STEM | STEAM | STREAM

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STEM/STEAM/STREAM APPROACH IN THEORY AND PRACTICE OF CONTEMPORARY EDUCATION

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PREFACE

“STEM/STEAM/STREAM Approach in Theory and Practice of Contemporary Education” is a publication compiled from papers presented at the conference of the same name, held at the Faculty of Education in Jagodina on May 31, 2024. The collected works explore STEM, STEAM, and STREAM approaches from both theoretical and practical perspectives, aiming to enhance understanding and promote their broader and more effective implementation in Serbian schools.

STEM is an integrated educational approach to learning and teaching that requires a deliberate connection between curriculum learning objectives, standards, assessments, and lesson design and implementation. In response to the evolving workforce demands of modern society, there is a growing emphasis on the role of the arts in STEM, leading to the development and exploration of STEAM (Science, Technology, Engineering, Arts, and Mathematics) programs. Integrating the arts into STEM education enhances teaching and student achievement, fosters inquiry and problem-solving skills, stimulates creative thinking, increases students’ interest in science and its applications, and provides diverse entry points for engaging in the creative process while meeting learning objectives across all subject areas (Dell’ Erba, 2019; Psycharis, 2018; Kim et al., 2013). STEAM skills, such as computational thinking, problem identification and solving, creativity, and innovation are essential for developing smarter products and advancing various aspects of human life. Students who excel academically in STEAM subjects are more likely to secure employment, earn higher wages, and access better career opportunities. In fact, STEAM related jobs have grown three times faster over the past decade compared to those in other fields (U.S. Department of Commerce, 2011).

Given the vast opportunities for growth and expansion offered by this interdisciplinary concept, the central aim of the conference is to advance it through the STREAM model. This model breaks down traditional boundaries between language (Reading) and other disciplines such as Science, Technology, Language, Engineering, Art, and Mathematics, integrating them into meaningful, real-world learning experiences that are relevant to students. By applying their knowledge in authentic contexts, students not only strengthen their language skills but also develop essential competencies for a rapidly evolving world. Each STREAM discipline fosters a diverse set of skills, including critical thinking and problem-solving, digital literacy, communication, creativity and self-expression, mathematical reasoning, and analytical thinking. In today's world, where lifelong learning and continuous development are imperative, it is crucial to equip students with the ability to synthesize knowledge across disciplines. This holistic approach enables them to tackle a wide range of personal, professional, and societal challenges effectively.

The papers in this volume highlight the efforts of STEM/STEAM/STREAM educators to implement STREAM-based principles across various teaching contexts. Several contributions examine the challenges and opportunities associated with the STEM/STEAM/STREAM approach in both theory and practice within contemporary education. This book aims to foster a deeper understanding of STREAM as an integrated instructional design approach, incorporating science, technology, reading, engineering, arts, and mathematics. The topics explored include: integrated approach to instructional design using science, technology, reading, engineering, arts, and math in early learning (Carlise Womack Wynne); innovating science teaching using STEAM education (Aleksandra Filipović, Dušan Ristanović and Olivera Cekić Jovanović); potential pitfalls and resources for implementing the maker movement - learning to make, making to learn: STEAM meets maker movement (Jelena Joksimović and Jelena Starčević); curriculum potentials for the STEM/STEAM approach in the first cycle of elementary education in Serbia (Sanja Blagdanić and Miroslava Ristić); the development of 21st century competencies related to learning natural sciences (Katarina B. Putica); the importance of early digital literacy of preschool children through the integration of the STEAM approach (Marija Krstić Radojković); teaching history with the aid of educational robotics (Argyrios Kourea, Athanasios Angeioplasti, Dimitrios Varsamis, Natsikas Konstantinos and Alkiviadis Tsimpiris); some reflections on steam epistemiologies (Predrag Živković); application of the STEAM concept in a flipped classroom (Sanja K. Nikolić and Jelena Marković).

