, accelerometers, gyroscopes, voice recognition, sound reproduction, as well as various other software tools.

Moreover, recent developments in AI, particularly in generative AI, are rapidly penetrating various sectors of society, transforming industries with unprecedented efficiency and scalability. Multiple AI tools, are not only revolutionizing content creation in media and entertainment but are also reshaping fields like medicine (Chabra et al., 2013), (Stojanov & Koceski, 2014), (Kotevski et al., 2024), healthcare (Devedžić et al., 2021), (Stojanova et al., 2019), social care (Koceski & Koceska, 2016), (Koceska et al., 2019), robotics (Koceska et al., 2013), (Velinov et al., 2024), finance, business (Kirovska & Koceski, 2015), education (Duh et al., 2017), (Koceski & Koceska, 2022), (Koceska et al., 2024) and customer service.

AI-driven tools, like speech-to-text and text-to-speech applications, assist students in reading and writing, allowing them to process information at their own pace. Adaptive learning platforms use algorithms to assess each child's specific needs, tailoring lessons and exercises to strengthen literacy skills without overwhelming the learner. This personalized support helps dyslexic students build foundational skills in a structured, manageable way.

AI-powered reading assistants and dyslexia-friendly fonts simplify text comprehension by reducing visual strain and offering real-time feedback, making reading a more positive experience. Additionally, AI tools like predictive text and grammar correction improve writing confidence by addressing frequent spelling or structure-related issues. Virtual classrooms and gamified apps create engaging, multisensory environments that reinforce memory and cognitive skills through interactive, enjoyable exercises. All these ICT and AI advancements are fostering a more inclusive educational environment, empowering dyslexic students to thrive alongside their peers and adapt to a rapidly digitalizing world.

1.1 Role of Technology in Dyslexia Intervention

Therefore, the boom in ICT has given way to new, innovative interventions for children with dyslexia. From simple web-based applications to full-fledged desktop and mobile software, these technologies are aimed at helping children with dyslexia in reading and writing. Several studies have indicated that ICT tools can help traditional educational interventions by providing tailored learning environments that meet the special needs of children with dyslexia (Cidrim & Madeiro, 2017).

- **Text-to-speech** (TTS) software enables children to hear written text, which can improve reading comprehension and fluency. Applications that highlight words as they are spoken allow the child to visually follow the text while hearing it, thus supporting both auditory and visual learning.
- **Speech-to-text tools** (STT) applications convert spoken words to written text, thus allowing dyslexic students to write without the constant embarrassment of spelling and grammatical mistakes.
- **Dyslexia-friendly fonts** like OpenDyslexic, used across many platforms, improve readability by altering the appearance of letters in a way that reduces visual confusion (Lerga et al., 2021).

2 RELATED WORK

Several studies have reviewed the effectiveness of ICT tools in supporting learners with dyslexia. A scoping review by Dean, Pascoe, and le Roux (2023) was conducted on ICT reading interventions; the authors placed much emphasis on text-to-speech and adaptive learning environments. Their results indicated that many digital tools are effective in improving reading comprehension, fluency, and engagement.

Olivier & Nell (2020) conducted a scoping review of ICT-based literacy interventions and found that these technologies significantly improve reading fluency and comprehension. Cidrim and Madeiro (2017) presented a wide-based review of ICT applied to dyslexia, identifying a large range of applications that have been successfully used to enhance learning. They emphasized the importance of customized software, which adapts to the particular needs of the learner, allowing dyslexic children to work at their own pace.

Similarly, Kalyvoti and Mikropoulos (2014) explored the use of virtual environments for dyslexic learners, displaying how immersive experiences can be used to improve phonological awareness and memory retention.

Dean et al. (2023) addressed the role of reading interventions and indicated that, besides providing practical solutions for dyslexic learners, ICT tools also create engagement and motivation.

Furthermore, Lerga, Candrlic, and Jakupovic (2021) examined assistive technologies, noting that mobile apps, desktop software, and web-based tools are integral in improving the literacy skills of students with dyslexia. Exploring virtual environments, as afforded by Kalyvoti and Mikropoulos (2014), it became evident that new opportunities for learners with dyslexia come alive through virtual environments in a manner that offers experiential, hands-on learning to strengthen their cognitive and literacy abilities.

Many of these tools include visual and auditory supports, which are very much in line with the multisensory approach demonstrated to be effective for learners with dyslexia (Di Paolo et al., 2021).

3 TECHNOLOGY AND DYSLEXIA

Technological advancements have significantly expanded the tools available to support children with dyslexia. Technological support tools available fall into three main categories: web applications, desktop software, and mobile applications, each offering distinct features that specifically target certain challenges in literacy.

Table 1 summarizes the categories of software applications used in dyslexia intervention, highlighting their core features and benefits.

Table 1. Categories of Software Applications for Dyslexia Support

<i>Category</i>	<i>Examples</i>	<i>Features</i>	<i>Benefits</i>
Web Applications	Natural Reader, Rewordify	Text-to-speech, Speech-to-text, Dyslexia-friendly fonts	Accessible on multiple devices, improves reading comprehension
Desktop Software	Kurzweil 3000, Grammarly	Advanced text-to-speech, Grammar/spelling checks, Mind-mapping	Comprehensive tools for reading, writing, and organizing thoughts
Mobile Applications	Dyslexia Quest, Reading Eggs, Voice Dream Reader	Phonics training, Spelling games, Audiobook integration	Engaging, portable, provides interactive learning experiences

3.1 Web Applications

In most cases, web applications take the lead as the first line of support because of their accessibility and user-friendliness. Some tools integrate text-to-speech, where a webpage can read written material out loud in order to help children understand its content. A well-known example is Natural Reader, a text-to-speech application used in supporting dyslexic learners through the auditory feature of listening while simultaneously following text visually (Dean, Pascoe, & le Roux, 2023).

Similar is the case with other Web applications like Rewordify, which simplify complex texts for easier comprehension by dyslexic readers. These tools increase access in their presentation since they offer alternative routes to understanding. The use of dyslexia-friendly fonts and adjustable layouts enhances readability, thereby reducing the cognitive load on dyslexic students (Cidrim & Madeiro, 2017).

3.2 Desktop Applications

Desktop software provides more comprehensive support for dyslexic students by, in many cases, offering advanced features that are not possible with web-based software. Such applications are particularly useful for tasks that require significant processing power, such as speech recognition or mind mapping.

- **Text-to-speech** with advanced features: Desktop applications like Kurzweil 3000 offer enhanced text-to-speech functionalities, including word highlighting and speech rate control. These tools support dyslexic learners by helping them follow along with the text visually while hearing it read aloud (Dean, Pascoe, & le Roux, 2023).
- **Grammar and spelling correction:** Many desktop tools provide real-time grammar and spelling checks that are especially useful for children struggling with written language. Grammarly and other such tools immediately identify errors related to dyslexia and offer appropriate suggestions for correction so that the student may gradually learn correct writing (Lerga et al., 2021).

- **Mind-mapping tools:** Organizing thoughts and structuring essays can be challenging for dyslexic students. Desktop applications like Inspiration offer mind-mapping features that allow users to visually organize ideas, making the writing process smoother and more intuitive (Kalyvioti & Mikropoulos, 2014).

3.3 Mobile Applications

In a nutshell, mobile apps are probably one of the most user-friendly and portable tools that a dyslexic child could leverage. These applications provide interactive and engaging ways to develop literacy skills through games and exercises, making learning fun and accessible.

- **Phonics training:** Apps such as Reading Eggs use interactive games to teach phonics and improve reading fluency. These apps are designed to be intuitive and adaptive, adjusting to each child's progress and providing real-time feedback (Di Paolo et al., 2021).
- **Spelling and handwriting practice:** Apps such as Dyslexia Quest engage children in puzzles and exercises to strengthen spelling and handwriting skills by reinforcing correct letter formation and spelling patterns (Cidrim & Madeiro, 2017).
- **Audiobooks and reading apps:** Dyslexic learners benefit from audiobooks, which allow them to listen to stories while following the highlighted text on the screen. Voice Dream Reader is a popular app that combines text and audio to help children improve their reading comprehension through a multisensory approach (Wilmot et al., 2023).

Mobile applications offer personalized learning paths, in which the development of each child is tracked, and accordingly, the difficulty levels are changed. This kind of individual learning experience is very important to keep children with dyslexia motivated and involved in their studies.

4 CONCLUSION

Integration of technology in educational interventions for children with dyslexia has been transformational in offering new solutions to a traditionally difficult learning disability. ICT-based tools, including web applications, desktop software, and mobile apps, provide practical, flexible, and personalized approaches that adapt to the individual learning needs of dyslexic students. Technologies can also enable learners to engage with literacy tasks in ways that are often more accessible, interactive, and enjoyable, which can lead to increased motivation and confidence.

One of the key benefits of these tools is their ability to provide multisensory learning environments, combining auditory, visual, and sometimes kinesthetic elements. With their aids, the tools cater to the different learning styles of dyslexic children, and by doing so, they help overcome some of the main difficulties related to dyslexia: phonological processing difficulties, poor working memory, and visual word recognition. For example, TTS applications enhance fluency and comprehension in reading, while STT applications help children express their thoughts without having their creativity handicapped by spelling or writing difficulties.

Moreover, ICT-based interventions can be tailored to specific literacy challenges, offering personalized feedback and adaptive learning paths. This way, the tailoring ensures that learners progress at their own pace without being overwhelmed by difficulties encountered individually. Such adaptive tools are especially useful for young children who may not do well with usual one-size-fits-all teaching methods.

However, there are still some challenges to guaranteeing equitable access to those technologies, especially in low-resource settings or developing countries where the infrastructure of ICTs may not be adequate. Additionally, there is a need for further research on the long-term efficacy of these tools, particularly regarding how they impact dyslexic learners' academic performance and psychological well-being over time. Ensuring that educators are adequately trained in using these tools is also crucial to their successful implementation.

The future should see more complex applications of evolving technology, such as virtual reality and artificial intelligence-driven tools for an even more immersive and responsive experience. To illustrate, virtual environments can simulate real-life reading and writing tasks in controlled, stress-free environments that may help dyslexic learners build up their confidence and practice their skills in new ways. Even better, technology in this area may increasingly incorporate AI, which can instantly provide data-based feedback adjusted to the particular learning profile of the pupil. In conclusion, the potential of ICT to support children with dyslexia is huge.

The current level of technologies, from plain web-based tools to complex desktop and mobile applications, offers a variety of opportunities to improve literacy skills and overcome learning difficulties. They are technologies that will continue to advance and therefore could gradually become of greater importance within dyslexia interventions, giving more power to the student in his or her learning journey and beyond. By ensuring equity of access and continuing to innovate, we can create more inclusive and supportive learning environments for all dyslexic students, regardless of their location or background.

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Blended Learning: Challenges and Opportunities for Higher Education

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Abstract. Blended learning, which combines traditional face-to-face teaching with online components, has transformed higher education in Serbia. This paper investigates the challenges and opportunities that blended learning creates with respect to students' engagement and satisfaction, as well as academic performance, underlining personalized learning experiences. The COVID-19 pandemic accelerated the urge to rise with blended learning, and institutions consequently had to rethink their pedagogical strategies and readiness. The key components of blended learning are highly favoring the approach towards a series of differential learning styles for improved learning outcomes amongst students through active participation and collaboration. Issues related to technological disparities, faculty training, and institutional support have been identified as crucial in their successful implementation. These challenges can be met by creating conducive learning environments and through continuous professional development. Further integration of blended learning will constitute an important strategic step towards a continued development of the skills required by students in a complex global environment of higher education in Serbia. This therefore calls for the implication of blended learning by educational institutions in improving teaching and learning; this will lead to the bringing forth of an interactive and efficient educational environment to the students.

Keywords and phrases: Blended learning, personalized learning, technological disparities, conducive learning environments.

1 INTRODUCTION

Traditional lectures have long dominated higher education, though often at the cost of passivity among students and the inability of engaging them in active thinking. This shift toward blended learning encompasses some challenges and opportunities for educators since face-to-face interactions can only accommodate collaborative learning and higher-order thinking skills partially. This change in paradigm is even more important in countries such as Serbia, which faces unique socio-economic and cultural obstacles in the path toward higher education. Students believe classroom instruction is boring and has no relevance to life, which causes students to become detached and develop behavior problems. The increasing omnipresence of digital technologies has changed the behaviors that students exhibit, as devices and virtual distractions continue to shorten attention spans and decrease retention. This new reality has necessitated an evolution in the structure of educational practices to meet the new expectations students have for engagement in technologically enriched environments. Blended learning-classroom education combined with independent online learning components-offers an effective approach to increasing student learning and engagement.

This paper discusses the potential of blended learning within the framework of higher education in Serbia, considering its advantages yet showing obstacles to its implementation. After a short explanation of what blended learning is, the discussion will outline the relevance of blended learning in today's educational landscape, present the challenges that may be faced by the institutions, and offer practical recommendations for effective integration of technology. However, guided by UNESCO's focus on quality education as a core human right, and its commitment to inclusion and gender equality, this paper will try to contribute to the discussion of how blended learning can serve as one of the transformative approaches to higher education,

especially for developing contexts such as Serbia. All of these dimensions are explored in the paper to a greater extent with the view of informing educators and policymakers on likely pathways toward improving educational quality and access through blended-learning methodologies. [1][2]

2 BLENDED LEARNING

2.1 Definition and principles

Blended learning has emerged as one of the more critical modes of higher education these days, which integrates traditional face-to-face instruction with online learning. The model offers not only a truly enhanced educational experience but also at the same time offers a wide range of options for today's diverse student population. The definitions and conceptualization of various frameworks regarding blended learning are indicative of its flexibility and how educational practices are continually evolving. It combines online content delivery with classroom interactions, thus allowing personalized learning experiences tailored to each student's needs. This personalization is conducive to engagement and reflective thought, for the more students are involved, the greater their academic self-confidence has been found to be [3].

Research on blended learning in higher education has emphasized that though fewer frameworks may have been documented, implementation practices are becoming more standardized across institutions. This consistency points to the increasing recognition of the benefits of blended learning in the enhancement of student engagement and learning outcomes. Interaction is a crucial ingredient in any form of effective learning environment, including blended learning, where students can obtain richer experiences through collaboration activities and simulations. Such interactive features provide an interactive learning environment that encourages active participation and cooperation among the students themselves [3].

It is also the case that institutional support is indispensable for the successful implementation of blended learning. In addition, readiness assessment, resource provision, and faculty support in adapting to new technologies are some significant ways by which administrators have to prepare their institutions. This is due to the fact that most educators have come to be generally skeptical about adopting the mode of blended learning because perceived challenges and unfamiliarity with technology always arise. A supportive learning environment, with adequate facilities and qualified teaching staff, means a great deal toward raising the quality of blended learning experiences [4].

The COVID-19 pandemic accelerated this trend toward blended learning; the need thereafter was that institutions had to adapt to remote modalities. This has obvious implications for flexibility within learning—that students can learn at their own pace, which is really beneficial for those who have to balance academic, work, and family responsibilities. Digital tools were useful in aiding blended learning; although, a positive attitude by the student toward this format is considered crucial for the successful acquisition of knowledge [4].

3 EFFECTS AND IMPACT OF BLENDED LEARNING

Blended learning has emerged as an important educational paradigm that incorporates both traditional face-to-face classroom instruction and online learning components. Blended learning, therefore, is poised to become a flexible and even more effective way of teaching and learning while capitalizing on these two modes of delivery. This chapter examines the effects and impact of blended learning on student performance, engagement, motivation, teacher efficiency, and the general education experience, with regard to empirical research and theoretical insights [5].

3.1.1 Student Learning Outcomes

This is somewhat supported by its potential to enhance learning outcomes. The limited but increasing number of BL studies indicates that classes taught via BL exhibit higher levels of academic performance compared to traditional instruction. This is because it combines the most effective characteristics of face-to-face contact with the personalization and flexibility of online learning, creating a variety of ways in which students can access the content [5].

Means et al. (2010) found that blended learning generally outperforms solely face-to-face and fully online learning environments. From this meta-analysis, blended learning had been a positive influence across many academic disciplines and levels of education towards students' achievement. In another instance, in the study by Zhao et al. (2002), BL offered even deeper learning experiences for students because they interacted with instructional materials more frequently and were more engaged with their learning process [6][7].

Blended learning environments offer students opportunities to learn at their own pace, to access a variety of learning materials, and to interact with activities. Such opportunities permit them to focus more deeply on course content, typically resulting in improved performance on assessments and deeper understanding of course material [6][7].

3.1.2 *Engagement and Motivation*

Engagement and motivation are critical factors that contribute to student success. Blended learning environments are uniquely positioned to enhance both. The integration of diverse media, including videos, interactive simulations, and discussion forums, has been shown to increase student interest and involvement in their coursework. Blended learning also supports active learning strategies, such as problem-based learning and collaborative projects, which have been linked to higher levels of engagement [8].

In particular, Vaughan (2014) emphasizes the importance of creating engaging and meaningful learning experiences through the strategic design of blended learning courses. According to Vaughan, when students are given the flexibility to engage with content in various ways (e.g., through videos, readings, quizzes, and peer discussions), they are more likely to feel motivated and engaged. This flexibility allows students to take ownership of their learning, which is a key driver of motivation [9].

Additionally, the ability to revisit online materials and receive immediate feedback helps sustain student interest and reinforces learning, leading to better retention of information. The incorporation of gamified elements and interactive features in many blended learning environments further enhances motivation by making the learning process more enjoyable and dynamic [8][9].

3.1.3 *Flexibility and Accessibility*

Perhaps the most deep-seated benefit of blended learning is its inherent ability for flexibility. In addition to conventional face-to-face interaction, it integrates online learning, in which students can learn the content at those times and in ways that are best for them. To this end, the flexibility hardwired into blended learning models pertain even more so to adult learners, working professionals, and/or students from geographically remote regions where traditional access may not be as feasible [10].

Blended learning, according to the research of Graham, opens more avenues for accessing teaching materials and activities any time and from any place, thus breaking all barriers that have been developed by fixed classroom schedules. For example, flexibility enables personal learning: students can learn at their own pace, review areas of difficulty, and revise materials outside of the class [10].

Furthermore, the online component in blended learning often caters to a wide range of learning styles and preferences by offering multiple modes of instruction through videos, readings, discussions, and quizzes. This diversity makes learning all the more accessible and easy for students to tailor according to their needs [10].

3.1.4 *Student Satisfaction*

Student satisfaction is an important outcome of any educational model. However, some evidence from the literature postulates that blended learning may have a positive effect on student satisfaction because this mode of learning tends to be more attractive, flexible, and interactive. In blended learning, students have a certain extent of freedom regarding when and how they learn—a factor enjoyed by many students in learning [11].

A meta-analysis by Bernard et al. (2014) found that students were more satisfied in blended classes compared to their traditional face-to-face or fully online counterparts. In the review, the students expressed satisfaction because of the interactive and varied nature of the learning activities. Students seemed to especially appreciate the reinforcing of classroom learning with online resources and the flexibility to work through materials at their own pace [11].

McGee and Reis (2012) further observed that students' levels of satisfaction with the course increased with greater autonomy and responsibility for the learning process in blended learning environments [12].

3.1.5 *Teacher Pedagogy and Effectiveness*

Blended learning also influences teaching practices, as instructors tend to be more dynamic and interactive in their pedagogical approaches. Instructors, with the combination of face-to-face and online components, can make the learning experiences even more varied with a view to fostering the development of collaboration, critical thinking, and problem-solving skills among students. Instructors are encouraged to avoid traditional lecture-based teaching and instead focus on active learning strategies, emphasizing student participation and engagement [12].

McGee and Reis added that with the advent of blended learning, more avenues had been opened to teachers to differentiate instruction and address a wider range of needs for more interactive, student-centered learning environments. The use of online tools for quizzes, assignments, and discussion boards permits instructors to provide immediate feedback and more easily track student progress [12].

But this shift toward blended learning requires that the teachers be adequately prepared for effective design and implementation of such courses. Teachers must become well-versed in online pedagogies and the technical tools to support online learning. Tobin and Dawson stress that such professional development for instructors is especially necessary in how to use technology meaningfully to enhance their teaching [13].

3.1.6 *Collaboration and Social Learning*

Blended learning affords even more collaboration and interaction among and between students. For instance, online platforms facilitate communication and collaborative learning through discussions, group projects, and peer review systems, which may well exceed the limitations of a physical classroom. Therefore, from this perspective, BL is quite important for promoting social learning and community building within the classroom.