The articles also show that solutions may lie in examining students' and teachers' attitudes and as well as their educational needs within the STEM/STEAM/STREAM approach: primary school students' attitudes and interest in after-school STEAM activities (Aleksandra Mihajlović, Nenad Vulović, Miloš Đorđević); the views of foreign language teachers on STEM/STEAM/STREAM concept in education (Marija Stanojević Veselinović); high school students assess the importance of STEM workshops (Aleksandar Milenković, Aleksandra Maksimović, Dalibor Rajković and Dragutin Ostojić); students' perceptions of the STEAM approach in university teacher education (Ivana Milić and Jelena Mladenović); future pre-school teachers' attitudes towards the integration of the STEM learning approach in early childhood practice (Gordana Stepić); the perception of students' parents of the first cycle of primary education (Nedeljko

Milanović and Andrijana Miletić); EFL teachers' attitudes on STEM approach for 21st century skills and interdisciplinary development (Tamara Bradonjić); developing creative and critical thinking through STEAM projects in early English language learning (Sandra Tasić); integrating STEM into EFL curriculum through stem day activities (Vera Savić and Ana Živković).

Further, the authors explore the connection between STEM/STEAM/STREAM approach and IT teaching models: primary school students' motivation and enjoyment in learning programming through gamification (Verica Milutinović, Ivana Obradović and Suzana Đorđević); educational potential of video games for application in STEAM/STREAM approach in teaching (Nenad Stevanović); a case study on STEM problem-based learning approach in developing competencies for recognizing phishing emails (Andrej Ignjatić and Diana Božić); artificial intelligence integration in STEM education through mixed-methods approach (Milan Komnenović and Miloš Stojadinović).

The authors give concrete suggestions for successful implementation of STEM/STEAM/STREAM approach in teaching music, art and physical education: musical-didactic game in the STREAM approach (Nataša Vukićević, Emina Kopas-Vukašinović and Ivana Ćirković Miladinović); preschool teachers' intercultural communication in the context of traditional music (Ivana Paula Gortan-Carlin and Marina Diković); presentation of the project musical for children (Emilija Popović, Jelena Veljković Mekić, Dragana Dragutinović and Bojana Nikolić); influence of the covid-19 pandemic on the art teachers' utilization of blended learning in Croatia (Lana Skender); the role of physical education in STEAM learning (Aleksandar Ignjatović, Živorad Marković and Bojan Miloradović).

The papers further suggest positive effects of the STEM/STEAM/STREAM approach in teaching science: future impact of STEM concept application on misconceptions in science field (Anđela Milovanović, Irena Golubović-Ilić and Slađana Stanković); the role of the STEMS concept on the development of language abilities and the functionality of knowledge from mathematics and science (Jelena Spasić, Milan Milikić and Jelena Lukić); measurements and adventures at the interface of mathematics and environmental education (Mónika Bagota and Katalin Kulman);

Finally, in order to point out to the importance of professional development and competencies of educators for the STEM/STEAM/STREAM approach, authors presented the following papers: professional development of preschool teachers (Časlav Stoiljković, Aleksandra Janković, Igor Djurić and Maja Filipović); professional development of teachers working in preschool teacher training colleges (Mira Jovanović, Sanja Vuletić, Ljiljana Stankov and Nataša Dubljanin); competencies of employees in various educational institutions (Daliborka Popović and Božana Rašković).

To present the volume in numbers, we can phrase it as follows: The total number of authors contributing to this Conference Proceedings is 73, with 13 international authors. There are 33 papers published, 6 of which were authored by foreign contributors.

We extend our sincere gratitude to the Ministry of Science, Technological Development and Innovation of the Republic of Serbia for their financial support in organizing the conference. Our appreciation also goes to the reviewers, whose goodwill, expertise, and constructive approach ensured the thorough evaluation and refinement of the submitted papers. We are grateful to the members of the Program and Organizing Committees for their invaluable support and collaboration in preparing the international scientific conference.

Additionally, we would like to thank all other contributors whose efforts—ranging from proofreading, editing, and technical preparation to publication cataloging, conference facilitation, and technical support—played a crucial role in the successful organization of the event and the preparation of this Conference Proceedings.

It is our hope that this book will inspire further advancements and engagement in the field.