The integration of collaborative tools in blended learning environments promotes peer-to-peer interactions, leading to the enhancement of cognition and social development. Students participating in collaborative learning develop better problem-solving skills and tend to show an advanced understanding of the course materials. Blended learning sociality also aids in creating an enabling learning environment that is supportive of resource sharing and ideas for problem-solving [14].

3.1.7 *Cost-Effectiveness*

Blended learning models can offer an affordable education delivery for institutions by minimizing the physical classroom requirement and utilizing online materials. In this regard, the operational costs for educational institutions would be at a low while the learning experiences are at a high. Another added advantage is that blended learning can accommodate more numbers of students without compromising on the individual attention of students.

Allen and Seaman (2013) also discuss some of the cost savings around blended learning, particularly in higher education. Though the front-end investment in technology and training can be quite high, the long-term savings are often significant for large-scale courses or programs [15].

3.1.8 *Challenges and Considerations*

However, with the many benefits of blended learning, it also goes hand in hand with several challenges. First and foremost, there is unequal access to technology and the internet by all students. Students from socioeconomic classes or living in seclusive areas can hardly access the online aspects of blended learning programs. Similarly, instructors have to be well trained enough in order for them to be efficient in creating and facilitating blended learning environments.

Liu and Hwang, 2010 include in their overview the access to technology issues thus stating that "An very important factor any institution has to keep in mind while opting for a blended learning model is the students' technological capabilities and how support can be provided in this regard" [16].

3.1.9 *Long-Term Impact*

This might lead to long-term impact in the area of lifelong learning for students. In addition, BL prepares students to be successful in the workplace through self-directed learning and problem-solving skills due to the fact that many work environments require employees to continue learning and adapt to new situations. According to Martin and Sunley (2013), skills such as time management, digital literacy, and independent learning developed in blended learning environments contribute to their success in education in the long term and in their career [17].

4 OPPORTUNITIES OF BLENDED LEARNING IN HIGHER EDUCATION

Blended learning now increasingly combines the best of both worlds: the traditional face-to-face mode of instruction with online learning. Such a hybrid model affords a more flexible, motivating, and autonomous learning experience than ever and opens many new avenues for students, educators, and institutions alike. Blended learning provides a range of pedagogic, logistic, and economic advantages to meet the increasing diversification of learners' needs and the evolving educational landscape. For example, the chapter examines some of the main opportunities that blended learning provides for higher education, informed by recent research and practical wisdom coming from practice in the field.

4.1.1 *Enhanced Student Learning Experience*

Blended learning can support a better learning experience for students because more resources are available, and there are more modes of learning. Face-to-face and online components give the students the opportunity to experience content in multiple media formats: videos, readings, interactive modules, live discussions-each supporting different learning styles. Blended learning provides students with some flexibility; they would invest more time in the lessons, for their time is not wasted listening passively to a lecture in person but online or through an instructional video that one re-watches for further learning.

Graham (2006) has referred to the resultant more holistic learning environment generated from blended learning than either purely an online or a face-to-face learning environment could provide. The online parts offer flexibility and self-pacing, while in-person interactions allow for social

learning, collaboration, and a richer interaction with instructors and peers. This blend, therefore, improves learning outcomes-not just of content mastery but also of critical thinking and problem-solving skills. This two-way process can be particularly useful in higher education, where students are often required to engage with complex and subtly articulated material [10].

In the meta-analysis conducted by Means et al. (2010), the general finding was that, against single face-to-face learning, blended learning clearly does a better job in leading to improved performance among students. The current research underlined that students in blended learning environments turn out to be higher achievers, and found to demonstrate better retention and application of knowledge. Improved learning also finds expression in increased student satisfaction due to the fact that diverse modes of instruction allow students to interact with content in ways that suit their needs best [6].

4.1.2 Increased Flexibility and Accessibility

This is one of the greatest affordances offered to students by blended learning: it can allow students to have greater flexibility in their educational experience. Blended learning allows students to access learning materials and engage with course content at a time and place that is conducive to their schedule. This is particularly helpful for non-traditional students who may have difficulty attending on-campus courses due to work obligations, family commitments, or other life pressures.

According to Vaughan (2014), one of the central aspects of blended learning is the fact that it gives students great leeway in learning at their own pace and time. Since the students can access the online components of a class at any time, they have more ability to balance and manage their time well, as well as interact with other commitments. This would be very helpful during those times when the student's schedule has become increasingly complex and multi-dimensional [9].

It also overcomes geographical barriers, as courses can be offered to students who cannot attend for whatever reason due to distance and other limiting factors. This provides an opportunity for institutions to expand their pool and service more diverse student populations at a national and even international scale. As Picciano and Seaman (2009) comment, blended learning is particularly good at making higher education more accessible and does so with considerable flexibility compared to traditional classroom-based learning [18].

4.1.3 Fostering Collaborative Learning

Blended learning environments are also more likely to increase collaboration among participants. Online aspects of blended learning include the discussions, group projects, and peer review systems that facilitate interaction among students, even when these students are not physically present within the same physical classroom. These collaborative tools foster peer-to-peer learning, enabling students to interact with other ideas and cultivate communication skills, along with important teamwork competence applicable in academic and professional domains.

Alammary, Sheard, and Carbone (2014) noted that online collaborative tools in blended learning environments will definitely foster social learning; students in blended courses tend to have more peer interaction, a greater opportunity for idea-sharing, and application of problem-solving through cooperation, which may all account for better understanding. This blends online collaboration with face-to-face interaction and helps foster a sense of community and belonging among students, enriching the learning experience [14].

This collaborative nature of learning may further evoke negotiation, conflict resolution, and leadership skills in students, which are increasingly in demand by employers. As Anderson (2008) has mentioned, such social dimensions to blended learning hold great promise in embedding "soft skills" in the learners and enhancing employability [19].

4.1.4 *Improved Teaching Practices*

Instructors can view blended learning as an opportunity to reimagine traditional teaching practices and to adopt more dynamic, student-centered approaches. For instance, instead of standing and lecturing, educators may use a range of online resources to deliver content more effectively through multimedia, interactive simulations, and self-assessment quizzes. This shift in concept enables instructors to move away from a pedagogical perspective of "sage on the stage" to "guide on the side," in which students become more responsible for their learning.

McGee and Reis note that blended learning enhances more effective and engaging teaching methods. Therefore, instructors are called upon to use online platforms to facilitate different instructional approaches, such as flipped classrooms, project-based learning, collaborative learning, and giving effective peer review. Such variation enables instructors to meet various student needs and accommodate a range of learning styles [12].

Moreover, blended learning provides more opportunities for timely and personalized feedback by the instructor. Online learning tools enable the instructor to monitor student progress, observe what students understand and what they do not, and intervene early in their struggles. This data-driven approach helps refine the quality of instruction, thus improving student outcomes where educators tailor their teaching to better meet the needs of all students [12].

4.1.5 *Scalability and Cost-Effectiveness*

Blended learning allows institutions significant leeway in scaling up the number of students taking certain courses while keeping overall costs down. Blended courses minimize the need for in-person classroom sessions since online components can take over much of this burden; thus, the physical infrastructure and faculties are not under great pressure. By making lectures available to students through recordings, instructors should not be repetitively presenting instructional materials, which also boosts teaching efficiency by reusing other online content.

Allen and Seaman 2013 observe that blended learning is scalable. It allows institutions to expand their access and increase the number of students served while minimizing additional costs. This would be possible in cases where online resources would be combined with traditional face-to-face instruction, and institutions would be capable of serving more students without extra physical classroom space or the addition of instructional staff. This cost efficiency is important in relation to the growing demand for higher education and the continued rise of tuition [15].

This also gives the ability to provide course materials asynchronously using online modules, which allows much more flexibility in scheduling, reducing the need for students to conform to rigid course schedules. This will help institutions manage resources more effectively while providing high-quality learning experiences [15].

4.1.6 *Promotion of Self-Directed Learning*

Blended learning requires students to take a more active responsibility in their learning process, as it encourages self-directed learning. Many online components of the classes require the student to act autonomously, setting learning goals and monitoring their progress. This independence is important in lifelong learning, using critical thinking and problem-solving [17].

According to Martin and Sunley, in a blended approach self-directed learning is a key for adults. The time available will be used in more independent ways: learning at their own pace, re-viewing class material, and practicing activities that develop self-regulation and autonomy. Such skills can easily leak into many other dimensions of life and work, and in the long term, this turns out to be an essential tool for students in preparation for the pressures of the contemporary labor market [17].

In addition, blended learning environments often afford students a variety of learning materials, including videos, readings, and practice exercises. This allows students to engage more actively in the learning process and explore topics in greater depth, developing intellectual curiosity and a love of lifelong learning [17].

4.1.7 Global Reach and International Collaboration

Blended learning can also transcend borders, potentially promoting global interactions among students and educators. Through the use of digital learning tools, students from diverse countries can share experiences, discuss issues of interest across intercultural backgrounds, and work on projects that enable them to develop global perspectives. This is really useful in a connected world where an understanding of different perspectives and the ability to work in international teams are very fast-becoming essential knowledge [20].

As Bates points out, blended learning may give an opportunity for world collaboration since students can take part both in courses and discussions with other people anywhere around the world. This enriches not only a learning experience but also helps develop in learners those cross-cultural communication skills increasingly demanded in the global labor market [20].

Besides, the concept of blended learning opens up pathways for institutions to offer courses to a broader audience, including international students who may not be in a position to attend classes face-to-face due to restrictions in travel or financial constraints. According to Miller (2007), one of the main advantages of blended learning is an increase in access to higher education and, by that virtue, inclusiveness of more students from different walks of life [21].

5 CONCLUSION

Blended learning has emerged as one of the transformational models in higher education, marrying strengths of traditional face-to-face instruction with the flexibility of online learning. The hybrid approach to instruction greatly enhances student engagement and improves academic performance and satisfaction because students have unique learning experiences that meet the diverse needs of today's students. This flexibility in blended learning offers students the opportunity to learn at their own pace, promoting self-directed learning and, hence, deeper and more interactive experiences.

In blended learning, educators also have more opportunities to try dynamic, student-centered teaching methods and to collaborate more effectively with the students themselves than they are likely to have in purely face-to-face learning models. Blended learning may provide scalable, cost-effective solutions for institutions, expanding access to education while reducing operational costs.

Add to these deterrents the many reasons showcased here, technology access, instructor training, and long-term benefits of blended learning-improved learning outcomes, global collaboration, and adaptability-make it one of the key models that meet the future of education. In other words, this is what blended learning offers: a flexible, inclusive, effective way of yielding to modern students' evolving demands and better preparing them for success in a digital world.

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Using ICT in the Education of Children with Special Needs: a Scoping Review

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Abstract. According to recent UNICEF reports, the number of children with special needs is increasing every day. These children face multiple and often compounding challenges in realizing their rights, including the right to education. One way to address the needs of children with special needs and to help them in education process is through the use of information and communication technologies (ICT). This scoping review provides insight into recent technology practices in special education contexts, reviewing studies during the period 2019-2024. Following the PRISMA methodology, we analyzed 29 articles that met the inclusion criteria, out of a total of 340 identified. The articles were selected from major databases including Scopus, IEEE, ERIC, and ScienceDirect. The research systematically classifies these studies based on four key criteria: the type of technology implemented (assistive technology, AR/VR, mobile/computer applications, or e-learning platforms), the specific disability addressed (including visual impairments, autism spectrum disorders, intellectual disabilities, dyslexia, and multiple disabilities), the target age group and the benefits from the technology used. The purpose of this review is to provide evidence of good practices and recommendations for successful implementation of ICT in an educational context for children with special needs.

Keywords and phrases: special education, assistive technology, augmented reality, virtual reality, e-learning, educational technology, children with special needs.

1 INTRODUCTION

Every child may sometimes experience difficulties in learning some material, but if that difficulty is not temporary, then we have a case of a child with special educational needs (SEN). The term SEN is used to describe learning difficulties or disabilities that make it harder for children to learn than most children their age. Children with special educational needs usually have difficulties that can be divided into several areas:

- Difficulties in thinking, understanding, and learning
- Difficulties in speech, communication, and language
- Problems with managing emotions and behavior
- Physical or sensory difficulties
- A combination of multiple difficulties

Education should be a guaranteed right for every child regardless of their limitations, whether physical or mental. However, children with SEN may require additional support and special attention, to reach their outcomes or learning goals. To provide this support and implement an adequate educational process for every child, ICT technology can be used.

Surrounded by technology, since birth, it is natural for children to learn through technology (Duh et.al., 2017), (Gogova et. al., 2014), (Runcev et. al., 2017), (Timoski et. al., 2020), (Koceski and Koceska, 2022). Children with SEN are no exception. Digital technology engagement to support children with SEN is becoming more common nowadays. It can provide a more learner-centered approach to education focusing on the individual children's needs. It can help create continuity between home and school learning, as well as allow greater independence. ICT has the potential to be an effective leveller for children with SEN creating the conditions for

equal opportunity to learn and access to the curriculum. However, it should be carefully used and under the supervision of trained personnel in order to maximize benefits.

Researchers have investigated various technologies that support children with SEN in their learning process. Mobile, web and desktop applications have been created to help them better understand the complex concepts being taught and provide assistance with the educational material. On the other hand, applications need to be attractive, interactive, motivating and fun to attract children to use them, while at the same time making them feel comfortable and safe. Therefore, these applications are enriched with various multimedia elements, like audio, video, 3D object etc. AR and VR are also used to promote various supports in education, and to facilitate learning activities, integrating real-life situations with the virtual ones.

Previous review studies have attempted to explore the use of ICT in education of children with SEN. However, these reviews fail to provide comprehensive knowledge on the most recent state of the literature. For instance, Sarasola Sanchez-Serrano et. al. (2020) provided a bibliographic review of studies undertaken between 2009–2019, presenting the data according to their citation and repercussion index. Chelkowski et. al. (2019) focused only on using mobile devices with students with disabilities across education settings. They examine the literature on who is using the devices, what specific mobile devices are being used, how mobile devices are used, and what the major effects are. Dogan and Delialioğlu (2020) review the technological tools utilized to exchange reading, writing and math skills in children with SEN. Baykal et al. (2020) focused only on collaborative technologies for children with special needs. Haleem et.al (2022) discussed the needs for digital technologies in education, as well as the challenges of using these technologies in education settings. Apart from these reviews, there are some other reviews that focused only on one disability within the educational domain (Zhang et.al.,2022), (Anagnostopoulou et.al.,2021), (Cibrian et. al, 2022).

The aim of this scoping review is to analyze and synthesize the scientific work published in the last 5 years (from 2019 to 2024), on the use of ICT to support children with special needs, which has been evaluated with at least one child with some form of disability.

2 METHODS

The scoping review was conducted utilizing the PRISMA methodology, through which a significant number of relevant scientific papers were identified and analyzed. The steps of this study consisted of framing research questions, defining eligibility criteria, as well as search strategy, and data acquisition and analyses process.

2.1 Scope and research questions

The purpose of this review is to identify research studies dealing with the use of technology to support and assist children with special needs, including the evaluation process and resultant outcomes. The technology in focus was intended to assist or support educational activities for children with special needs, facilitate their learning process, capture and maintain their attention, create an accessible virtual environment suitable to learning, and establish conditions where they will not feel excluded or disadvantaged compared to their peers without disabilities.

For each article included in the analysis process, we were particularly interested in examining the type of technology used, its purpose and implementation, the target group, and the specific type of disability addressed. To this end, the following research questions were formulated to extract relevant information from each article:

- RQ1: What technology was implemented?
- RQ2: What was the purpose and application of the technology?
- RQ3: Which specific group of children with special needs was the technology designed for or utilized with?
- RQ4: What was the target age group for which the technology was designed or evaluated with?

2.2 Eligibility criteria

The selection of studies for inclusion in our research was guided by the following inclusion criteria: (1) Only articles and conference papers were considered; (2) Publications written in English language; (3) Studies published within the last five years (2019-2024); (4) Articles documenting technological applications in the educational process of children with special needs; (5) Studies that included evaluation of the implemented technology with at least one child.

The exclusion criteria were defined as follows: (1) All types of review papers; (2) Articles describing technology use in educational processes but not specifically for children with special needs; (3) Studies where evaluation was not conducted with children with special needs; (4) Articles where technology was utilized solely for rehabilitation purposes.

2.3 Sources and search strategy

The literature search was conducted across multiple databases including Scopus, IEEE, ERIC, and ScienceDirect. The search was filtered to include only publications from the past five years (2019-2024), written in English, and limited to articles and conference papers. The following keyword search terms were used during the electronic scanning phase: ((Information and communication technology) OR (Computer technology) OR (ICT)) AND (education) AND ((children with special needs) OR (children with disabilities)). The initial search across all databases yielded a total of 367 publications: 4 publications from ScienceDirect, 4 publications from ERIC database, 188 publications from Scopus and 171 publications from IEEE database. After removing 27 duplicate entries, the final corpus consisted of 340 unique publications.

2.4 Selection of studies

After compiling the initial list of publications from our database searches, the next phase involved screening titles and abstracts to determine which studies warranted further consideration. This screening process resulted in the identification of 115 potentially relevant publications.

Subsequently, we attempted to access the full texts of these 115 publications. However, 54 publications were inaccessible, while we successfully obtained and thoroughly reviewed 61 full-text articles. Upon evaluation of these articles against our research objectives and inclusion criteria, only 29 publications were found to be directly relevant to our research questions and were included in the final literature review and analysis. The complete selection and elimination process is illustrated in Fig.1.

This systematic screening process followed standard academic protocols for literature review methodology, ensuring a rigorous and transparent selection of relevant studies for our analysis.

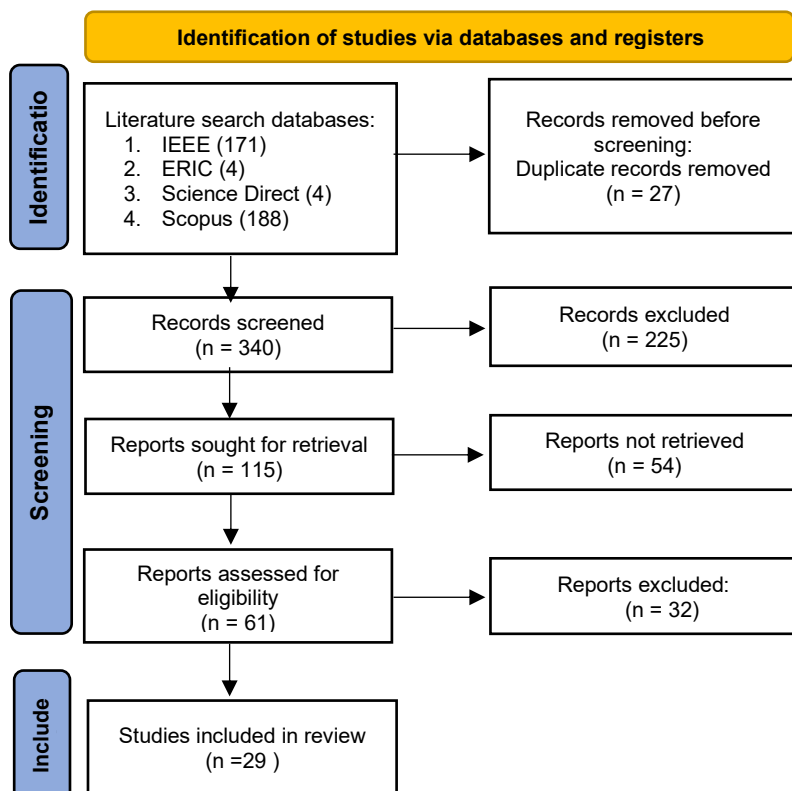


Figure 1. PRISMA Flow Diagram

3 RESULTS

The corpus of 29 studies that document and evaluate technological interventions in inclusive educational settings is presented in Table 1. These studies were further subjected to detailed analysis and systematic classification according to their contributions to our research objectives and their ability to address our primary research questions.

Title	Authors	RQ1: What technology was implemented?	RQ2: What was the purpose and application of the technology?	RQ3: Which specific group of children with special needs was the technology designed for or utilized with?	RQ4: What was the target age group for which the technology was designed or evaluated with?
Serious Exergame for Special Education Needs using 3D-Depth Camera	Kusumaningsih, A. Kurniawati A., Wahyuningru R. T., Khozaimi A., Pratama R. N.	Virtual reality	For supporting cognitive learning and therapy in developing motor skills, balance, and coordination	For children with Mild Autistic Spectrum Disorder and Low-Level Intelligence	For children from 7 to 20 years old
Class VR: Learning Class Environment for Special Educational Needs using Virtual Reality Games	Kurniawati A. Kusumaningsih A., Hasan I.	Virtual reality	For motoric training	For autism-mental disabilities and learning disabilities	6-20 average years
Augmented Reality Application for Improving Writing and Motoric Skills in Children With Disabilities	Kotevski B., Koceska N., Koceski S.	Augmented reality	For Improving Writing and Motoric Skills	For children with various forms of disabilities	For primary school children
User-Centered Virtual Reality Environments to Support the Educational Needs of Children With ADHD in the COVID-19 Pandemic	Cardona-Reyes, H., Ortiz-Aguñaga, G., Barba-Gonzalez, M. L., & Muñoz-Arteaga, J.	Virtual reality	To improve attention	For children with ADHD	For children from elementary school
Augmented Reality Based Learning Environment for Children with Special Needs	Shaltout, E. H., Afifi, A., & Amin, K. M.	Augmented reality	For enhancing the Reading and Cognitive skills	For children with Down syndrome and Autistic Children	For children from elementary school
A Context-Aware Augmentative and Alternative Communication System for School Children with Intellectual Disabilities	Chan, R. Y. Y., Sato-Shimokawara, E., Bai, X., Yukiharu, M., Kuo, S. W., & Chung, A.	Assistive technology	For improving their communication skills	Children with Intellectual Disabilities (ID)	It can be used for elementary-middle and high school environments
Effectiveness of "Maghzineh"- Cognitive Video Game on Reading Performance of Students with Learning Disabilities in Reading	Kashani-Vahid L., Taskooh S. K., Moradi H.	Computer technology	Increasing problem solving and decision making and improving reading performance	For children with Learning Disability (Dyslexia, Dyscalculia, Math Disabilities)	Elementary School
e-Ucumari: A multimedia device based on ontologies and embedded systems for pedagogical support of children with multi-disabilities	Robles-Bykbaev V., Arévalo-Illescas C.; Carrera-Hidalgo P., Robles-Bykbaev Y., Tigre-Andrade G., Ochoa-Fajardo D., Quisi-Peralta D., Pesántez-Avilés F., Martínez-Gutiérrez J.	Assistive technology	Maintain longer periods of attention, greater knowledge of their own body and basic spatial notions	For children with Multiply Disabilities	For all ages of children.
ICT, Inclusion and Pedagogical Diferention: Exploratory Study	Filipe M., Marques N., Pedro S.S., Gil H.	Mobile technology	To stimulate fine motor skills, develop visual perception skills and eye-hand coordination, improve cognitive ability, language and improve memory, logic and concentration.	For children with multiple disabilities	For kindergarten
Design and Development of Educational Game Using ARCS Model	Koceska N, Koceski S., Tashkova E.	E-learning/online learning	For improving motoric skills	For children with learning disabilities	For kindergarten and elementary school
Using tangible interfaces for teaching Braille	Andrés Sandoval-Bringas J., Carreño-León M. A., Durán Encinas I., Leyva Carrillo A., Estrada Cota I., Cosío Castro R.	Assistive technology	For Helping the Visual Impaired Children to learn Braille	For children with Visual Impairments	Preschool children

Title	Authors	RQ1: What technology was implemented?	RQ2: What was the purpose and application of the technology?	RQ3: Which specific group of children with special needs was the technology designed for or utilized with?	RQ4: What was the target age group for which the technology was designed or evaluated with?
Use of Learning Paths Through a Digital Ecosystem to Support Children With Learning Problems in Basic Math	Cardona-Reyes H., Ortiz-Esparza M. Á., Muñoz-Arteaga J.	E-learning/ online learning	For creating customized paths in the moodle for mastering and improving basic math skills	For children with learning disabilities	For elementary school kids
Design and Development of an Android App (HandDex) to Enhance Hand Dexterity in Children With Poor Handwriting	John S. and Renumol V. G.	Mobile technology	For improving and supporting handwriting skills	For children with writing difficulty	Primary school children
The effectiveness of a mobile application "Kalcal" on the learning of mathematics in students with dyscalculia	Dehghani H.	Mobile technology	For teaching arithmetic and computational skills	For children with Dyscalculia	For elementary school.
Digital transformation to support literacy teaching to deaf Children: From storytelling to digital interactive storytelling	Leandro Flórez-Aristizábal, Sandra Cano, César A. Collazos, Fernando Benavides, Fernando Moreira, Habib M. Fardoun	Computer technology	For Supporting Literacy Teaching	For Deaf Children	For preschool and elementary school children
Attention-driven read-aloud technology increases reading comprehension in children with reading disabilities	Schiavo G., Mana N., Mich O., Zancanaro M., Job R.	Assistive technology	For increasing the Reading	For Children with Development Dyslexia	For primary school
ICT use and competencies of school children with intellectual disabilities in low-resource settings: the case of Ghana in sub-Saharan Africa	Bayor A.A., Brereton M., Sitbon L., Ploderer B.	Mobile technology	For supporting the learning process	For children with intellectual and developmental impairments	For all ages
Feasibility of an eye-gaze technology intervention for students with severe motor and communication difficulties in Taiwan	Hsieh Y.-H., Granlund M., Hwang A.-W., Hemmingsson H.	Assistive technology	Allow students to communicate and participate in curriculum activities and leisure	For children with severe motor and communication difficulties	For all ages
Web Technologies in the Development of Computational Thinking of Students with Mental Disabilities	Assainova A., Abykenova D., Aubakirova Z., Mukhamediyeva K., Kozhageldinova K.	E-learning/ online learning	For teaching computational thinking	For children with mental disabilities	For primary school
Information and communication technologies-based teaching methodologies for Peruvian children with down syndrome	Villasante J., Poma S., Gutierrez-Cardenas J., Rodriguez-Rodriguez N.	Mobile phone	For improving mathematical and language skills	For children with Down Syndrome	For elementary and primary school children
Time orientation technologies in special education	Guillomía M.A., Falcó J.L., Artigas J.I., García-Camino M.	Assistive technology	For improving time orientation skills in classroom	For Children with various forms of disabilities	For all ages
The role of technology-mediated music-making in enhancing engagement and social communication in children with autism and intellectual disabilities	Kossyvaki L., Curran S.	Assistive technology	For enhancing engagement and social communication	For children with dual diagnosis of autism and intellectual disabilities	For preschool and primary school children.
Physical Programming for Blind and Low Vision Children at Scale	Morrison C., Villar N., Hadwen-Bennett A., Regan T., Cletheroe D., Thieme A., Sentance S.	Assistive technology	For teaching computational learning	For Blind and Low Vision children	For primary school
Design of an interactive system of tangible interfaces to support	Carreno-Leon M.A.; Andres Sandoval-Bringas J., Encinas I.D., Cosio Castro	Assistive technology	For teaching colors	For Children with Autism	Preschool and elementary school

Title	Authors	RQ1: What technology was implemented?	RQ2: What was the purpose and application of the technology?	RQ3: Which specific group of children with special needs was the technology designed for or utilized with?	RQ4: What was the target age group for which the technology was designed or evaluated with?
learning in children with autism	R., Cota I.E., Leyva Carrillo A.				
An emotion regulation app for school inclusion of children with ASD: Design principles and evaluation	Fage C., Consel C., Etchevoyhen K., Amestoy A., Bouvard M., Mazon C., Sauz�on H.	Assistive technology	For better emotion regulation in mainstream classrooms	For children with autism spectrum disorder and Intellectual Disabilities	For adolescents
Conceptual learning through accessible play: Project Torino and computational thinking for blind children in India	India G., Ramakrishna G., Pal J., Swaminathan M.	Assistive technology	For teaching computational thinking	For visual impaired children	For primary school children
UDL using ICT for Inclusive Learning; Learning Support for Students with Diverse Learning Styles, Including Students who Need Special Support	Shimojo M., Teruya H., Soland M.	Computer technology	For learning English	For Children with various forms of learning disabilities	Primary School
Effects of gesture-based match-to-sample instruction via virtual reality technology for Chinese students with autism spectrum disorders	Hu X., Han Z.R.	Virtual reality	For improving match-to-sample skills	For children with autism spectrum disorder	For children in elementary school
Serious game as support for the development of computational thinking for children with hearing impairment	Cano S., Naranjo J.S., Henao C., Rusu C., Albiol-p�rez S.	Assistive technology	For Development of Computational Thinking	For Children with Hearing Impairments	For children in elementary school

Table 1. Overview of the studies

3.1 Assistive Technology

Assistive Technology encompasses devices, tools, and software solutions that help overcome learning and communication barriers for individuals with various types of special needs. From our research examining assistive technology applications in education for visually impaired individuals, we identified three significant papers focusing on this area. These studies predominantly emphasize the utilization of tangible interfaces. The evaluation results reported by Andr s Sandoval-Bringas et al. (2020) show that learning Braille through tangible interfaces reduces learning time by up to 40% while simultaneously reducing children's frustration from repeated failure. In terms of tangible systems, TORINO system, designed to develop computational thinking through play, was evaluated in two articles. The evaluation conducted from (India et al., 2020) demonstrated a positive effect on children, highlighting the importance of creating an environment with creative freedom and playful exploration opportunities. Morrison et al. (2021) not only documented active student participation and engagement but also received positive feedback from teachers regarding the system's ease of implementation and use.

In the domain of computational thinking development, we identified a study from (Cano et al., 2021) working with hearing-impaired children utilizing the Perdi-Dog game. Post-evaluation findings indicated high student motivation and benefits in decision-making and problem-solving skills.

Regarding assistive technology applications for children with autism and intellectual disabilities, several studies were identified. Chan, et al. (2020) published a study that presented the design, implementation, and evaluation of a Bluetooth low energy-based context-aware augmentative and alternative communication system. The system facilitates daily communication for nonverbal school children with moderate intellectual

disabilities. The Cosmo hardware, discussed in the music-making study (Kossyvaki and Curran, 2020), contributed to communication, curiosity, and motivation of children with autism and intellectual disabilities at school. The positive outcomes, regarding social communication skills, are reported, which are of significant value to educational researchers and school staff. Tangible user interface enabled natural object interaction during learning, while supporting communication and self-expression were reported by Carreno-Leon et al.(2020). The prototype was evaluated by experts, and by end users with characteristics of the autism spectrum, and the results obtained were considered favorable. Assistive technology for emotional support of adolescents with autistic spectrum disorders in a typical everyday classroom environment, is of great importance because it not only improves childrens' behavioral outcomes but also contributes for the development of their social and cognitive skills (Fage et al., 2019).

Among the articles examining assistive technology and its evaluation, the study by Guillomía et al. (2019) concentrates on temporal orientation of children with special needs in educational settings through the implementation of an audio-visual system. The reported results show a consistent improvement in performance related to time orientation, which in turn provides a basis for improving personal autonomy.

To overcome dyslexia-related challenges in reading and writing, Schiavo et al. (2021) utilize eye-tracking technology that synchronizes audio with text, based on the user's gaze direction. Similarly, assistive technology based on eye-tracking was also used by Hsieh et al. (2024), but for children with severe motor and communication impairments.

Among all identified studies focusing on assistive technology, only one study (Robles-Bykbaev, et al., 2019) addresses children with multiple disabilities (in this case a child with cerebral palsy and hearing loss concomitantly). The research shows an easily modifiable solution, based on electronic device and an ontology, that facilitates the inclusion of children with SEN in the educational process.

3.2 AR, VR

AR (Augmented Reality) and VR (Virtual Reality) technologies create immersive and interactive experiences that can be leveraged in education to enhance learning outcomes and engagement for students with special needs. Children with autism and intellectual disabilities sometimes find it more challenging to connect with teachers than with technology. The study by Kurniawati, et al. (2019) investigates a user-friendly virtual environment that motivates children to independently follow instructions through virtual games. The study reported a positive outcome, particularly in improving cognitive and motor skills. Another research shows how virtual reality enhances curiosity, promotes whole-body activity, and improves cognitive, motor, and language skills (Kusumaningsih et al., 2022). Hu and Han (2019) investigate the effectiveness of using gesture-based instruction via Leap Motion-aided virtual reality technology to teach matching skills to school-aged students with autism spectrum disorder. Virtual reality also found significant application in education during the COVID-19 pandemic. In this context, VR technology was utilized to provide a friendly, focused, and calming environment where children could engage in problem-solving activities while teachers can continue the teaching process despite pandemic restrictions (Cardona-Reyes et al., 2021).

Regarding augmented reality applications, two studies that document improvements in writing, reading, motor, and cognitive skills were identified (Kotevski, et al., 2024) (Shaltout, et al., 2020). The first study examines the application of augmented reality for children with ADHD, while the second investigates the use of AR application in children with Down syndrome and ADHD in the process of learning to read and write. These applications make the learning process interactive, entertaining, and motivating while increasing concentration and eliminating boredom.

3.3 Mobile Technology, Tablets and Computers

Mobile technology (smartphones and tablets) are ubiquitous and readily accessible technologies in our daily lives. Several studies evaluate the implementation of mobile technology in special education. John and Renumol (2022) examine mobile technology's application in improving handwriting skills. Dehghani (2019) focused on developing arithmetic and computational skills in children with dyscalculia. The study by Villasante et al. (2019) utilizes mobile technology to enhance mathematical and language skills. Filipe et. al. (2019) used mobile technology to stimulate fine motor skills, develop visual perception skills and eye-hand

coordination, improve cognitive ability, improve memory, logic and concentration, while Bayor et al. (2023) investigated the use of mobile technology in supporting and facilitating the overall educational process.

Evaluation and implementation of computer technology in the educational process for children with learning disabilities and hearing impairments can be found in several studies (Kashani-Vahid et al., 2019), (Leandro Flórez-Aristizábal et al., 2019), (Shimojo et al., 2020). The results from these implementations demonstrate improvements in problem-solving and decision-making capabilities (computational thinking), reading proficiency, and language and literature learning.

3.4 E-learning, online learning

E-learning or online learning refers to an educational process conducted through internet platforms and technology, as opposed to traditional physical environments. The implementation of these technologies in the educational process for children with learning difficulties has demonstrated several beneficial outcomes:

- Enhancement of motor and cognitive skills (Koceska et al., 2024)
- Creation of customized learning materials tailored to individual children's needs (Cardona-Reyes et al., 2022)
- Improvement of computational thinking abilities (Assainova et al., 2023)

4 CONCLUSION

The analysis of studies in this scoping review, demonstrates the diverse and evolving landscape of technological solutions that support children with special needs in educational settings. The research highlights four primary categories of technological interventions: assistive technology, AR/VR/MAR solutions, mobile/tablet/computer applications, and e-learning platforms.

Assistive technologies, particularly those incorporating tangible interfaces and eye-tracking capabilities, show promising results in reducing learning barriers and enhancing engagement for students with various disabilities. AR and VR technologies demonstrate significant potential in creating immersive, safe learning environments that improve cognitive, motor, and social skills, particularly for children with autism and intellectual disabilities. Mobile and computer-based technologies have proven effective in developing specific skills such as handwriting, arithmetic, and computational thinking. E-learning platforms offer great opportunities for personalized learning experiences even during challenging conditions such as the COVID-19 pandemic.

The review underscores the transformative potential of technology in special education while highlighting the importance of continued innovation and evaluation to ensure these tools effectively serve their intended purpose of creating more inclusive and accessible educational environments.

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Software Evolution Monitoring Framework in the Context of Software Projects and Maintenance Standards: Case Study of Preschool Institution Web Portal

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Abstract. Software evolution has been elaborated with Lehman's laws, which emphasize the need for constant change in aim to enable users' satisfaction. In the context of these laws, software evolves with getting more complex structure and more functions. Of course, user requirements could also be in non-functional area, mostly addressing performance and other features. International Standards Organization (ISO) standards define four categories of maintenance: adaptive, preventive, perfective and corrective. Aim of this paper is to present a case study with three new versions of official Preschool Institution Zrenjanin's web portal, that were developed in the period of ten years within software projects. The process and results of the evolution of this web portal is placed in the context of the Lehman's software evolution laws and ISO standards, in aim to present empirical evidence of their applicability. This paper also provides a general software development monitoring framework that puts software evolution in four dimensions of maintenance categories.

Keywords and phrases: Lehman's software evolution laws, ISO standards, software maintenance, web programming, preschool institution, software development monitoring

1 INTRODUCTION

Software development in contemporary agile professional practice (Agile Manifesto, 2001) is a constant process that welcomes changes, in aim to keep the software users satisfied. According to Agile Manifesto, working software has higher priority than documentation and collaboration is more important than strict formulation of a contract, following the procedure and a plan. Ambler & Lines (2012) propose disciplined approach in agile software development, with integration of different agile methods and enterprise awareness in agile software project planning (Dybå, Dingsøyr & Moe, 2014). During software development, changes are constant and the software evolves (Lehman, 1980), usually by enhancing the set of functionalities, but also in non-functional aspects. It is very important to keep this evolution managed, in aim to have control over current status and, if possible, to have prediction of possible future directions (Bhattacharya, Iliofotou, Neamtiu, & Faloutsos, 2012). Lehman (1980) identified sources that stimulate constant software maintenance activities and evolution. International standards organization defined standards related to maintenance (ISO/IEC 14764:2006, replaced with ISO/IEC/IEEE 14764:2022) as one of the software lifecycle processes.

According to ISO 14764 standards, there are four categories of software maintenance: corrective, adaptive, perfective and preventive. These four software maintenance categories could be considered as dimensions of software evolution. This paper contributes with software development monitoring approach in the continual process of software evolution, having these four categories of software maintenance as important aspects. This way, Lehman's evolution laws are integrated with ISO-defined software maintenance categories and they

form a kind of general software development monitoring framework. The aim of this paper is to present a case study of software evolution in ten years period – particular case of Official Web Portal of Preschool institution Zrenjanin, Serbia. This case study presents the evolution of this web portal with three software versions, which brings an example of software evolution. The presentation of this evolution has been put in the context of Lehman’s laws and ISO-standard defined software maintenance categories.

The rest of the paper is organized as follows: second section presents the background and related work about software evolution, Lehman’s laws and software maintenance, third section presents the proposed software development monitoring framework, fourth section presents case study results and discussion and the final fifth section provides conclusions and future work directions.

2 BACKGROUND AND RELATED WORK

Software evolution as a term is commonly related to M.M. Lehman. He started to formulate the software evolution laws within research in this field in 1960ties, related to the IBM programming process. First laws he formulated and presented in his publications in mid 1970ties, others during 1980 ties and 1990ties (Lehman, 1980, Lehman 1997). Other authors also conduct their analysis and systematic reviews of published papers regarding software evolution (Herraiz, Rodriguez, Robles & Gonzalez-Barahona, 2013) and the relation between software evolution and maintenance (Rajlich, 2014). These commonly recognized eight Lehman’s laws are: “1) An E-type program that is used, must be continually adapted; else it becomes less satisfactory; 2) As a program is evolved, its complexity increases unless work is done to maintain or reduce it; 3) The program evolution process is self-regulating with close to normal distribution of measures of product and process attributes; 4) The average effective global activity rate on an evolving system is invariant over the product life time; 5) During the active life of an evolving program, the content of successive releases is statistically invariant; 6) Functional content of a program must be continually increased to maintain user satisfaction over its lifetime; 7) E-Type programs will be perceived as of declining quality unless rigorously maintained and adapted to a changing operational environment; 8) E-type programming processes constitute multi-loop, multi-level feedback systems and must be treated as such to be successfully modified or improved.” (Lehman, 1997)

By definition (IEEE, 2001), software maintenance is an integral part of a software life cycle – it is the totality of activities required to provide cost-effective support to a software system. Activities are performed during the pre-delivery stage as well as the post-delivery stage (includes software modification, training and operating a help desk). First three software maintenance categories were defined by E. Burton Swanson (Swanson, 1976) (Lientz & Swanson, 1980), that conducted research by using empirical data from industry maintainers. He defined corrective, adaptive and perfective categories of software maintenance (Arthur, 1988). International Organization of Standards (ISO) updated the list with a new category and all four categories received recognition within international standard ISO/IEC 14764 (ISO 14764, 2006), also published in SWEBOOK (IEEE, 2001). They are all performed upon software product after delivery to: 1) Corrective maintenance – react in aim to correct the discovered problems; 2) Adaptive maintenance – keep a software product usable in a changed or changing environment; 3) Perfective maintenance – improve the performance or maintainability; 4) Preventive maintenance – detect and correct latent faults in the software product before they become effective faults (IEEE, 2001).