Editors

I

CHALLENGES AND PERSPECTIVES OF THE STEM/ STEAM/STREAM APPROACH IN THE THEORY AND PRACTICE OF CONTEMPORARY EDUCATION

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INSTEAD OF AN INTRODUCTION: STREAM AS LIFE AN INTEGRATED APPROACH TO INSTRUCTIONAL DESIGN USING SCIENCE, TECHNOLOGY, READING, ENGINEERING, ARTS, AND MATH IN EARLY LEARNING

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INTRODUCTION

STREAM is a method of instruction that allows Science, Technology, Reading, Engineering, Arts, and Math to be taught using an integrated approach rather than teaching individual subjects in isolation (Mariana & Kristanto, 2003; Nuangchalerm et al. 2020). Subjects taught in isolation focus on mastery of individual skill sets rather than focusing on the intersectionality of content and its application to real-life scenarios that fit the ever-changing and rapidly evolving environments in which they live. This is especially true for very young learners. To this end, reading and writing skills are emphasized within the STREAM-based approach (Sun & Zhong, 2024). While reading solidifies a student's knowledge base and supports their knowledge acquisition, writing allows students to process and authentically communicate their learning (Nuangchalerm et al., 2020; Suteu et al., 2024; Sun & Zhong, 2024).

STREAM OVERVIEW

In primary and elementary settings, STREAM focuses on introducing basic principles of scientific thinking and mathematical processing, fostering curiosity in the world around students, and developing foundational language and literacy skills (Li & Talib, 2024; Phang et al., 2023). As students progress through their academic programs, learning becomes more structured, integrating a variety of disciplines appropriate to the query, promoting problem-solving, critical thinking, and collaboration between peers. This critical shift in development has profound implications for not only the individual's learning but for all children, regardless of ability level within each peer group (Phang

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et al., 2023; Prommaboon et al., 2022). Of importance are the concepts of both technical skills within each discipline, but also an emphasis on soft skills like critical thinking, communication, collaboration, and creativity. While technical skills are important, researchers are finding that these skills alone, without the ability to communicate and collaborate are less valuable to the future marketplace. These 21st-century skills, including digital literacy, are critical to the fundamental success of students who are ready to engage in a global world where complex problems will often require complex but creative solutions (Kitamura, 2024; Rickey et al., 2023; Starciogeanu, 2023; Wilson et al., 2021; Xiaodong & Chengche, 2024).

As our world becomes more dependent on technology, and each industry becomes more globally and technologically interdependent, the implications of offering a STREAM-based approach to learning become magnified. As we strive to provide career-ready students, we must realize that the careers of today will dynamically shift by the time young learners reach maturity and enter the workforce. Essentially, we do not only prepare our students to be career-ready, but also future-ready, by giving them the tools they need to problem-solve, collaborate, and investigate rather than teaching written facts (Phang et al., 2023; Yang & Hsueh, 2024).

By including STREAM programs in educational systems, especially in the younger years, nations make themselves more competitive in the global marketplace. To effectively do this, we must also consider the preparation of our teaching force to meet the needs of our future-ready students. This requires an intentional development of the teaching force to include pedagogical techniques, base knowledge, and intellectual and physical resources necessary to facilitate high-level teaching and learning in the early years (Li & Talib, 2024; Phang et al., 2023).

HISTORICAL CONTEXT

Late in the 20th century, STEM fields reemerged as a critically important area within the global economy. As technology created interconnectedness through commerce and communication, STEM fields began to become increasingly important in national and international relations (Brada et al., 2023; Topalska, 2021). As early as 1986, the National Science Board in the United States released a report emphasizing the importance of STEM education (Yang & Hsueh, 2024). As technology boomed, so did the need for and interest in these fields. By the early 21st century, the concept of STEM education expanded to include the arts, yielding the beginning of the STEAM movement which was designed to promote a more interconnected approach to problem-solving (Brada et al., 2023;

Mertala et al., 2004; Oladele & Ndlovu, 2024). In 2006, the first mention of STEAM education as an integrated approach to curriculum development was included as an initiative at the Rhode Island School of Design to emphasize art and design (Oladele & Ndlovu, 2024).

Shaw et al. (2021) asserted that one distinct advantage of utilizing an integrated approach that includes the arts focused on the ability of a student to think about a problem both technically and creatively, making room for the uncertainty of the inquiry process, yielding a more transversal thinking process, actively utilizing both sides of the brain, and focusing on teamwork and communication (Starciogeanu, 2023). The inclusion of literacy strategies as a foundation of STREAM education is a recent development within the integrated approach that combines both technical and soft skills to support students as they navigate a landscape where technology can simultaneously help and hinder societies.