3 THE PROPOSED SOFTWARE EVOLUTION MONITORING FRAMEWORK

This section presents the proposed software evolution monitoring framework, which could be applied with multiple projects that are conducted with one software solution. The proposed approach includes using a table (Table 1) to present key outcomes of the project before (in planning) and after the software project finishes. By using this table, it is clearly stated what are the improvements (comparing to previous state of the software), i.e. what has been planned and gained with this project. The important aspects and dimensions are related to key software quality dimensions - structural, graphical and functional, having them related to the important aspects regarding four maintenance categories.

By using this table (Table 1) in the software evolution monitoring process, one evolving software could be presented with key characteristics that were improved. At least one table could be created per software project at the end of the project, to have a status that is a starting point for the next project.

TABLE I. THE PROPOSED SOFTWARE EVOLUTION MONITORING FRAMEWORK TOOL AT SOFTWARE PROJECT LEVEL

MAINTENANCE CATEGORY aspect	STRUCTURAL dimension	GRAPHICAL dimension	FUNCTIONAL dimension
<i>CORRECTIVE</i>	<Features list and characteristics>	<Features list and characteristics>	<Features list and characteristics>
<i>PERFECTIVE</i>	<Features list and characteristics>	<Features list and characteristics>	<Features list and characteristics>
<i>ADAPTIVE</i>	<Features list and characteristics>	<Features list and characteristics>	<Features list and characteristics>
<i>PREVENTIVE</i>	<Features list and characteristics>	<Features list and characteristics>	<Features list and characteristics>

4 CASE STUDY

This section presents the software evolution case study of Preschool institution Zrenjanin official web portal (www.predskolskazr.edu.rs). This web portal has been improved periodically, within particular projects. Each of these projects had specific targets, i.e. goals.

4.1 Results in software evolution with multiple projects

Starting (first, “old”) solution of this web portal was WordPress-based web portal with presentation and CMS (Content Management System) part, developed in period before 2014 year. Issues that were found in this solution were related to data and multimedia update at the website, i.e. adding data and multimedia and their visibility at the presentation part. The solution was not flexible enough for maintenance and CMS did not support all needs. Not all web portal elements could be found at the hosting, so the solution was not independent of remote URL (Uniform Resource Locator) calls within the implementation.

The first new solution was created in December 2014 and January 2015, as the complete hosting-based (without any frameworks or remote URL calls), by using HTML, CSS, MySQL database and PHP structural programming. It enabled better CMS availability and more flexible graphical presentation. Second solution was created in 2020-2021 years, in aim to support switch from PHP5 to PHP7 platform at hosting. This solution was object-oriented, where separate semantic classes (having SQL scripts) inherit base classes. These base classes were created to encapsulate technology part - having support to database connection and query processing at abstract level, for both PHP5 and PHP7 syntax. The abstract database-connection class also included mechanism for hosting platform detection and direction of the whole application towards using appropriate version – PHP5 or PHP7 code. The third solution was created upon results from second version, but with aim to enhance user experience at presentation part (main web portal) and in CMS. This way both functional and graphical aspects of user experience were targeted.

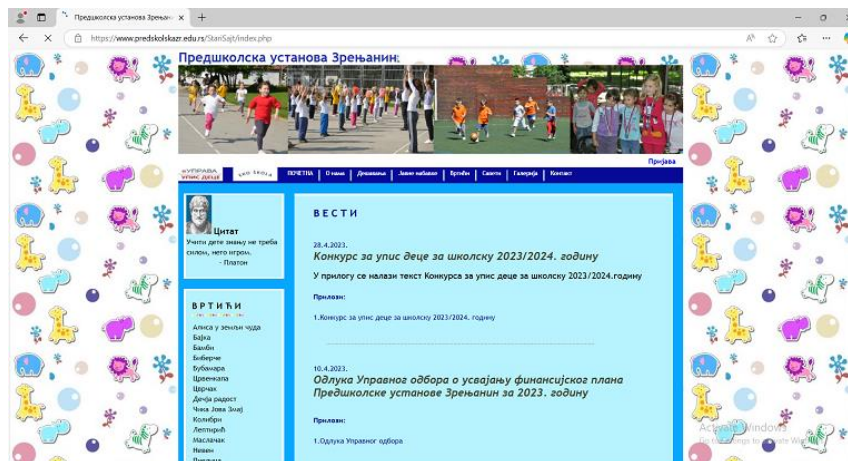


Figure 1. First page of the first and second independent solution of www.predskolskazr.edu.rs

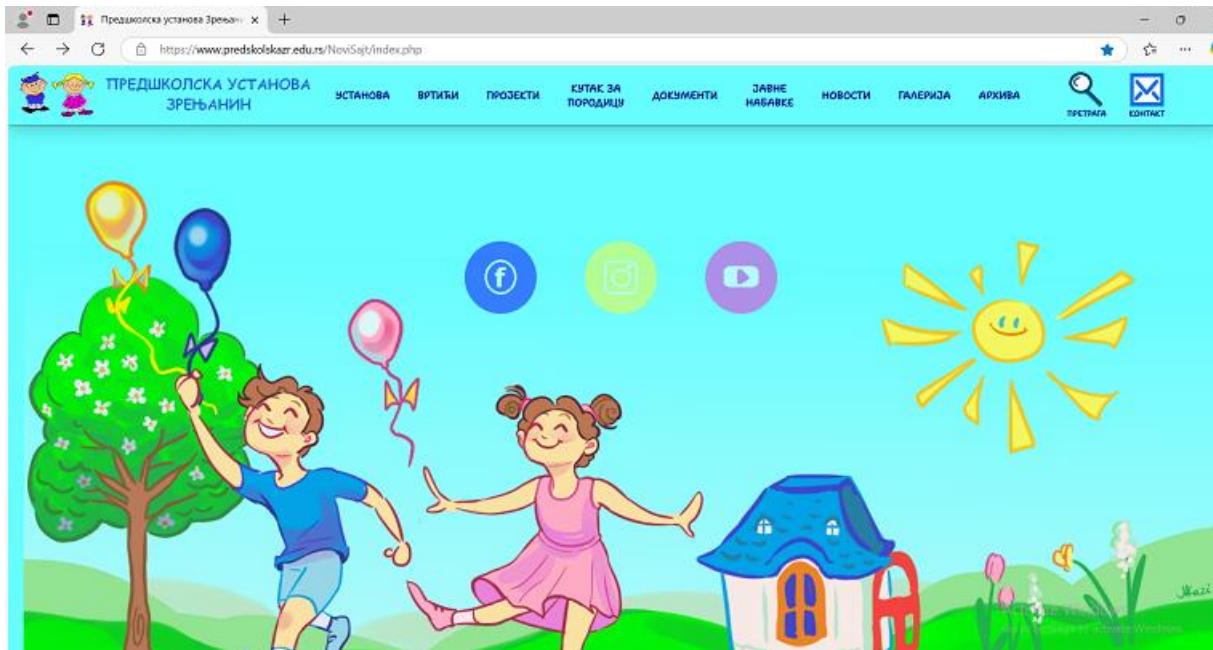


Figure 2. First page of the third independent solution of www.predskolskazr.edu.rs

TABLE II. LIST OF PROJECTS OF PRESCHOOL INSTITUTION ZRENJANIN WEB PORTAL EVOLUTION

Year of project conduction	Project name	Maintenance type	Changes in	Basic Features	Publication
Before 2014/15		-		WordPress solution	
2014/15 First independent solution	New official web portal of Preschool institution with complete independent hosting solution	Perfective	Completely new solution with two modules: Graphical Presentation, CMS functions and data	PHP/MySQL solution, structured programming, multi-page	(Kazi, Kazi & Lojovic, 2017)
2020-2021 Second independent Solution	New official web portal of Preschool institution with dynamic self adaptation to hosting platform	Perfective, Adaptive, Preventive	Graphical presentation, CMS functions and data are the same as in previous solution <i>The change:</i> Back-end refactoring - implementation of PHP technology support to different hosting platforms, no changes in	PHP/MySQL solution, object-oriented programming with separation of technology and semantic classes and self-adaptation mechanism to hosting platform change (PHP 5 and PHP 7 support), multi-page architecture	(Kazi et al, 2020) (Kazi et al, 2021)
2023-2024 Third independent solution	New official web portal of Preschool institution with enhanced user experience	Perfective	Back-end base abstract classes (for database connection and table data processing) are the same as in previous solution <i>The change:</i> In presentation at web portal, CMS functions and data structures, semantic data layer classes	PHP/MySQL solution, object-oriented programming with separation of technology and semantic classes and self-adaptation mechanism to hosting platform change (PHP 5 and PHP 7 support) Addition: single page architecture, MVC, support to all multimedia, broader set of functions in CMS, dynamic use of presentation models, animations, transitions, graphical effects, responsive	(Kazi et al, 2023)

4.2 Discussion and the utilization of the proposed software monitoring framework tool

According to previously presented Table 2, obviously there were several goals that lead to the web portal enhancements:

1. The independence from frameworks and remote functional calls – first independent version, structural dimension,
2. Hosting platform changes adaptation – second change, structural dimension,
3. Data and functions availability and flexibility, improving graphical representation and interaction and responsiveness to device changes – third change, structural, graphical and functional dimension.

According to previously presented results in software evolution (Table 2.), it could be concluded that some versions of web portal were completely (as for first independent version comparing to previous WordPress version) or partially replaced by new versions. The final version kept good results from previous versions, but added new values. Table 3. presents the proposed tool (Table 1) utilized to present the final status after the last software project.

TABLE III. THE PROPOSED SOFTWARE EVOLUTION MONITORING FRAMEWORK TOOL UTILIZED WITH THE LAST VERSION OF WEB PORTAL IN THE PRESCHOOL INSTITUTION OFFICIAL WEB PORTAL CASE STUDY

MAINTENANCE CATEGORY aspect	STRUCTURAL dimension	GRAPHICAL dimension	FUNCTIONAL dimension
CORRECTIVE			
PERFECTIVE	Object oriented, with separation of semantic and technology classes	Web portal presentation: Animations Transitions Graphical effects	Complete set of CMS functions Complete set of web portal presentation functions
ADAPTIVE	hosting platform detection mechanism	Responsive (to different devices)	
PREVENTIVE	hosting platform detection mechanism		

Particularly for the presented case study, Table 3 shows that there is uncovered “adaptive – functional” aspect-dimension. This means that software needs further improvements, to add functions that could enable users to *adapt* the *functionality* to their needs, such as adding accessibility adjustment options (W3C, 2024), that are currently missing.

5 CONCLUSION

This paper presents the case study of evolution of Preschool institution Zrenjanin’s web portal development, in the period of 10 years. By integrating software maintenance aspects with key dimensions of software quality, the new software development framework has been proposed to be used with multiple projects during software evolution. The applicability of the proposed framework was illustrated with the data from the case study.

The proposed framework could be used for software evolution monitoring. Each version could utilize Table 1 (used as an instrument or tool) with filling the appropriate data related to the software project planning or outcome. This way, it would be clearer what the benefits of that version are, i.e. what improvements have been gained in that version. By using this tool, different software versions could be compared more easily.

Future scientific work could be directed towards development of more complex software development frameworks that would enable more precise software development monitoring. In that more complex software monitoring frameworks, other relevant aspects of software quality could be included in multi-dimensional data acquisition and visualization for the software development progress monitoring and decision making.

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Integrating OLAP for Assessing and Enhancing Teacher Digital Competencies in Modern Education

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Abstract. This paper explores the integration of Online Analytical Processing (OLAP) as a powerful tool for assessing and improving teacher digital competencies in modern education. By leveraging multidimensional data such as professional development hours, classroom technology usage, and student performance metrics, OLAP systems enable precise benchmarking of teacher digital skills against peer groups. This data-driven approach identifies areas where targeted professional development is needed, ensuring that teachers can focus on improving specific competencies. A dashboard, designed using OLAP principles in Power BI, is introduced to demonstrate how institutions can visualize and assess teacher progress over time. The dashboard allows teachers to compare their performance with peers, receive personalized recommendations for improvement, and monitor the impact of their training on classroom outcomes. This method provides a scalable, data-driven solution for educational institutions, fostering continuous professional growth while aligning professional development efforts with measurable improvements in teaching effectiveness and student success. Ultimately, OLAP offers educational institutions the tools to create more targeted, efficient strategies for enhancing digital literacy among teachers and improving overall classroom outcomes.

Key words and phrases: OLAP (Online Analytical Processing), teacher digital competencies, professional development in education, benchmarking in education, educational data analytics.

1 INTRODUCTION

Teachers' digital competencies have become essential to fostering effective, technology-enhanced learning environments in today's digitally transforming educational landscape. The UNESCO ICT Competency Framework for Teachers (2018) highlights the critical need for educators to develop skills in utilizing digital tools to improve pedagogy and promote student-centered learning. Yet, many educators face challenges in developing these skills due to limited access to targeted, ongoing professional development (Jackson, 2019).

Educational data analytics has emerged as a solution for bridging this gap. According to Romero and Ventura (2020), data mining and learning analytics allow institutions to assess teacher performance and identify specific areas for improvement. This paper introduces an Online Analytical Processing (OLAP) dashboard in Power BI, designed to assess and enhance teachers' digital competencies by visualizing their progress, comparing their performance to peers, and providing tailored recommendations. By leveraging multidimensional data, including professional development hours and classroom technology usage, the dashboard supports continuous, data-driven growth aligned with the Ministry of Education, Science, and Technological Development of the Republic of Serbia's strategic goals.

To illustrate the dashboard's capabilities, a synthetic dataset simulates real-world teacher performance data, enabling this study to demonstrate the dashboard's functions without compromising data privacy.

2. LITERATURE REVIEW

2.1 Digital Competencies in Education

Digital competencies, as outlined in UNESCO's ICT Competency Framework for Teachers (2018), are foundational for teachers aiming to integrate technology in the classroom effectively. This framework defines the skills educators need to leverage digital tools in accessing information, creating resources, and implementing innovative teaching methods that enhance student learning. In an increasingly digital world, these competencies extend beyond technical skills, encompassing the ability to adapt pedagogical practices to a tech-centric educational environment.

Teacher digital competency is directly linked to student success, as digitally proficient educators can create more engaging, accessible, and personalized learning experiences. Despite this, Jackson (2019) points out that many educators lack structured, ongoing opportunities for professional development that align with the evolving demands of digital education. Consequently, there is a growing need for tools and systems that can assess and support teachers' digital competencies in a targeted, continuous manner.

2.2 Use of Data Analytics in Education

The rise of educational data mining and learning analytics has introduced new ways to improve teaching practices through data-driven insights. Romero and Ventura (2020) emphasize that educational data mining can reveal patterns and trends that assist institutions in making informed decisions about instructional improvements and resource allocation. Specifically, data analytics allows for the assessment of teacher performance metrics, which are crucial for identifying both strengths and areas needing improvement in digital competency.

Dashboards, particularly those powered by OLAP, provide interactive platforms for visualizing and analyzing complex, multidimensional data. According to Viberg et al. (2018), dashboards in educational settings offer clear advantages by enabling teachers and administrators to track progress, set goals, and visualize performance in real-time. When designed effectively, these dashboards not only display relevant data but also support actionable insights, empowering teachers to improve their skills based on personalized data feedback.

2.3 Benchmarking and Professional Development

Benchmarking in education enables educators to compare their performance metrics against peers, offering insights into where they stand and fostering motivation for improvement. Jackson (2019) describes benchmarking as a valuable tool for self-assessment, allowing institutions to promote continuous improvement by identifying best practices. In the context of teacher development, benchmarking can provide meaningful feedback that highlights specific competency gaps and growth opportunities.

Furthermore, Lachner et al. (2021) discuss how data-driven approaches can support targeted professional development by offering insights tailored to individual teacher needs. Peer comparisons can encourage teachers to engage in professional growth, especially when they see how their performance aligns with broader standards or peer group averages. By integrating OLAP-driven recommendations, the proposed dashboard leverages benchmarking to guide teachers toward focused development areas, thereby enhancing their digital competencies and aligning professional growth with measurable improvements.

3. METHODOLOGY

3.1 Data Generation Process

To address privacy and ethical concerns, a synthetic dataset was created to emulate teacher performance metrics, including professional development hours, classroom technology usage, and student performance indicators (e.g., engagement levels, test scores). This data, designed with realistic ranges and distributions, reflects typical patterns observed in educational settings and supports the demonstration of OLAP functionalities.

The dataset represents 50 teachers with varying teaching experience and subject specializations, enabling a comprehensive approach to benchmarking, self-assessment, and growth recommendations.

3.2 Design and Development of the OLAP Dashboard

The dashboard was developed in Microsoft Power BI, utilizing OLAP capabilities to create an interactive platform that enables teachers and administrators to assess digital competencies. Using SQL Server Analysis Services (SSAS), the data was modeled into a multidimensional structure, supporting dynamic analysis through real-time slicing and filtering.

The data structure, illustrated in Fig. 1, is organized into three primary dimensions: Time, Teacher Demographics, and Competency Areas. These dimensions support in-depth analysis of teacher performance metrics across semesters, enabling longitudinal tracking and insights based on teacher characteristics (e.g., experience and subject area) and competency metrics (e.g., professional development hours, technology usage frequency, and engagement scores).

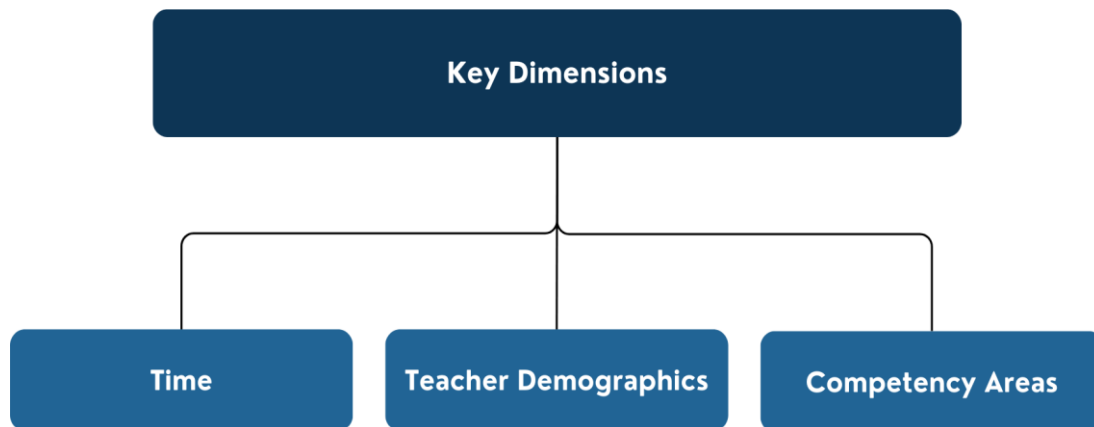


Figure 1. Graphical representation of chosen key dimensions

These dimensions allow for granular analysis, enabling stakeholders to track growth over time and pinpoint specific areas for development.

The dashboard's core components include performance tracking, peer benchmarking, and personalized recommendations. Performance tracking allows for the visualization of individual teacher metrics across various competencies, providing a clear overview of each teacher's progress. Peer benchmarking enables teachers to anonymously compare their metrics with those of peers in similar subject areas or experience levels, fostering a culture of self-assessment and improvement. Finally, the dashboard offers personalized recommendations, suggesting tailored professional development actions based on each teacher's performance data, such as targeted training to enhance digital integration skills.

3.3 Assessment Metrics

The dashboard uses Key Performance Indicators (KPIs), as illustrated in Fig. 2, to assess and benchmark teacher development. These metrics include the Digital Competency Score, measuring overall proficiency based on UNESCO's ICT Competency Framework, Professional Development Hours for tracking PD engagement, and the Technology Integration Score to evaluate classroom technology use effectiveness. Additionally, the Student Performance Improvement Index provides insights into changes in student engagement and performance associated with teacher digital competencies.