HOLISTIC APPROACH TO LEARNING

While a traditional approach to learning includes a compartmentalized approach to curriculum development and deployment, STREAM is integrated. This integrated approach to teaching and learning provides a more holistic and student-centered focus, which breaks down silos between disciplines. The traditional, siloed approach to education can hinder a child's ability to make connections between concepts in other disciplines, which in turn, creates barriers to the application of knowledge across disciplines (Starciogeanu, 2023). A STREAM-based approach to education involves the interconnectedness of concepts and the impact of each facet of a problem on the eventual solution (Olivato & Silva, 2023). Students are encouraged and expected to take a 360-degree view of any problem to analyze all potential impacts before posing a solution. This multidisciplinary approach to teaching, learning, and thinking allows students to connect theoretical concepts to real-world scenarios (Mariana & Kristanto, 2023; Oladele & Ndlovu, 2024; Rickey et al., 2023). This constructivist approach to learning promotes autonomy in learning, as well as a sense of agency. Students are moved from a passive to a highly participatory role in learning, engaging their knowledge and allowing for the application of knowledge to occur more readily (Rickey et al., 2023; Xiaodong & Chengche, 2024).

Inherent to the nature of STREAM-based pedagogy is the ability to promote differentiation and choice in learning. By creating a learning environment that is engaging and inquiry-rich, STREAM-based pedagogical approaches promote differentiation amongst learners. Teachers who structure STREAM-based classrooms appropriately can scale instruction up for more advanced learners as well as down to reinforce content for those who may need remediation (Mariana & Kristanto, 2023; Xiaodong & Chengche, 2024). One particular approach, Problem-Based Learning (PBL) is particularly well suited to provide a platform for teachers to cater to the diverse and varied needs of the learners in their classrooms (Oladele & Ndlovu, 2024, Olivato & Silva, 2023). By scaling the expectations, the focus of the content, product, or process of the learning to meet the level of a learner, teachers can customize learning experiences to a variety of needs within a single classroom, allowing students to work towards mastery and enrichment side by side (Starciogeanu, 2023; Wilson et al, 2021). Coupled with the multiple and varied ways in which the integration of literacy elements such as writing and communication of ideas, students are empowered to demonstrate mastery in which they have a choice (Nuangchalerm et al., 2020; Shaw et al., 2021). Students are encouraged to leverage their areas of strength and creativity when working to increase their foundational skills in any given content area.

PEDAGOGICAL APPROACHES IN STREAM

Research indicates that the most effective pedagogical approaches in STREAM-based education revolve around experiential learning (Shaw et al., 2021). Inquiry-based instruction where students are allowed to explore, fail, and try again is critical to developing the critical thinking skills and resilience that are often associated with this method of instruction (Oladele & Ndlovu, 2024; Suteu et al, 2024). Inquiry is a foundational element of STREAM-based learning (Kitamura, 2024). Kitamura (2024) suggests that inquiry transcends the framework of individual content, and allows students to connect pertinent elements of any STEM-based content to real-world situations while integrating creative and artistic elements. Suteu and colleagues (2024) determined that there were two dimensions of cognition relevant to STREAM-based instructional methods. The first is the metacognitive dimension, in which a student becomes aware of his or her learning preferences, actual knowledge, and where he or she needs to strengthen the knowledge base. The second dimension, metacognitive regulation, is the one in which a student is actively engaged in the learning and utilizes their actual knowledge as well as their knowledge of their learning processes and preferences, and is actively engaged in strategizing ways in which to overcome difficulties experienced during the learning (Kitamura, 2024). Not only is a student empowered to deepen their understanding of content, he or she acquires knowledge of how he or she learns best; which can be applied to multiple situations across content and real-world settings.

Two additional techniques that are similar but distinct approaches are Problem-based Learning and Project-based Learning. Many professionals use PBL to describe both methods, but the two have distinct features and are not interchangeable. Project-based Learning incorporates a real-world problem into the curriculum which students then attempt to pose a solution for, using investigation, exploration, and hands-on learning. Project-based Learning is an overarching theme that allows for integration across multiple disciplines and takes an extended period to fully investigate and complete. In line with preparing students who have mastered 21st-century skills, Project-based Learning focuses on communication through collaboration and an active role in the learning (Olivato & Silva, 2023). Problem-based Learning is equally effective at blending technical and 21st-century skills, along with developing soft skills like creativity and communication while allowing for engagement and agency in the learning (Oladele & Ndlovu, 2024; Xue, 2022). While both approaches are highly student-centered, there are some distinguishing features. Problem-based Learning (PBL) tends to be more structured and has a narrower focus on a specific problem that must be solved. Project-based Learning (PjBL) allows for a more student-directed approach and a wider framework in which to navigate (Xue, 2022; Yang & Hsueh, 2024). PBL frequently focuses on a specific solution to a clearly defined problem, whereas PjBL allows students to demonstrate mastery of learning through creative expression and the completion of a project (Yang & Hsueh, 2024). Assessment in PBL is focused on a successful solution to a problem, whereas PjBL provides an opportunity for creativity, has a wider range of criteria on which the assessment is based, and includes competency in 21st-century skills. Other instructional methods appropriate for younger learners include the incorporation of drama-based activities, storytelling, gamification of learning, and competency-based educational models (Bertling & Galbraith, 2024; Juntakoon et al., 2004a; Juntakoon et al., 2004b; Kasvary & Geza, 2024; Oladele & Ndlovu, 2024).

When structured appropriately, PBL and PjBL are appropriate for all learners even our youngest ones. There are, however, methods that work best with older learners. Methods such as blended learning, a hybrid approach, involve utilizing both in-person and online learning to enhance student mastery of knowledge (Cai, 2023). Additionally, the utilization of a flipped classroom could also be impactful for older learners. A flipped approach to learning generally refers to students who access curated materials online before a class meeting and engage in application activities during a class session (Oladele & Ndlovu, 2024). This approach is best suited for learners who have access to an online learning platform as well as those who are self-directed enough to prepare for an in-class session before each meeting. Finally, the integration of creative and visual materials is critical to the overall impact of STREAM-based education. Students must be able to utilize real-world materials, practice critical analysis of digital materials, and apply their analytical skills to photographs, maps, and art to develop the skill set needed to engage effectively in a multidisciplinary environment that reflects the real world (Shaw et al., 2021).

ASSESSMENT METHODS IN STREAM

While some instructional methods embed assessment criteria within the framework of the instruction (e.g. PBL/PjBL), others require consideration for an appropriate approach. Some of the most effective methods of assessment in a STREAM environment include authentic assessments, performance-based assessments, and student self-assessments (SSA) (Mariana & Kristanto, 2023; Rickey et al., 2023; Wilson et al., 2021). Authentic Assessment relies heavily on simulating a real-world environment, focuses on the application of knowledge, and involves the direct application of knowledge (Rickey et al., 2023). Performance-based assessments rely on the demonstration of mastery of knowledge in a variety of disciplines to communicate a final result. This is an ideal method of assessment in a STREAM classroom due to the opportunity to include creative expression and allow for student direction in the production of the final product (Wilson et al., 2021). SSA is a method of assessment that taps into a student's metacognitive knowledge (Rickey et al., 2023). A student can include reflection, goal setting, creation of prototypes, self-testing, and communication with peers and assessors (Rickey et al., 2023).

THE ROLE OF THE EDUCATOR IN STREAM

To facilitate a high-quality STREAM-based environment, teachers require specialized support and development. Initially, teachers must learn how to transition from the role of a gatekeeper of knowledge to a facilitator of learning and must have strong pedagogical knowledge and skills in STREAM concepts (Li & Talib, 2024; Oladele & Ndlovu, 2024; Olivato & Silva, 2023; Phang et al., 2023; Wilson et al., 2021). Not only must they have expertise in structuring the learning environment and processes, but also in identifying struggling learners and providing scaffolding opportunities for them (Brada et al., 2023; Gulhan, 2024; Shaw et al., 2021; Oladele & Ndlovu, 2024; Wilson et al., 2021).

There are factors outside the control of a classroom teacher. Teachers must have a supportive administration that provides professional development. Current information in both pedagogy, as well as content, is critical to the function of a high-quality STREAM program. Additionally, teachers must have access not only to physical materials in the room appropriate to the age of students in their care, but also technological platforms, instructional technology, and access to stakeholders with real-world connections to ensure that children can actively and fully engage in a STREAM program (Zan et al., 2024). Some challenges that teachers face in implementing STREAM education include teacher expertise and confidence, limited resources, time constraints, and efficacy with assessments appropriate to an interdisciplinary curriculum (Brada et al., 2023; Phang et al., 2023; Shaw et al., 2021).