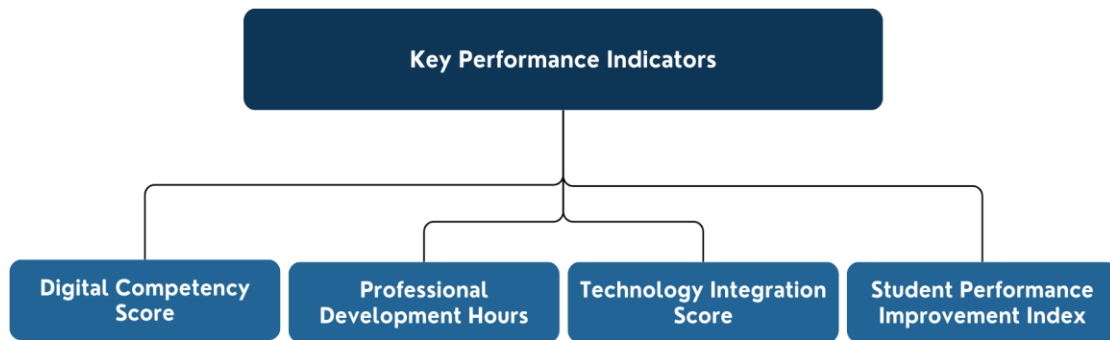


Figure 2. Graphical representation of chosen key performance indicators

3.4 Ethical Considerations

The use of synthetic data eliminates privacy risks while demonstrating the dashboard's capabilities. For real-world applications, ensuring data privacy and obtaining participants' consent would be essential, with data anonymization and aggregation employed as protective measures.

4. RESULTS

4.1 Dashboard Overview

The Power BI dashboard provides an interactive platform for assessing teacher digital competencies across multiple dimensions. By leveraging the synthetic dataset, the dashboard models real-world scenarios where teachers and administrators can evaluate performance metrics, identify gaps, and develop targeted improvement plans. The dashboard's structure is centered on providing insights in a user-friendly format, empowering educators to make data-informed decisions.



Figure 3. Teacher digital competencies dashboard solution

4.2 Key Findings from the Dashboard

The dashboard analysis highlights significant insights into teacher digital competencies, offering a comprehensive view of performance across key areas, as shown in the Fig. 3.

- **Professional Development Patterns:** The PD Hours by Semester and PD Activity Type visuals reveal trends in professional development engagement, indicating which types of activities (workshops,

online courses, conferences) are most utilized and how engagement varies over time.

- **Competency Growth and Benchmarking:** The Digital Competency Score by Semester and Top/Bottom Performers visuals show growth in teacher competencies over time and provide a comparison within the cohort, identifying high and low performers to support targeted professional development.
- **Influential Factors on Competency:** The Key Influencers visual highlights critical drivers of digital competency improvement, such as professional development hours, technology usage frequency, and student engagement, offering insights for focused interventions.

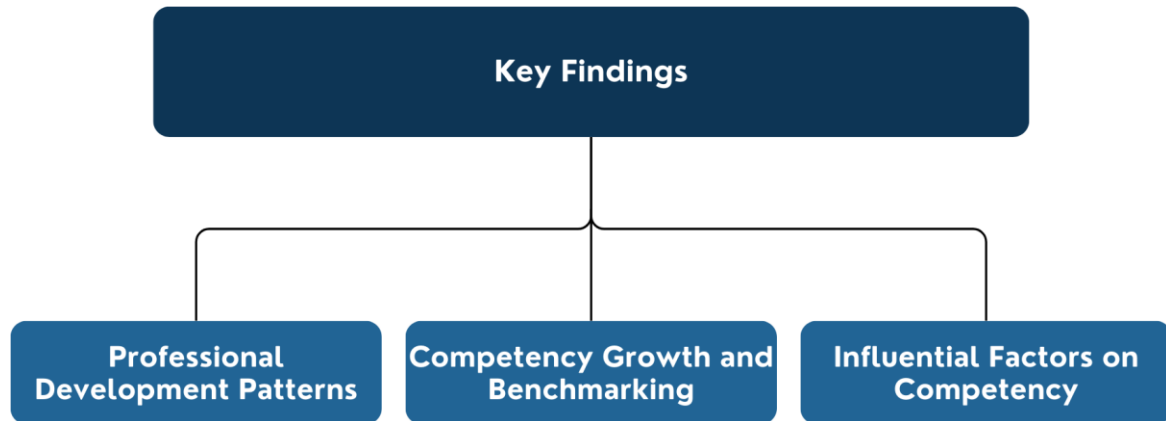


Figure 4. Graphical representation of dashboard key findings

4.3 Impact of Dashboard Insights

Through the dashboard, teachers gain a visual understanding of their digital competencies, helping them to identify growth opportunities. For example, teachers prompted to complete additional professional development hours displayed improvements in both Digital Competency Scores and Classroom Technology Integration Scores, validating the role of targeted, data-driven training in enhancing professional growth.

Institutions also benefit by aligning professional development resources with areas that require the most attention. The OLAP dashboard allows administrators to monitor teacher competencies effectively, providing a scalable approach to support the ongoing development of digital skills across the educational workforce.

5. DISCUSSION

5.1 Interpretation of Results

The OLAP dashboard developed in this study demonstrates how data-driven insights can enhance teacher digital competencies by enabling targeted, personalized professional development. The synthetic dataset findings suggest a positive relationship between professional development hours and digital competency scores shown in Fig. 5, which aligns with previous research indicating that targeted training improves teachers' ability to integrate technology into their pedagogy (Lachner et al., 2021). The dashboard's peer benchmarking feature further supports this improvement by allowing teachers to self-assess relative to their colleagues, a motivating factor for professional growth as discussed by Jackson (2019).

The use of personalized recommendations within the dashboard is particularly valuable, as it provides teachers with clear, actionable insights into areas where they could benefit from additional training. This targeted approach not only addresses individual needs but also supports institutions in efficiently allocating training resources, ensuring that professional development efforts are both impactful and cost-effective.

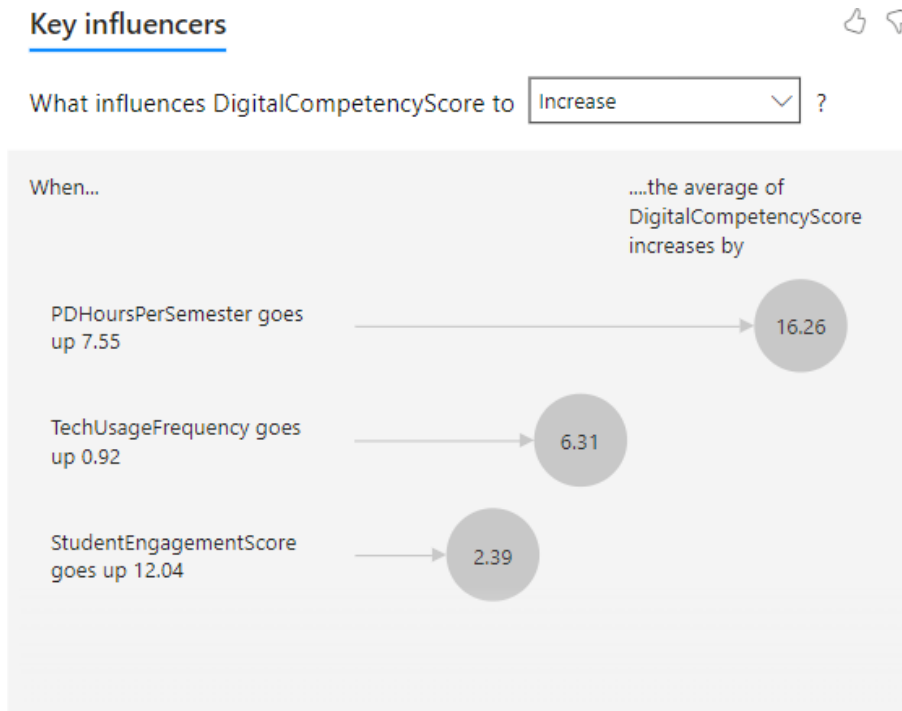


Figure 5. Personalized recommendation key influencers panel

5.2 Implications for Educational Institutions

The findings have several practical implications for educational institutions. By implementing similar dashboards, institutions can more effectively track and support teacher development. Institutions could use such a tool to identify areas where their teaching staff may benefit from targeted training and professional development, ensuring that resources are directed toward the competencies that will have the most significant impact on student outcomes.

On the other hand, the scalability of the OLAP dashboard allows it to be used across departments and institutions, fostering a culture of data-driven growth. Educational institutions can tailor the tool to include additional KPIs or customize benchmarks, thus providing a flexible solution adaptable to varying educational settings.

5.3 Challenges and Limitations

While the dashboard presents many benefits, several limitations must be acknowledged. Firstly, the use of synthetic data, though essential for privacy compliance, means that the findings cannot fully represent real-world outcomes. Future studies should validate the dashboard's functionality with actual teacher performance data, ensuring that the insights and recommendations provided are genuinely applicable in educational contexts.

While the dashboard offers valuable insights, it requires teachers to engage with the tool consistently for sustained impact. Teachers who are less familiar with data interpretation may need initial support to use the dashboard effectively, suggesting the need for accompanying training or guidelines on data literacy to maximize its potential. Lastly, as with any data-driven approach, it is essential to maintain data privacy and security, ensuring that personal and performance data are protected according to institutional policies and regulations.

5.4 Future Research Directions

Future research could build on this study by implementing the dashboard in real educational settings and analyzing its impact on actual teacher competency development. Longitudinal studies tracking teacher performance over time could reveal more about how data-driven recommendations affect skill development and student outcomes. Furthermore, expanding the dashboard's capabilities to include additional metrics, such as feedback from students or observations from peer teachers, could provide a more holistic view of

teacher effectiveness.

Exploring ways to integrate this tool within existing teacher training programs may also enhance its utility, allowing educational institutions to streamline professional development initiatives and create a sustainable model for continuous improvement. With these additions, OLAP-driven tools could play a crucial role in shaping data-informed educational practices and promoting a culture of continuous growth in digital competencies.

9. CONCLUSION

This study introduces an OLAP-powered dashboard designed to assess and enhance teacher digital competencies, addressing a critical need for data-driven professional development in modern education. By leveraging multidimensional data on professional development hours, technology integration, and student performance, the dashboard provides teachers with a personalized view of their digital skills, benchmarks against peers, and tailored recommendations for improvement.

The findings demonstrate the potential of this dashboard to empower teachers with actionable insights, encouraging continuous growth in digital competencies. The dashboard's peer benchmarking and personalized feedback allow teachers to engage in self-assessment, addressing specific areas for development and fostering a sense of accountability. Additionally, by visualizing competency areas and linking them to student outcomes, the dashboard offers educational institutions a scalable tool to monitor and support professional growth, thus ensuring that professional development resources are allocated effectively.

Despite its benefits, the study acknowledges limitations, particularly the use of synthetic data, which while essential for ethical compliance, limits real-world generalizability. Future research should validate these findings with actual teacher data to confirm the dashboard's effectiveness in real educational contexts. Furthermore, as educational institutions consider implementing such tools, accompanying training on data interpretation will be critical for maximizing the dashboard's impact.

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Digitalization and Legal Education

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Abstract. Digitization has become a key factor in the transformation of educational systems around the world, including law faculties. The introduction of digital technologies into the educational processes at law faculties allows students and teachers access to new tools and teaching methods that improve the quality of education. This paper explores the impact of digitization on law faculties education, focusing on the challenges and benefits this change brings. Given the changes in work, business and education conditions it is necessary to consider the potential that technology and its application can provide in certain processes.¹

Keywords and phrases: Law, digitalization, higher education.

1 INTRODUCTORY CONSIDERATIONS

Digitization involves the process of transforming information from analog to digital form for further processing using a computer. Theoretically, its only drawback is the potential loss of information that inevitably occurs during discretization and quantization of the analog signal. In higher education, digitization has significantly changed the way of working. Traditional green boards and white chalk have been replaced by smart boards, and classrooms and amphitheatres are now equipped with internet-connected computers. At the same time, students can register for exams electronically, and teachers can attend sessions remotely, even when they are away from the institution. These changes introduce new terms such as e-faculty, e-teaching and e-index. Students will attend the e-faculty, where they will follow e-teaching and perform administrative tasks using the e-index. However, in order for the e-faculty to function successfully in practice, it is crucial to establish appropriate legal regulations (Kupusinac, 2018, p. 1).

According to the Strategy of Development and Education in the Republic of Serbia until 2030, digital education refers to two different but complementary areas of education policy: one includes measures aimed at the digital competence of teachers and students, while the other includes the pedagogical application of digital technologies in order to improve the quality of teaching and learning (Strategy of development and education in the Republic of Serbia 2020). On the other hand, in the Strategy for the Development of Digital Skills in the Republic of Serbia for the period 2020-2024, digital education was not highlighted as a priority. A similar deficiency is present in the Strategy for the Development of the Information Society and Information Security in the Republic of Serbia for the period 2021-2026. year, where e-education mainly refers to activities in the field of pre-university education and existing or initiated initiatives for its improvement. National strategy for youth for the period 2023-2030. refers to the previously mentioned strategies. Finally, neither the Law on Higher Education (Official Gazette of RS, no. 88/2017, 73/2018, 27/2018 - other laws, 67/2019, 6/2020 - other laws, 11/2021 - authentic interpretation, 67/2021, 67/2021 – other laws and 76/2023), as the basic legal act that regulates this area, does not contain provisions related to digital education.

The Action Plan for Digital Education (2021-2027) is a renewed policy initiative of the European Union with a shared vision of quality, inclusive and accessible digital education in Europe. Its goal is to help member states adapt their education systems to the digital age. The action plan calls for more cooperation in the field of digital education at the level of the whole of Europe in order to heal the consequences of the pandemic and open up new opportunities for everyone involved in education and training: teaching staff, pupils and

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students, policy makers, the academic community and scientists at the national, European and international level (Akcijski plan za digitalno obrazovanje (2021 – 2027), 2021).

The unstoppable process of digitization can also be seen in the "Digital Europe" Program (2021-2027), which aims at digital transformation in the sphere of economy, industry and society (Article 3). The "Digital Europe" program is the first program of the European Union dedicated to implementing the digital transformation of Europe, in which the Republic of Serbia has become a full member. The program focuses on several key areas, including digital skills and education, with the aim of enabling European citizens to adapt to digital changes in society and the workplace (Bugarski&Fišer Šobot, 2024, p. 321).

Students perceive digitization as an extremely important process, but at the same time they notice numerous shortcomings that make it difficult to fully implement it in higher education. The most common problems include the absence of adequate or modern digital infrastructure, as well as the lack of training in the use of digital tools. These challenges require a deeper analysis in order to take advantage of all the opportunities and advantages that digitization offers (Kolarski, 2022, p. 61). It is necessary to intensify efforts in the promotion and effective application of digitalization at faculties, because insufficient information among students about this concept often leads to skepticism regarding its role in improving the quality of education (Kolarski, 2022, p. 64).

2 DIGITAL TRANSFORMATION OF LEGAL EDUCATION

Education is extremely dynamic and increasingly relies on the use of technological tools, especially in higher education (Marošević&Blažević, p. 212). Bearing in mind the need for orientation towards the future and the possibility of combining traditional methods and teaching processes with technological innovations that will develop more and more, the implementation, education and acceptance of these innovations for educational purposes become key prerequisites for modern learning and teaching (Marošević&Blažević, p. 226).

The formation of the professional competence of lawyers in the current stage of development of higher education institutions is unthinkable without integration into the general system of preparing digital education (Bugarski&Fišer Šobot, 2024, p. 322). The education of lawyers in higher education institutions is of particular importance in the era of digitization and development of information and communication technologies. The competencies and skills of future lawyers directly affect the quality of their work in all professional areas, which, in turn, reflects on the overall quality of life and functioning of society (Bugarski&Fišer Šobot, 2024, p. 324).

In order to equip future lawyers with “advanced” knowledge, it is necessary to develop personal educational pathways for students, to form the basic competences of a lawyer, to modify the certification system that minimizes the ability to reproduce ready-made knowledge. It is important to ensure the education of a harmoniously developed and socially responsible person (Sadkov, Kvitsinia, Sandalova, 2021, p. 2). In the UK, digitalization in legal education, research, and practice includes offering legal technology modules, integrating social media and virtual spaces into curricula, and establishing online law clinics, such as the Open Justice Centre. These initiatives enhance students' digital, legal ethics, and client communication skills while using mobile technology and apps for practical learning. Many law faculties also offer online degree programs. In legal practice, advancements include digitalized evidence, virtual hearings, online dispute resolution platforms, and AI-based contract management systems (Ignjatović, 2024, p. 34).

AI-technologies (AI-assistants, generative Open-AI ChatGPT) are increasingly used in legal research, case analysis, legal writing, drafting documents, etc. (Ignjatović, 2024, p. 35). Legal decision-making entails interpreting and applying laws to particular cases. Historically, this process has been carried out by judges and lawyers relying on their understanding of legal statutes and precedents. The integration of AI, especially machine learning, offers the potential to improve this process by delivering insights and forecasts derived from extensive legal data (Kabir&Alam, 2023, p. 1088). The application of AI in the legal field brings up several ethical and legal challenges. Ethical issues involve the risk of bias in AI algorithms, the possibility of errors in decision-making, and the potential effect on employment opportunities for human lawyers and judges. Legal concerns include accountability for mistakes made by AI systems, the necessity for regulations and standards governing AI in the legal profession, and the risk of AI undermining core legal values such as fairness and justice (Kabir&Alam, 2023, p. 1090).

Both current and future lawyers are cognizant of the transformations in the legal profession brought about by

digitalization and recognize the necessity for a substantial overhaul of the educational process. Additionally, the respondents indicated that they expect the educational system to not only impart knowledge of new digital technologies but also to focus on cultivating the essential skills and competencies needed to work with these technologies. In order to establish standardized approaches for selecting digital competencies for lawyers, it is crucial to develop a Framework for the Digital Competence of Lawyers. This framework would empower them to effectively utilize LegalTech in their practice. New methods for acquiring skills include computer or virtual simulators, which provide opportunities to work with online platforms, digital platform demonstrations, and LegalTech hackathons (Kharitonova&Sannikova, 2022, p. 70).

If we want to increase digitization in law faculties in Serbia, we should provide adequate support and investment in digital infrastructure, including high-speed internet, Wi-Fi in classrooms, and essential hardware and software, while ensuring access to digital platforms through academic networks; prioritize data protection, privacy, and the security of personal information, alongside developing ethical guidelines for the use of digital tools in education and research; offer training for both educators and students on security, privacy, and digital competencies, using tools like DigComp for self-assessment enhance students' skills in data, media, and digital literacy, and promote teachers' capabilities in digital design, content creation, classroom management, and assessment, supported by tools like DigComp Selfie for Educators; facilitate professional development opportunities and validate digital credentials (Ignjatović, 2024, p. 40-41).

3 CONCLUSION

Traditional classroom teaching and physical presence offer distinct advantages, yet the same can be said for online education, which also comes with its own set of benefits and drawbacks. This highlights that, alongside the evolution of modern society, learning methods are advancing in parallel with the availability of new technologies. Consequently, various e-learning systems have emerged as a part of contemporary education.

The necessity of modernizing education stems from the fact that a new generation of digital natives has grown up, which actively uses new technologies in everyday life. At the same time, research by IT experts indicates a wide application of technologies not only in professional activities, but also in the processes of socialization and communication. Therefore, the digitization of education will enable greater adaptability to the modern generation, which will improve the competitiveness of universities on the educational market, contribute to the creation of additional values and increase the engagement of students.

Legal education has traditionally been quite conservative, often resistant and cautious when it comes to altering practices that are firmly embedded in a particular legal tradition. Digitization of education at law faculties is an inevitable step in the modernization and improvement of legal education. The introduction of new technologies, such as online teaching, digital learning platforms and LegalTech tools, opens up a wide range of opportunities for improving the quality of teaching, but also for the more effective development of legal skills and competencies among students. Digitization enables greater availability of educational content, flexibility in learning and student engagement, and also contributes to the reduction of administrative burdens.

However, considering the complexity of the legal system and the specificity of legal education, it is necessary to carefully approach the integration of digital technologies into the teaching process. It is crucial to develop adequate digital competences among students and professors, as well as to provide the necessary infrastructure for the smooth use of new tools. Also, it is important to ensure that digitalization does not threaten basic legal values, such as fairness and equality, and that it is aimed at strengthening the quality of education.

In the future, digitization should be strategically planned and implemented, with continuous training and adaptation of the curriculum to market needs and advanced technological achievements. Therefore, law faculties must become centers of innovation, where students are not only prepared for practical work in a digitized legal environment, but also for the application of new technologies in legal processes and services.

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The Importance and Role of Elementary Schools Website in the Realization of Distance Learning

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Abstract. This paper describes the importance and role of the elementary school website in the implementation of distance learning. The reasons that led to the transition of classes from school desks to classes via "small screens" are described. The concepts of distance learning and web site are defined. The structure of the website intended for elementary school is given. Based on the analysis of school websites in the region and in the country, a survey was conducted among users of the school website. The obtained results indicated the shortcomings of the existing site, based on which recommendations were given for overcoming the given problems in order to improve the site.

Keywords and phrases: school website, distance learning, elementary school

1 INTRODUCTION

In the past few years in the Republic of Serbia, it has been prescribed that every school institution should have its own website. The basic goals and functions of the elementary school website are twofold: they serve as information systems for site visitors and act as mediators between numerous actors in the educational process. Retrieved from: <https://www.researchgate.net>

The use of the website gained particular importance during the pandemic caused by the Covid-19 virus, which had a huge impact on both the world economy and education. At one point, there was a mass closing of schools, and the transition to teaching from home. Teachers, students and their parents were taken aback by this development. Overnight, everyone was in a dilemma as to how to continue further education. The solution was distance learning, which has become an everyday thing, not only in the Republic of Serbia, but also in the whole world.

2 DISTANCE LEARNING

Distance learning is a special form of educational work where students receive basic education and teaching in a way that ensures the achievement of prescribed goals, outcomes and standards of achievement. Teaching and learning take place using information and communication technologies (ICT), when students are unable to attend regular classes, directly at school. The possibility of attending the course according to their own time, as well as use of time for learning, individual work or group learner capacity, information structuring and teacher's new working methods, are qualities that DL brings about to teaching-learning processes (Fenollera & Goicoechea, 2011; Choi, 2011, Kember, 1994; Link, 2006, Packham, 2004, Pardanjac, 2014). The entire teaching is then regulated by a special program that contains: specific lesson length, recommendations for the organization of teaching, necessary contents, didactic-methodical instructions for the realization of the contents and the period of realization of the contents. (2020, „Službeni glasnik RS“, br.109/2020)

Distance learning is not a new concept, it existed before, only it was not used at all levels of education, nor in all countries equally. Distance learning is mostly associated with higher education institutions, mostly in the world. Universities are beginning to offer courses of distance learning based on information technology and the

Internet, which in the last ten years have risen sharply, becoming widely used in universities around the world (Jara & Mellar, 2007). The first university to offer distance learning was the University of London (1859). After him, the University of South Africa introduced Correspondence Education courses before 1946. Great Britain has been home to the largest Open University since 1969. Today, there are over 90 institutions in the world that offer distance learning. (Medan, 2009).

3 SCHOOL WEBSITE

A school website has great utility. Starting with the primary purpose, that is, the promotion of the school, through the teaching staff, school management, support of the teaching process of any subject, and all the way to parents and children. Retrieved from: <http://www.skolskiportal.edu.me>

Publishing student works on the school website has a motivational effect on students, teachers, students and parents and provides quality and proven resources. Through the website, parents get relevant information related to the school, create an image of the school without actually going there. (Stepić, 2012)

A school website is an ideal place where children can be offered numerous opportunities:

- extracurricular and free activities
- school newspaper in electronic edition
- links to additional interesting content
- educational games and the like. Retrieved from: <http://www.skolskiportal.edu.me>

In addition to content aimed at children, the school website helps parents and teaching staff in some of the following ways:

- various forums on the relationship between parents - teachers, teachers - teachers
- obtaining quick and accurate information about school events
- parents' access to school documents (school plan, statute...)
- student insurance
- schedule of classes, bells, consultations with teaching staff and professional associates
- electronic diary, etc.

4 METHODS OF RESEARCH

The goal of the research is to determine whether elementary school websites meet the needs of their users (teachers, parents and students). The obtained results will point to possible further directions for improving the site, in order to satisfy the needs of its users. The sample consisted of teachers and students of "Petar Kočić" elementary school in Temerin, as well as the parents of those students. The survey was created via Google Forms, and forwarded via Viber groups. The survey is anonymous, contains 12 questions, 10 questions are answered, where the respondent chooses one or more answers, while two questions are answered with a short text. The planned sample included 50 students, 30 parents and 25 teachers, but 212 respondents participated in the survey (96 parents, 82 students and 34 teachers). The survey was completed in the period from 09/21/2021. until 30.09.2021.

The main hypothesis of the research is: elementary school websites were used much more during online classes, than in conditions where classes are held directly in the school building.

The sub-hypotheses of expression are:

- 1 School websites meet the basic principles of web design and meet the needs of their users.
- 2 Access to information from the site is possible from any device.

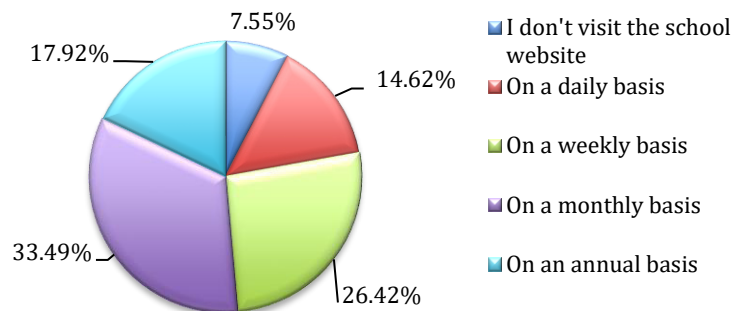
5 RESEARCH RESULTS

The first question was of a demographic type and related to the role the respondents have in relation to the school: Out of 212 respondents, 96 (45.28%) are parents, 82 (38.68%) are students and 34 (16.04%) teachers (Table 1).

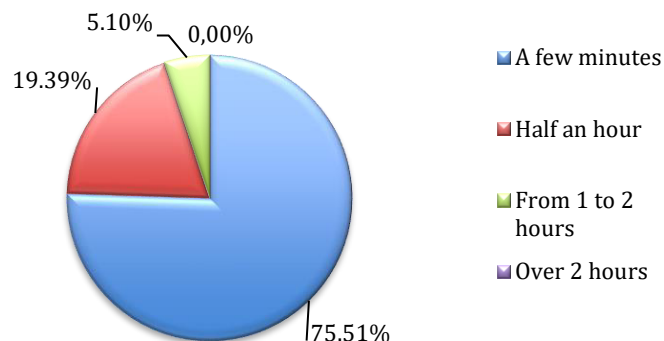
Table 1. Respondent's relationship with the school

Parents		Pupils		Teachers	
	%	Number	%	Number	%
	45,28	82	38,68	34	16,04

Graph number 1 shows how often respondents visit the school website: out of 212 respondents, only 16 (7.55%) do not visit the school website. 31 (14.62%) respondents access the website daily, 20 of them are students. 56 (26.42%) respondents visit the site weekly, 71 (33.49%) per month, and 38 (17.92%) respondents per year. This question was also an elimination question, because of the initial 212 respondents, 196 respondents answered the following 10 questions. Respondents who answered that they do not visit the school website, did not answer the other questions in the survey.

**Figure 1. How often respondents visit the school website**

In the next question, respondents answered how long time they spend on the site (Figure 2): out of 196 respondents, 148 (75.51%) stay only a few minutes. 38 (19.39%) respondents stayed for half an hour. Only 10 (5.10%) of the respondents stay up to 2 hours on the site.

**Figure 2. How long-time respondents spend on the site**

Respondents mostly use a mobile phone to access the site (Figure 3) – 130 (66.33%). A tablet is used by 3 (1.53%) respondents, and a computer by 63 (32.14%). Mobile phones are the most common among parents (81%), among students the percentage is slightly lower (67%), and among teachers only 25%. Teachers mostly use computers, which is shown by a high percentage of use (69% of the 32 teachers who responded to the survey). The fact that mobile phones have become widely represented in our lives, and that even children have them, has the effect that the largest number of respondents access the site via mobile phones. Their ease, both in use and mass, has caused them to become a more commonly used technology than a tablet or computer.

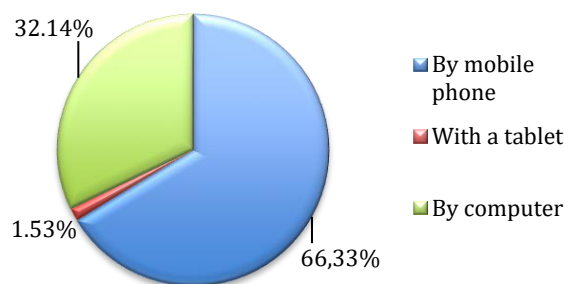


Figure 3. The device through which the site is accessed

To the next question, the respondents agreed or disagreed with the expressed attitudes and opinions about the characteristics of the school's website (Table 2.). The respondent could answer the given statements with one of the two offered answers (yes/no).

Of the 196 respondents, a high percentage agreed with the statements made, and less than a quarter disagreed. The table shows disagreements on the third, fourth, fifth, sixth and seventh statements, because respondents answered both yes and no to those statements.

Almost all respondents agreed that the school website is easy to use and that they find the necessary information on it (over 90%). Students find the information on the site clear, useful and complete. Slightly less than half of the teachers believe that it is necessary to update the site more regularly, with which 28% of the students agree. Parents and students confirm that the site is designed according to the purpose, while teachers think that the site design should still be worked on. The biggest problem students and parents have is that they do not know exactly in which part of the site to find the necessary information. Analyzing the website of this school, the conclusion is reached that out of the mentioned eight claims, the majority of respondents agree with the fact that the site loads relatively quickly and is designed in accordance with the purpose, while the other six claims cannot be answered by a higher percentage.

When asked what should be added to the school website, parents and teachers had the most suggestions. Some of the proposals were related to the content on the site: add students of the generation, awards from competitions, public procurement, student insurance, access to public libraries, institutions, museums, extracurricular activities, sections, visits, trips, a page about successful former students and some of their messages to current students, forums, parents' reception, bell schedule, parents' questions, teacher's portfolio, decisions of the School Board, problems facing the school, windows by department with all information related to that department. The second part of the proposal related to the design of the school's website itself, where they would like the website to be more attractive, better organized, important items more visually striking, updates to be much more regular. However, although there were a lot of suggestions to improve the site, 57% of the respondents answered with nothing, I don't know and leaving the field empty.

As with the previous question, the next question also sought the opinion of respondents in terms of what should be removed from the school website. Regarding this question, the answers of all three groups of respondents were consistent. In 86%, the answer was nothing and I don't know. The other 14% of respondents agree that outdated information that is still on the school's website should be removed from the website.

Table 2. Attitudes and opinions about the characteristics of the school's website

Statements and answers	Parent		Studentr		Teacher	
	Yes	No	Yes	No	Yes	No
The school website is easy to use.	87	2	71	4	30	2
I find the necessary information on the site.	84	5	73	1	29	3
The information on the site is clear, useful and complete.	79	10	69	6	22	10
The structure of the site is clear and logical.	82	7	63	10	24	8
The site is updated regularly.	75	13	54	21	18	14
The site loads very fast.	79	10	54	20	28	4
I know exactly where to find the information I need.	69	20	57	18	27	5
The site is designed according to the purpose.	84	5	72	3	28	4

The majority of respondents (152, 77.55%) (Figure 4.) believe that the school website meets the basic principles of design, i.e. that it is functional, usable and useful. Less than 5% disagree with the majority, while 35% say they don't know. The website of the school that is the subject of the questionnaire can be said to be functional, and as it serves its purpose, it can be concluded that it is useful.

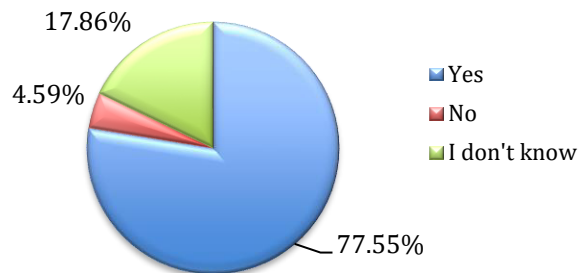


Figure 4. The school website meets the principles of design

Based on the analysis of 196 respondents' answers, it was concluded that the school website leaves an excellent impression on 45.92% (90) of the respondents (Figure 5.). None of the respondents rated the school website with a rating of one, or rather as extremely bad.

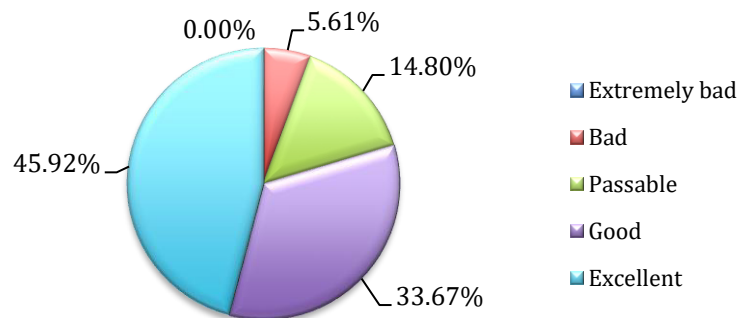


Figure 5. General impression of the school website

On the question of security for the intended users (Figure 6.), 161 (82.14%) respondents believe that school websites are safe. A small percentage said maybe (19, 9.69%) and I don't know (16, 8.16%). None of the respondents consider the school website unsafe to use. The material on the school's official website must comply with the regulations governing information security and measures to protect against misuse of access and data disclosure. The school should have a person or more persons in charge of checking the security of content posted on the school website, Facebook page, school newspaper and the like. There are various ways to protect websites that the person maintaining the school website should use, so that the school website is safe for users at all times. This includes regular updates, use of anti-malware software, security passwords, backups, and the like.

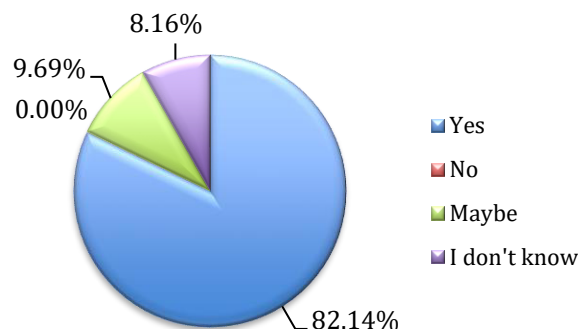


Figure 6. The school website is safe for its intended users

Based on the answers of the respondents to the question of how much the website was useful to them while attending classes from home, it is concluded that the school website was useful to the majority of respondents during the course of classes from home. On a scale from 1 to 5, over 50% declared themselves as 4 and 5. 20 (10.20%) respondents declared that they did not benefit from the school website. Teachers are most dissatisfied with the school website. 9 (28%) of the 32 teachers answered that they did not use the school's website at all, while only 4 (13%) teachers said that they benefited from the website while teaching from home. For parents and students, that percentage is reversed. 40% of parents said that they used the site during online classes, as did 35% of students. Only 5 parents and 6 students believe that they did not benefit from the school website.

6 CONCLUSION

Looking at all the results obtained by the survey, it was concluded that over 90% of the respondents visit the school website, which confirmed that it is relevant for the respondents. The most numerous visitors to the school website are teachers, followed by parents, and then students. The possibility of choosing at which level the respondents visit the school website (daily, weekly, monthly, yearly) is offered, where it is noticeable that the respondents mostly visit the school website on a monthly and weekly basis. One fifth of the surveyed students visited the site on a daily basis, and one third on a weekly basis. The main hypothesis can be confirmed for which student, because more than half of the students visited the school's website in search of information, while the same hypothesis was refuted in the sample of teachers and parents. Given that the information was provided on a daily or weekly basis, it is assumed that parents and teachers obtained the necessary information through other sources.

Sub-hypothesis 1 was confirmed by the respondents. The website of the school that is the subject of the questionnaire is functional, simple, intuitive, logical and understandable, so it can be concluded that it is usable. For these reasons, it can be said that it has fulfilled the principles of web design.

The second sub-hypothesis was confirmed by the analysis of the questionnaire, because most users access the site via mobile phone. The reason for the most massive access through this device is the availability and widespread use of the mobile phone. Nowadays, it is unthinkable that someone does not own a mobile phone. By the way, the progress of technology in today's time has led to the fact that mobile devices are now small computers, which have many functions, access to the Internet and many other options. Its ease of use, small dimensions are its most relevant features that put it in the first place of use.

After the conducted research, as well as the analysis of school websites, it is concluded that the school website plays a significant role in the implementation of distance learning, as well as in obtaining timely and relevant information for its users. It is necessary to work on the improvement of school websites in order to raise the number of users to an even higher level. The analysis of websites in the region and in the country showed that there are extremely few high-quality websites, and that there is no trace of distance learning on most of them. The assumption for this conclusion is that school websites are maintained by computer science teachers, so due to lack of time, the websites are of poor quality. The recommendation would be to hire a company to create school websites or for the school to have a person in charge exclusively of this type of work. The availability of technology and the situation in which the whole world finds itself, requires and provides the opportunity to improve teaching, and to improve the traditional way and combine it with modern technical possibilities. This implies the inclusion and availability of teaching materials on school websites, the combination of school teaching with digital classrooms, which should be available on the school website.

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Mobile Application for Music Streaming Services

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Abstract. This paper presents an application that provides users with a music streaming service. The application was created as a result of the Mobile Technologies IT bachelor studies course. Flutter technologies and Android Studio environment were used, which are also briefly presented in the paper. The application was created as a result of a comparison of existing streaming services, of which the two most famous on Android devices stand out: YouTube Music and Spotify. The comparison was based on various criteria, both visual and those concerning the application's capabilities compared to competitors, as well as the difference between the free and commercial versions of these services. The paper also deals with the personalization on these services, i.e. in what ways these services try to approach the user to convince him to switch to a commercial application model. The created application visually emulates the features of both services, with the functionality of playing music that is locally saved in the project. In that way, the paper illustrates outcomes of the teaching process in the best possible way.

Keywords and phrases: Mobile technologies, Mobile applications, Music streaming services.

1 INTRODUCTION

Users who do not pay for the music streaming services, unfortunately, do not have access to all the capabilities of the application and in that case, choose the one that supports the preferred way of listening to music. Those who prefer live music might rather migrate to YouTube Music because Spotify does not offer recordings of live performances, but only studio versions of songs. If the user listens to music while doing other activities, and wants to turn off the device, he will rather use Spotify, because the free version of YouTube Music does not allow background listening. The commercial versions of the service unlock all the possibilities, but they still differ greatly from each other, primarily in terms of the highest quality of sound they can produce. Taking into account the analysis of the characteristics of these services, an application was created that visually tries to emulate the characteristics of both services, with the functionality of playing music that is locally saved in the project. The MusicApp application is made in Flutter, so the paper deals with Flutter and the Android Studio environment, from how it was created, to how Flutter plays widgets. Education for the use of these technologies was carried out during the Mobile Technologies course, IT study program of undergraduate studies. Therefore, the case study of the mentioned application represents the best illustration of the outcome of the educational process.

2 ANDROID STUDIO AND VIRTUAL DEVICES (AVD)

Android Studio is the official integrated development environment (IDE) for developing Android applications. Based on IntelliJ IDEA's code editor and developer tools, Android Studio offers features that improve productivity when building Android applications, such as: a flexible build system based on Gradle, a fast and rich emulator, a single development environment for all Android devices, and live editing to update composed elements in emulators and physical devices in real time (<https://developer.android.com/studio/intro>, 2024).

Android Virtual Device is essentially an emulator that allows testing Android applications without the need to install the application on a physical Android device, i.e. a mobile device. AVD can be configured to emulate various hardware features, including options such as screen size, memory capacity, or other features such as camera, GPS navigation support, or accelerometer (Smyth, 2017).

3 FLUTTER

Although relatively new, Flutter has seen a lot of experimentation and evolution over the years. It was introduced as Flutter in 2016, and with its first Alpha release in May 2017, it was already being developed for iOS and Android systems. It evolved from community feedback to its first stable release in late 2018. (Biessek, 2019)

Flutter takes care of displaying the user interface itself, placing them directly on the canvas, and at the same time, it requires nothing more than the canvas from the platform so it is not limited by rules and conventions.

Flutter combines application development using components, and the Dart language. Flutter is a cross-platform toolkit for building applications that can be used on multiple operating systems. It also allows applications to connect directly to the platform's core services. The goal is to enable developers to deliver high-performance applications while maintaining the features of the platform they are on (Jovanov et al, 2022).

When talking about Flutter and its composition, the quote "everything is a widget" is often encountered. According to Dieter Meiler: "Widget is an artificial word, obtained by combining the words Window and Gadget" (Meiller, 2021). In the Serbian language, the closest description of this word would be "thing" or "device", and it represents the basic building component of the Flutter application.

3.1 Flutter Widgets

Widget is by definition the name for components in Flutter, and all user-visible elements of the application are presented through widgets. The essence of components is to create an independent, reusable piece of code. (<https://developer.android.com/studio/intro>, 2024)

Another important concept in the Flutter layout is the Widget Tree, i.e. logical display of all user interface widgets (Biessek, 2019).

A typical user interface will consist of many widgets, some of which will never change their properties after being instantiated (stateless widget). They have no condition; that is, they do not change during an action.

Unlike stateless widgets, there are widgets that change their state depending on the parent widget's instructions (Stateful Widget), they aim to dynamically change their state during their cycle. By definition, stateful widgets are also immutable, but have a state type that represents the current state of the widget it is in (Biessek, 2019).

4 MUSIC STREAMING SERVICES

The music streaming service offers its users several functions, the main focus of which is to supply extensive libraries of songs and albums over the Internet (Zimmer, 2018). Today, these services are growing the fastest compared to other ways of listening to music (Cesareo and Pastore, 2014). There are two types of users of streaming services: those who do not pay a monthly fee and their service serves advertisements, and those who subscribe and pay a monthly fee, which offers additional features compared to the free version (Thomes, 2013).

In 2020, the use of these services through paid subscriptions has been constantly growing, around 18.5%, compared to 2019, with the tendency for this value to continue to grow (Global Music Report 2021). Analyzing data from the same source, it is known that revenue from the sale of physical copies decreased by 4.7%, and digital music downloads followed the same downward trend: by 15.7% less, in 2020 worldwide (Global Music Report 2021). In 2020, streaming revenue for this industry grew by 19.9% due to an increase of 18.5% of total streaming (Global Music Report 2021). Through these facts, it is assumed that we can consider streaming as the preferred way of listening to music, mainly due to the massive use of smart devices with Internet access (Kim, 2017; Lopes Barata and Simões Coelho, 2021).

The „Freemium" business strategy is based on providing something at no additional cost, and during use, users are encouraged to pay for premium features (Sciglimpaglia and Raafat, 2022). From the consumers'

perspective, the „Freemium" model allows them to familiarize themselves with the service without the risk of financial loss (Ritzer and Jurgenson, 2010). So the key to this business model lies in convincing consumers of the benefits of the premium version through their use of the free version. The free version can significantly reduce consumers' uncertainty about the service (Luo et al., 2022; Tyrväinen and Karjaluo, 2024).

Music streaming platforms, through their branded offerings and features powered by algorithmic personalization and manual data curation, are setting the boundaries and possibilities for music listening within their software and interfaces. More broadly, with their powerful analytical and algorithmic capabilities, music streaming services have the potential to enable, inform and prescribe cultural practices and experiences of and with music (Morris and Powers, 2015). "Taste" and "mood" are shifting from subjective human traits and experiences to commercial and algorithmic data for recommendations and advertising (Prey, 2020; Freeman, 2022).

4.1 Spotify

Spotify is a music streaming service that provides users with access to many songs and podcasts, therefore allowing users to fully tailor the way they access the application depending on their own tastes, affinity or mood. As a digital service, it was created in 2008 and since then it has been among the first in the sphere of online music streaming. The service exists in two variants, free with advertisements, and a commercial Premium model, which removes advertisements and enables additional functionalities of the mobile application (<https://intuji.com/how-does-spotify-work-tech-stack-explored/>, 2024).

Spotify uses a distributed network of servers to store and deliver music and podcasts to its users. These servers are located in several locations around the world, and they are all networked together to make content available to the user quickly and securely. Spotify uses the so-called "Content Delivery Network" (CDN) server infrastructure structure. Essentially, the server closest to the user based on their location will send the content to the user upon request, which in turn reduces latency and the content is streamed to the user's device faster (<https://intuji.com/how-does-spotify-work-tech-stack-explored/>, 2024).

To provide personalized recommendations, Spotify uses a unique combination of machine and deep learning models, along with human data curation, to process and interpret music attributes and user behavior (listening) data to offer recommendations and personalization (Freeman, 2022; Goldschmitt and Seaver, 2019).

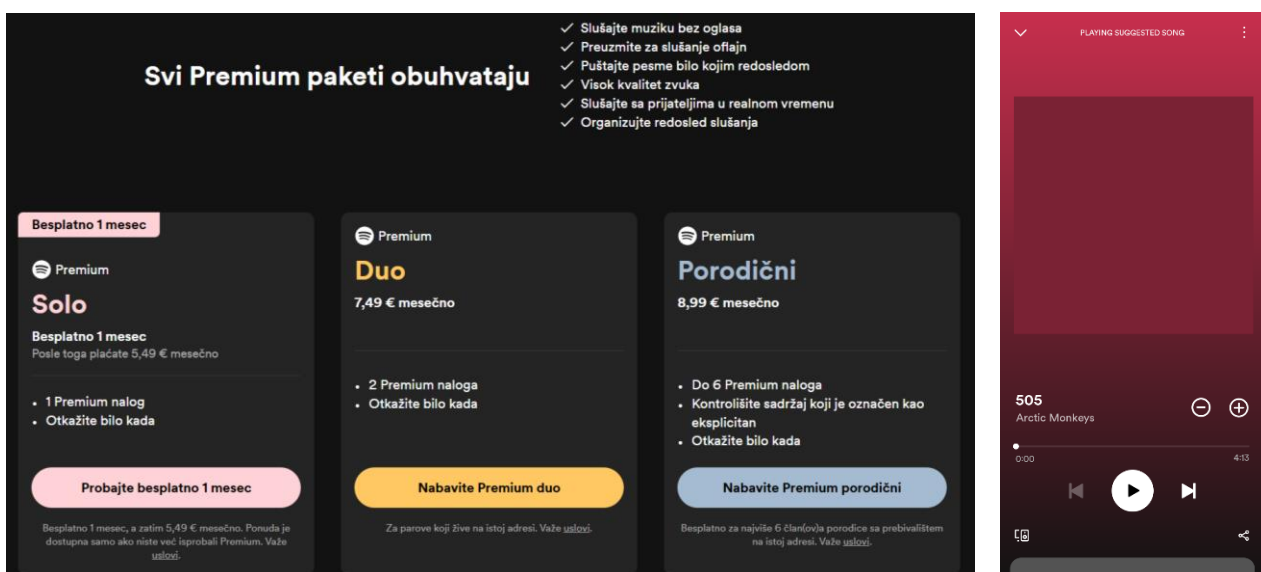


Figure 1. The Spotify Premium box offer in Serbia and Spotify music player user interface (<https://www.spotify.com/rs-sr/premium/>, 2024)

The Spotify Premium box offer in Serbia, as well as user interface of the music player in Spotify can be seen in the Figure 1. Like the player itself, the user interface of the music streaming platform Spotify can be described as dynamic and colorful, while at the same time also minimalistic. All the edges of the elements are rounded, which adds to the modern impression. The background color has a gradient, and a large range of

colors it can display, depending on the song. Instead of a gradient, Spotify can also show snippets of a music video, or loop (play without stopping) a video from the video or an exclusive clip that is set for that particular song, chosen by the artist (Visualizer). In this case, the video overflows the entire screen of the mobile device.

Spotify in the top corner of the app has a button to exit the music player on the left and 3 dots for additional options on the right. In the middle is the album art which is shaded and highlighted by the background color. Below the album is the name of the song and the artist, and in the right corner of the name there are plus and minus signs, which serves the algorithm to determine which songs to place to the user if the user declares that he likes or dislikes a song. By clicking on the minus, that particular song will no longer appear in the algorithm. Below the song bar are controls for playing, pausing, and rewinding the music. There are buttons to indicate which device Spotify is connected to on the left, and song sharing buttons on the side right. Spotify partially hides a rounded part that when pulled up reveals the song's lyrics, which can also be followed in real time. The application interface, although simple, has enough visual details to make a nice impression. Nothing is flat, there are shadows, gradients, rounded edges, Spotify's font that highlights the aesthetic part of this music player. This also helps artists who may want to post their visuals on their song, getting even more exposure. It is quite possible to hide Spotify's UI so that the user can focus completely on the visuals.

4.2 Youtube Music

In September 2020, Google shuts down Google Play Music and stops supporting the app in order to fully migrate to the YouTube Music app. The user interface of YouTube Music is reflected in its simplicity and ease of use. This platform tries to adapt its content to the user, by initially showing him the content with which the user is familiar (<https://www.pocket-lint.com/what-is-youtube-music-youtube-s-new-music-streaming-service-explained/>, 2024).

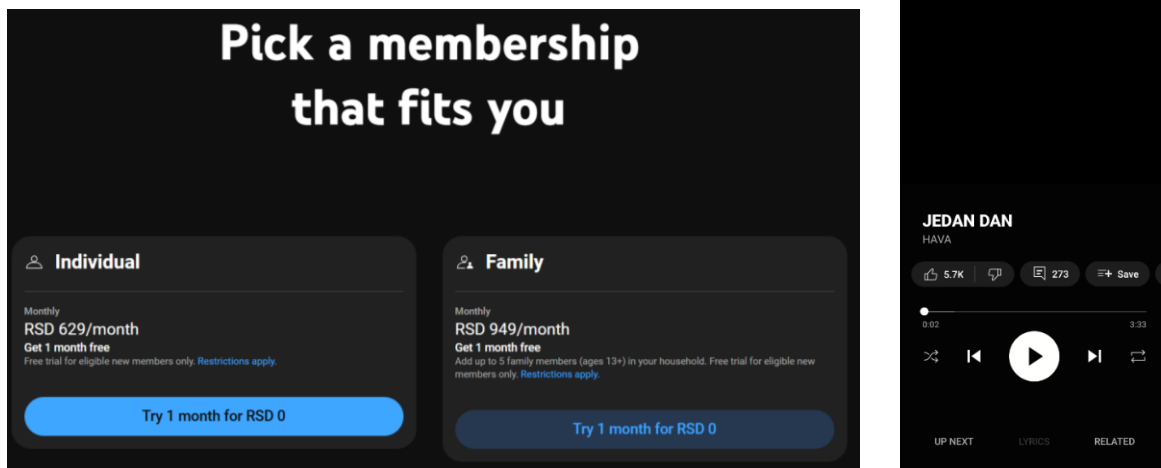


Figure 2. The price of YouTube Music Premium in Serbia and YouTube Music music player user interface (<https://www.youtube.com/musicpremium>, 2024)

The biggest advantage of YouTube Music is the repertoire of songs, artists and albums. Local and global artists alike, those at the top of the music industry, can be found on this platform. YouTube Music uses the same search algorithm as YouTube itself, so the song recommendation itself and the search results on the platform are at a high level. It is noteworthy that on this platform, in addition to studio versions of songs, you can also find recordings of live concerts and public performances. As for ads, the most common case on free versions of music streaming apps is that ads can't be skipped, ie. they have to go through an entire advertisement, which sometimes lasts even half a minute, in order to return to enjoying the music. On the YouTube music platform, this is not the case, and commercials can be skipped at the click of a button. Skipping music countless times is also an option that YouTube Music boasts as an advantage over other music streaming services. One of the disadvantages of this music streaming app compared to its competitors

is that the regular version does not allow the user to listen to music in the background, which can affect the overall user experience on a mobile device, as the app must be centered in order to function. This shortcoming, as well as other functionalities, can be eliminated, or added, by investing in the Premium version of this streaming music application (<https://www.makeuseof.com/is-youtube-music-worth-it-pros-and-cons/>, 2024).

The Figure 2 shows the price of YouTube Music Premium in Serbia and user interface of the music player in the YouTube Music application. The user interface of the music streaming platform YouTube Music itself is quite visually simple and does not try to distract the user much, but is the accent on the song or video being played. This is also one of the features of Google apps to make them easier for mobile devices to load, which affects the performance of the app itself. The interface is monotonous, i.e. mostly monochrome, and the background color is determined depending on which primary color is used by the album art.

4.3 Comparison of Youtube Music and Spotify Music Streaming Applications

There are many reasons, both technical and non-technical, that influence which music streaming service a user will choose. Non-technically, they are related to preference, the user finds it easier to navigate the application, uses it for a long time, the application is already installed on a new mobile device and many others. Technically, it is reflected in the functionality of the application itself, the benefits they offer, if the user subscribes to the premium model, is it cheaper, is it worth more, does it have more services than competitors, etc. In some cases, when a user chooses between YouTube Music or Spotify, it is possible to list the pros and cons of both music streaming services, tabulate them, and then decide on one of the two, which the user might eventually subscribe to. The comparison of the mentioned services can be realized according to the criteria: sound quality and characteristics of the free plans of these services. The mentioned comparisons are shown in tables 1 and 2.

Table 1. Comparison of sound quality in music streaming applications

Adjusting the audio quality	Spotify	YouTube Music
Default	It depends on the speed of the Internet connection	-
Low quality	24 kbps	48 kbps
Average quality	96 kbps	128 kbps
High quality	160 kbps	256 kbps
Very high quality	320 kbps	256 kbps

Table 2. Comparison of the free versions of Spotify and YouTube Music

Features of the free plan	Spotify	YouTube Music
Access to the entire music library	Yes	Yes
Skipping ads	No	Yes, after five seconds
Skipping songs	A maximum of six songs per hour	Yes
Background listening	Possible on all platforms	Only possible on the Web platform
Streaming without an Internet connection	No	No
Sound quality in a music application	Automatically, 24 kbps, 96 kbps, 160 kbps	Only 128 kbps
Highest possible streaming quality	160 kbps	128 kbps

YouTube Music is a great streaming platform where the user enjoys watching live concerts and performances as well as music videos. It has a huge capacity of songs. The sound quality is weaker compared to the competition, but this may be important for frequent travelers who want to avoid monthly costs from a network provider. Spotify offers the ultimate way to discover new music, and it's also possible to share music with friends within the app itself. Spotify features a huge library of music and podcasts, along with a user interface that makes it easy to explore and share content. Although slightly more expensive and with very high sound quality (+320 kbps), Spotify remains a top choice for those who value a comprehensive music platform with strong community aspects (<https://www.soundguys.com/youtube-music-vs-spotify-36176/>, 2024).

5 MUSICAPP MADE ON THE EXAMPLE OF MUSIC STREAMING SERVICES

MusicApp is a mini-project, that is, an application that is mainly based on UI elements, an attempt to emulate the most famous streaming services such as Spotify or YouTube Music. It's inspired by elements from both streaming apps in terms of looks, with minimal functionality. It is possible to play and listen to some of the

songs from the application, while many other elements are purely aesthetic in nature. The MusicApp application is built in Flutter, an environment that is used and specially installed in Android Studio.

The Figure 3 show a MusicApp playing one of the songs from the local files. Like Spotify, the emphasis is on the visual, with a song image or album art overflowing the entire screen of a mobile device. The image is also filled with a red gradient. Information related to the song and the player controls are located at the bottom, where they are most accessible to the user. At the bottom are the name of the song and the name of the artist, and below the name of the artist there is a bar that shows the length of the song, and exactly where the user is on the song. It is possible to pause a song, it is possible to skip to the next or previous song in a sequence (0, 1, 2) and it is possible to restart a song after pausing. The bar can also be dragged, where it is dragged, from that moment the song is played.

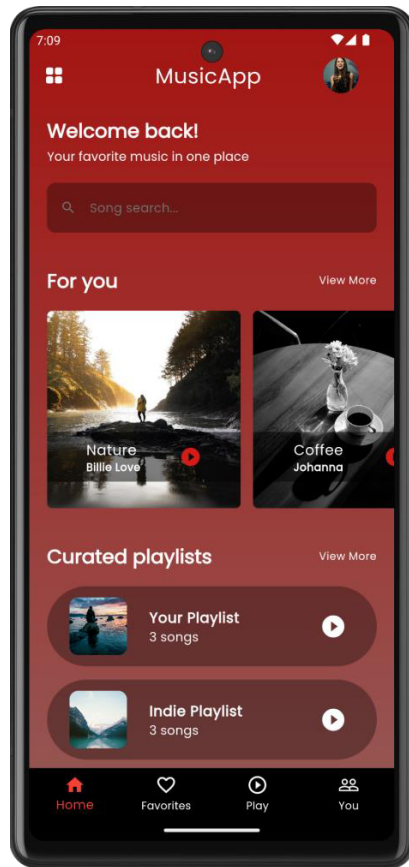


Figure 3. Home page of the MusicApp application

6 CONCLUSION

This paper presents a case study of the educational output of the Mobile Applications subject of the IT study program. All of the above: analysis of individual streaming services, their comparison, presentation of technologies for the development of mobile applications, presentation of the application itself, indicate the quality of education in the mentioned subject. It also points to the modernity of the subject matter and, therefore, the quality of the students studying in the IT study program. Such a cross-section of the situation can be of great benefit to all those related to higher education, considering that it is a real example.

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The Role of Artificial Intelligence in Agricultural Supply Chains in Developing Countries

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Abstract. Challenges affecting agriculture in developing countries are numerous and range from resource availability, climate change, markets instabilities, and restricted access to technology. These challenges act as a thorn in the side of developing economies when it comes to realizing sustainable agricultural growth amid a growing global demand for food. Computer technologies like the Artificial intelligence (AI) have shown a great potential in improving agricultural supply chain through bringing data and information-based solutions that can support efficient use of resources, predictions and management of the system based on the conditions of the locality. This paper provides a systematic review of the recent literature on the use of AI in solving major issues affecting agriculture in the developing world in areas such as energy use, land, and variability. Moreover, there is a discussion of contemporary digital cognitive technologies, such as machine learning, IoT, and remote sensing, as well as the possibilities of applying them for smallholder farmers, enhancing precision agriculture, and building resilience to market and environmental fluctuations.

Keywords and phrases: artificial intelligence, agricultural technologies, transformative potential, ecological productivity.

1 INTRODUCTION

In many developing countries, agriculture is a vital sector for economic stability, food security and employment, and may represent a major share of GDP and provide livelihoods for millions. However, despite its importance, agricultural supply chains in these regions are very inefficient and face a number of challenges. Substantial post-harvest losses caused by poor infrastructure, limited access to timely market information and inadequate storage facilities are often blamed for exacerbating food insecurity and instability of smallholder farmers' incomes. The need to address these inefficiencies becomes all the more urgent alongside increasingly unpredictable impacts of climate change on agricultural systems that particularly affect vulnerable rural populations. In view of these challenges, it is imperative to develop innovative solutions to boost productivity and resilience of agricultural supply chains in developing regions.

Artificial Intelligence (AI) with its ability to process data, recognize patterns, and predict outcomes is a strong avenue to optimize different stages of an agricultural supply chain (Javaid, Haleem, Khan, & Suman, 2022). AI through machine learning, neural networks and the Internet of Things (IoT) provides tools to help farmers increase yield in precision agriculture, from soil health monitoring to predict weather patterns and pest and disease detection (Javaid et al., 2023). For example, applications powered by AI can offer smallholder farmers with critical, real time data on planting and harvesting schedules, helping them to make better decisions and better manage resources. The AI can be leveraged at supply chain level to optimize logistics, minimizing losses and reducing delays, and making perishable goods reach markets in an efficient manner (Dash et al., 2019).

However, the potential of AI to solve agricultural supply chain inefficiencies is enormous, yet few developing countries have adopted such technologies. Accessibility and scalability of AI driven solutions is limited due to the lack of digital infrastructure, lack of technological literacy and high implementation costs (Lezoche et al., 2020). In addition, the availability of data and data quality, data privacy and ownership issues hinder broader AI integration in these places. To unleash the potential of AI, we need governments, the private sectors, and

NGOs to collaborate, to provide the necessary infrastructure, training, and regulatory frameworks to unlock the potential (Allam & Dhunny, 2019).

This paper seeks to look at the opportunities of applying Artificial Intelligence in the agricultural value chain particularly in productivity, profitability and sustainability. Analyzing the role of AI this paper includes the planning, resource management, cultivation, disease detection, and yield forecasting aspects of agriculture with the intention to investigate the application of AI throughout the agricultural value chain comprehensively.

2 LITERATURE REVIEW

Based on an analysis of some research studies between 2019 and 2024, this literature review takes a look at the major challenges for the agricultural sector in both developing and global economies. It also reviews the most important artificial intelligence (AI) and cognitive technologies to suggest a comprehensive range of digital solutions tailored to the specific requirements of developing countries in the agricultural field. The review shows the growth of AI technology adoption in the agro-industry, with countries focusing on the incorporation of AI in agriculture reported to have a competitive advantage in the global market (Javaid et al., 2022). The future growth of the agricultural sector is greatly dependent upon the strategic application of advanced technological tools, which has already contributed much through the use of digital cognitive technologies (Moreno et al., 2023). In modern farming, technologies like drones and other electronics are necessary to meet the ever increasing global food demand (Hafeez et al., 2022).

Research has found that the integration of emerging technologies, like AI, in the agricultural production cycle increases output in developed economies without additional traditional resources, such as land (Member Joy Usigbe et al., 2023). AI and modern computer technologies have largely been implemented in developed countries to drive the competitive and globalized nature of the agro-industry (Kumar et al., 2024).

Despite the extensive literature on the implications of AI for the global agricultural sector (Nishith Reddy Mannuru et al., 2023), a significant gap remains: “What impact does AI have on all dimensions of agricultural productivity in developing economies?” To our knowledge, no comprehensive research has yet been conducted to understand how much AI contributes to agricultural productivity in these regions across all facets, including what are the main problems and solutions for the agricultural sector.

2.1 *The Function Of Artificial Intelligence In Agriculture*

Artificial intelligence can help farmers forecast future events and thereby reduce errors and minimize the risks for crop failure. Eray (2022) emphasized that as of October 2021, 44 nations had already set up their own AI strategic plans. It proved their desire to take the lead in Artificial intelligence in the world. Michael et al. (2021) show that global climate change can be used by a farmer to produce accurate and timely weather information favorable to planting during global climate change. Eray (2022) stated that China and India are among the developing economies with a growing pace of developing AI programs.

Kim et al., (2008) stressed that artificial intelligence can distinguish the type of soil and crop to plant based on soil and crop conditions. The application of Artificial Intelligence, Machine learning, and IoT sensors combined with real time data generated by predetermined algorithms has greatly improved agricultural productivity, increased the productivity of crops and reduced the cost of production of food, according to Louis (2021). Michael et al. (2021) noted that methods like ML based surveillance systems to monitor field crops were efficient in preserving remote facilities, increasing crops and discouraging trespassers, while also identifying the employees who are working there Louis (2021).

Once real time sensor data is integrated, crop prediction yields can be guaranteed the use of visual analytics data coming from drones. Also, as per Michael et al. (2021), AI has made water management in the agricultural sector efficient, crop rotation, timely harvesting, crops planted the right way and management of pests and diseases.

2.2 *The Impact Of Ai In Agricultural Supply Chains In Developing Countries: Nigeria*

Artificial Intelligence (AI) has the potential to significantly enhance agricultural supply chains in Nigeria by addressing key challenges such as inefficient resource use, poor infrastructure, and climate variability (Pandey & Mishra, 2024). AI-driven tools like machine learning, Internet of things (IoT), and remote sensing enable Nigerian farmers to monitor crop health, optimize resource allocation, and predict weather patterns, fostering

better decision-making. These technologies can also streamline logistics, reduce post-harvest losses, and improve access to markets by providing real-time insights into consumer demands and price trends Michael et al. (2021).

In Nigeria, where agriculture remains a vital economic sector, the integration of AI can drive sustainable productivity, mitigate food insecurity, and support rural livelihoods (Villacis, Mayorga, & Mishra, 2022). However, challenges such as limited access to digital tools, poor infrastructure, and low digital literacy must be addressed to fully realize the benefits of AI in transforming the agricultural supply chain.

3 KEY CHALLENGES FACED BY THE AGRICULTURE SECTOR IN DEVELOPING ECONOMIES

Utilization of energy: Energy use in agriculture, especially in the developing world is a major issue as there are few options for cheap, clean, and effective energy. Agriculture is an energy-intensive activity owing to irrigation, mechanized planting and / or harvesting, post-harvest handling, and transport of produce. However, in many developing regions, the energy infrastructure is weak which leaves people to use inefficient, costly or pollute energy sources and products such as diesel generators and wood burning stoves.

Variability Management: Variability management in agriculture refers to the efforts made to deal with the changes and uncertainty in production environment that affects crop production, yield and quality, and profitability. This challenge is worse off in developing economies because of the scarce resource and adaptive technologies. Sources of variability can therefore be attributed to many factors such as weather conditions, fertility of the soil, diseases and pests, and changes in market price.

Farming Lands: The three major challenges of land resources in developing economies include the availability of the farming land, quality and management of the farming lands. Environmental changes such as population pressure, urbanization and industrialization have narrowed down the land size suitable for cultivation, farm produce often being grown in marginal soils.

Marginal Land Farming: Marginal land farming comprises the activities of farming on less favorable lands by virtue of poor soil, water, slope or climatic regimens that characterizes the area under question (Donatien Ntawuruhunga et al., 2023).

Decline in Agricultural Value: Decline in agricultural value denotes the reduction in the economic value of an agricultural output with respect to other sectors, a problem in most developing economies (Rafael, 2023). There are multiple causes of that, from productivity restrictions to a lack of investment in technology to volatility in global commodity prices which reduce the income and the economic stability of farming communities.

Poverty and Food Insecurity: Poverty and food insecurity are closely related issues in many developing countries, but especially in rural areas where agriculture is a means to subsistence as well as a livelihood (Sibhatu & Qaim, 2017). Access to quality seeds, fertilizers and irrigation is restricted because poverty restricts access to the resources needed to be productive, and the farmer cannot afford to adopt improved farming practices or technologies.

3.1 Economic Globalization

The concept of economic globalization, that is, the increasing integration and interdependence of global economies has important implications for agriculture, most particularly in developing countries (Awokuse et al., 2024). Due to its influence to globalize the agricultural markets, export potential increases and the international markets are more easily reached.

4 EMERGING COMPUTER TECHNOLOGIES AND AI SOLUTIONS FOR DEVELOPING ECONOMIES

New computer technologies and AI solutions present a transformative potential for agriculture in developing economies: smarter, more efficient, and more sustainable farming (Ashraf & Akanbi, 2023). Machine learning, IoT devices, and remote sensing offer real time data about soil conditions, weather and the health of crops which enables farmers to make decisions that will increase yields and decrease waste

Machine Learning: The ability of computers to analyze huge agricultural datasets and discern patterns and predict things like crop yields, disease outbreaks and best planting schedules, is made possible through machine learning (Ghulam Mohyuddin et al., 2024). It allows the farmers to take informed decisions as to what to grow,

where to grow it, and how to upscale their farms, all of which is helping to enhance farm productivity, conserve resources, and increase efficiency.

Internet of Things (IoT): IoT in agriculture is the use of interconnected sensors and devices that are placed on fields or equipment, and collects the data of soil moisture, temperature, crop health and equipment performance (Salam, 2024).

Remote Sensing: Satellite or drone imagery is used in remote sensing to capture information about large agricultural areas, including changes in soil health, crop growth and environmental conditions (Fuentes-Peñailillo et al., 2024).

Digital cognitive solutions: it enable farmers by enabling them to make critical, data driven decisions across many aspects of farming. For example, the solutions analyzed and presented the information about the health of soil, pest infestation, weather forecasts and other important parameters to the farmers to help them make the informed, time bound decisions based on the conditions of the field (Ghulam Mohyuddin et al., 2024).

5 RECOMMENDATION

Technologies like artificial intelligence are enhancing the possibility of the advancement of agricultural technology. Great advancements in the use of artificial intelligence are being put in place in order to increase social, economic, and ecological productivity in the developing countries. To meet the major issues arising from the development of the agricultural sector in developing countries the following recommendation can be used to incorporate Artificial Intelligence (AI)

Investment In Infrastructure: Governments and stakeholders in developing countries should prioritise digital infrastructure investments such as better internet connectivity and storage facilities. Enabling the easy to implement and scale agricultural AI.

Capacity Building: To increase the farmers' digital literacy through creating training programs and workshops. Only when people are well equipped with relevant skills to operate and maintain AI driven systems will they be adopted successfully.

Tailored Solutions: Build artificial intelligence applications tailor made for the needs and peculiarities of the farmers in developing countries. For AI technologies to be inclusive and practical, smallholder farmers, diverse crop types, and regional variations, must be incorporated.

Public Private Partnership: Agriculture innovation through AI can be driven by collaboration between government, private and academic institutions. Public private partnerships can help accelerate developing, testing and deploying of AI solutions.

Financial Support: The governments provide farmers financing, subsidies or grants to adopt AI technologies. Financial support will make initial costs more affordable and thus make those AI solutions available to more people.

6 CONCLUSION

This paper finds that AI and digital technologies such as machine learning, IoT, and remote sensing present a broader opportunity for addressing agricultural constraints in developing nations by improving resource efficiency, crop quality, and vulnerability to climate fluctuations. However, it is undeniable that some adoption barriers such as infrastructure constraint, associated cost, and low level of technology savvy have not been well-addressed. These challenges can only be addressed through extra investment in infrastructure as well as training other personnel and supportive policies. Hence, the application of AI improvements can inject productivity and food security gains in developing areas, but only if these technologies are meaningfully integrated into agriculture production systems on a sustainable basis.

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New Technologies in the Service of Industrial Digitalization: Industry 4.0 and the Evolution of Computer Networks

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Abstract. Industry 4.0 - the fourth industrial revolution - is transforming manufacturing and production processes with new technologies and networking solutions, particularly the development of computer networks. The proliferation of cyber-physical systems and networked devices increases data traffic that traditional network infrastructures can no longer efficiently serve. To address this, new technologies such as 5G/6G, edge computing and IIoT systems are emerging to reduce latency and optimise data processing. With IT and OT integration, network security will also become increasingly crucial as Industry 4.0 connects more and more devices and data. Cloud technology and hybrid cloud solutions will further increase scalability and data storage capabilities, helping to optimise manufacturing processes and increase efficiency. Industry 4.0 will fundamentally bring a new level of performance, security and reliability to industrial networks, supporting the digitalisation and competitiveness of the industry. This paper summarises the recent impact of Industry 4.0 on computer networks.

Keywords and phrases: Industry 4.0, Wireless Network Technologies, Industrial Internet of Things, Cloud Computing, Cybersecurity, Computer Networks.

1 INTRODUCTION

Industry 4.0, or the fourth industrial revolution, is fundamentally transforming modern industry through automation, digitalisation and networked systems. The emergence of smart factories and cyber-physical systems is dramatically impacting the development of computer networks. However, the challenges of real-time data management, scalability and reliability are being effectively addressed by the widespread use of new technologies such as 5G/6G networks, edge computing and IIoT (Industrial Internet of Things) tools, providing reassurance about the future of industrial processes.

This paper reviews how Industry 4.0 is shaping the architecture and operation of computer networks. In addition to examining the challenges and opportunities that the digitisation of manufacturing processes brings, it highlights solutions that contribute to increasing industrial systems' efficiency, security and sustainability.

2 THE IMPORTANCE OF OT AND IT INTEGRATION

One of the pillars of Industry 4.0 is the close integration of OT (Operational Technology) and IT (Information Technology) systems. OT systems have traditionally operated in closed networks that control industrial processes and equipment, such as production lines and robotic arms. However, according to the objectives of Industry 4.0, OT devices will increasingly need to be connected to IT networks to provide real-time data to business management systems (Lipnicki et al., 2018).

OT-IT convergence poses serious networking challenges, as OT devices are often designed for long lifetimes rather than for continuous network communication or to manage cyber security threats. The convergence of IT and OT networks requires new network architectures and security solutions such as firewalls, segmented

networks and endpoint protection technologies (Dobrilovic et al., 2021). The urgency and importance of these security measures cannot be overstated in the context of Industry 4.0 (Donnelly et al., 2013).

3 THE UPTAKE OF WIRELESS TECHNOLOGIES IN THE INDUSTRY

Wireless network technologies are gaining ground in industrial environments, enabling flexible and cost-effective device deployment. Wireless solutions such as Wi-Fi 6, Bluetooth Low Energy (BLE), and Low-Power Wide-Area Network (LPWAN) technologies address various needs (Li et al., 2017). For example:

- Wi-Fi 6: Provides the high data rates required to communicate with densely placed IoT devices.
- Bluetooth Low Energy (BLE): offers a low-power solution for low-bandwidth applications such as sensors and embedded systems.
- LPWAN (e.g. LoRa, NB-IoT): Excellent for covering longer distances with low power consumption, especially useful for dispersed devices or large area factories (Dobrilović et al., 2017).

These wireless technologies facilitate network infrastructure deployment and reduce maintenance costs (Basseley et al., 2024). However, they increase the network's security requirements, as wireless connections can be more vulnerable to cyber-attacks, making using advanced encryption and access management solutions essential (Borsos, 2024).

3.1 5G and later 6G technology roll-out

5G technology is the ideal solution for the high-speed, low-latency networks required by Industry 4.0. 5G allows large numbers of IoT devices to connect and communicate simultaneously without degrading network performance (Tóth, 2024). 5G technology also lays the foundation for developing 6G, increasing bandwidth and enabling even more efficient support for manufacturing processes (Salameh et al., 2022).

3.2 Using the Mesh sensor network

The new Neo.Cortec technology-based battery-powered wireless sensor boards and the Mesh shielding, complemented by a gateway to these devices that forms a local sensor network, provide a complete, independent, and secure IoT SBC solution for data collection in industrial environments. The IoT SBC's built-in sensors and a wired sensor network of external sensors connected via integrated I2C (longI2C) and SPI interfaces are complemented by a virtually infinite number of wireless sensors. The battery-powered smart sensors communicate with the gateway either through each other or directly to the IoT SBC device, which exits at a single point - via the GSM network - to the Internet. The data is sent to the cloud database using NB-IoT or LTE-M LPWA technology, which can also use the 2G network in case of coverage problems (Nurlan et al., 2022).

4 DESIGNING SELF-OPTIMISING AND INTELLIGENT NETWORKS

Self-optimising, artificial intelligence-enabled networks are increasingly important in Industry 4.0 systems. These networks can identify traffic patterns and optimise data flow, making the network more efficient and responsive to changes. Intelligent networks manage network resources efficiently, help reduce downtime, and keep production processes running smoothly (Nightingale et al., 2016).

5 DATA TRAFFIC GROWTH AND NETWORK CAPACITY NEEDS

In an Industry 4.0 environment, various sensors, robots and other IoT devices communicate with each other and with central systems, generating huge amounts of data (Dobrilovic & Stojanov, 2016). Networks must handle higher data traffic, which traditional infrastructures can only sometimes handle efficiently (Trabelsi & Kovács, 2024). This is why it is necessary to expand network capacity through high-speed optical networks and 5G technology, which provide fast and stable data transmission (Hazas et al., 2016).

6 PROLIFERATION OF IIOT SYSTEMS AND NETWORK SCALABILITY

With the proliferation of Industrial Internet of Things (IIoT) systems in factories, warehouses and other industrial environments, many devices are being networked - such as sensors, cameras, temperature gauges and energy monitors (Aichaoui & Kovács, 2024). These devices continuously collect data and transmit it to the cloud or local servers to help optimise plants and systems (Wu et al., 2021).

Networking IIoT devices increases the need for network scalability. A reliable network infrastructure with low latency, capable of supporting many devices without degrading network performance, is essential for these systems. To achieve this, industries increasingly rely on 5G and, later, 6G technologies and mesh networks (Chalapathi et al., 2021).

7 CLOUD COMPUTING AND DATA MANAGEMENT

In the data-driven world of Industry 4.0, cloud technologies allow industrial companies to collect and analyse large amounts of data, even in real time. The benefits of cloud computing include flexible data storage, scalability and cost-effectiveness. Companies can store and manage data from manufacturing processes, machine status, and sensor data in the cloud to optimise their processes.

Cloud-based systems require centralised data centres, which means that networks must be able to transmit large amounts of data quickly and efficiently from local factories to remote data centres. This means increased bandwidth requirements and the need for high-speed, low-latency connections (Sharma et al., 2023).

7.1 Hybrid cloud solutions for the industry

Many industrial companies use hybrid cloud solutions that allow sensitive data to be stored in a local, private cloud while other information is managed in a public cloud. The advantage of hybrid clouds is that they provide protection and low latency access to critical data while allowing for data processing and storage scalability (Sundarakani et al., 2021).

Such systems require strong network segmentation, creating separate but cooperative networks between private and public clouds. In addition, network security solutions such as VPNs, firewalls and access management systems are essential for the secure operation of hybrid cloud strategies (Garg et al., 2022).

7.2 Cloud analytics and machine learning

In the context of Industry 4.0, cloud service providers offer advanced analytics and machine learning solutions to help optimise production processes, predict maintenance needs and increase machine efficiency. Processing data directly in the cloud allows companies to perform instant analysis and make quick decisions, for example, when data indicating a machine failure is detected (Wu et al., 2016).

Machine learning models rely on large amounts of data, making high bandwidth and low latency networks essential. Cloud-based analytics increases the demand for network resources while offering the potential for more efficient, smarter manufacturing processes (Tirupati et al., 2022).

7.3 Cloud security and cybersecurity challenges

The use of cloud technologies in industrial systems is creating new security challenges for companies. The use of public and hybrid clouds exposes sensitive data and systems to potential cyber-attacks (Barta & Nyikes, 2024). In an Industry 4.0 environment, network infrastructure must protect against external threats and internal risks. Security solutions such as the Zero Trust model, end-to-end encryption and cloud-based identity management are essential to enhance cloud security (Ahmad et al., 2022).

8 EDGE COMPUTING AND LOCALISATION OF DATA PROCESSING

For example, industry 4.0 systems often require real-time data processing to optimise manufacturing processes. To reduce data traffic and speed up response times, edge computing technology has become popular, allowing data to be processed locally without being transmitted to a central data centre. This also reduces latency and reduces the load on the network (Shi et al., 2016).

8.1 Key benefits of edge computing

- **Reduced latency:** minimises the time data travels from the source to the processing centre and back. This latency reduction is critical for applications requiring real-time responses, such as autonomous vehicles, industrial automation and augmented reality.
- **Bandwidth optimisation:** by processing data locally, Edge Computing reduces the need to transfer large amounts of raw data to central cloud servers. This bandwidth optimisation is particularly beneficial when network connectivity is limited or expensive.

- Enhanced privacy and security: edge computing allows data to be processed at the source, alleviating privacy and security concerns. Sensitive information can be processed locally without being transferred to external servers, reducing the risk of data breaches.
- Scalability and resilience: edge computing is inherently scalable, as the processing load can be distributed across a network of edge devices. This flexibility allows organisations to adapt their computing infrastructure to the specific requirements of IoT applications (Naveen & Kounte, 2019).

9 NETWORK SECURITY CHALLENGES

The networking of devices used in Industry 4.0 increases the risk of cyberattacks (Ádám et al. 2024). The network infrastructure must secure sensitive data against potential attacks, which is significant for critical infrastructures such as energy or water supply (Durczy et al. 2024). Industrial environments require security technologies such as intrusion detection systems (IDS) and advanced encryption (Mentsiev et al. 2020).

10 CONCLUSIONS

The Industry 4.0 revolution has ushered in a new era for computer networks, which now support infrastructures and critical elements of manufacturing and production processes. The technologies presented in this paper - 5G/6G, edge computing, IIoT devices and hybrid clouds - all contribute to industrial networks' ability to meet real-time data management challenges, increased data traffic and stringent security requirements.

The integration of OT and IT systems, the proliferation of wireless networking technologies and the introduction of smart networking solutions are transforming industrial processes into a digitalised and automated environment. These advances not only increase the efficiency of industry but also help to stimulate innovation and increase industrial competitiveness.

The changes by Industry 4.0 will fundamentally reshape the role of industrial computer networks, creating new opportunities for data-driven manufacturing, sustainability and digitalisation.

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