CONCLUSION

STREAM-based education is a novel approach that engages students in a variety of cognitive and physical ways. Students are empowered, have agency in the learning, and can determine the direction of their inquiry. However, these processes all take time and intensive structure to ensure that they are implemented in a way that is beneficial to students. STREAM is a critical approach to developing students who can meet the needs of a workforce that does not exist yet, to engage with complex problems that their generation will face, and to pose complex and critically analytical solutions to those problems. Offering STREAM programs provides opportunities for content development and the holistic development of a child and his or her ability to navigate a complex and difficult world, especially in the early years.

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THEORETICAL FOUNDATIONS IN INNOVATING SCIENCE TEACHING USING STEAM EDUCATION

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Abstract: The paper explains the key theoretical and methodological assumptions of innovating and improving the quality of teaching science using STEAM education. Using the theoretical analysis, it was established that STEAM education is based on a cognitive process aimed at solving problems from the real world, project learning, cooperative learning, research teaching, and the application of procedures that encourage students to be productive, self-initiative, and reflective. The roles of students and teachers are founded on cooperation. The focus shifts to students who assume the role of researchers, creators, leaders, and evaluators; teachers take the role of facilitators in the teaching process. The application of STEAM has certain limitations. Primarily, teaching staff has insufficient capacities to conceive, design, implement, and evaluate teaching concerning STEAM. Moreover, the model structure in which the standards and outcomes of all disciplines included in STEAM would be equally represented is an intricate task. The conclusions indicate that the aspects, advantages, and positive characteristics of STEAM surpass the deficiencies. Hence, STEAM should be applied in teaching science to a greater extent.

Keywords: STEAM education, science teaching, content integration, knowledge transfer, active learning

INTRODUCTION

Narratives about the competencies necessary for life in the 21st century have stimulated numerous discussions about the imperatives of the contemporary educational system. There is a real danger that many of the skills taught to students today will become obsolete, due to rapid changes and advances in various

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fields, especially technology and industry. In addition, today's students' needs are very different from the needs of those educated just a few decades ago. That is why there is a growing need for education that will be able to create a more dynamic, flexible, and future-relevant learning environment (Belbase et al., 2022). The extent to which the imperatives of modern education, adapted to the acquisition of appropriate skills and functional knowledge, are represented in our educational system in the field of natural sciences, is attested in the findings obtained by analyzing the mistakes made by students of the fourth grade of primary school within the framework of the TIMSS research in 2019 (Stanišić, Blagdanić, & Marušić Jablanović, 2021). The results imply the need to connect knowledge with everyday life and train students to transfer knowledge from different fields. The new education should change the direction "from education intended for the student to education that starts from the student, education in which the student is less and less someone whom they form, shape, from whom they want to create something, and more and more a self-shaped, conscious personality, a subject which changes itself" (Vlahović, 2020: 21).

Science teaching, as part of modern education, represents an important link in the formation of an individual who will be able to use the acquired knowledge to explain how the world around us functions, formulate conclusions and understand the changes in the field of natural and social sciences. For these reasons, students should be trained to be active participants in a teaching process – initiators of activities, researchers who express themselves creatively, and critics and evaluators of their achievements.

METHODOLOGICAL FRAMEWORK

This paper aims to determine the basic theoretical assumptions behind the STEAM innovation in science teaching. To reach this goal, three research project tasks are set: 1) to determine the characteristics and structure of STEAM education in science teaching; 2) to determine the impact of STEAM education on the changes in student roles with respect to the traditional model of content acquisition in science teaching; 3) to determine the limitations in the STEAM application identified in the previous quantitative and qualitative research on the topic. This descriptive study analyzes the procedures in the theoretical and empirical scientific articles dealing with STEAM education.

RESULTS AND DISCUSSION

The following section provides an overview of the findings according to the previously defined research tasks.

STEAM Education: Innovative and Transformative Approach to Learning in Science Teaching

Contemporary methodical theory and practice strive to integrate several different scientific disciplines to contribute to the overall development of a personality. This is not a novelty if we take into account that Comenius believed that education should be students' preparation for life, whereby students should acquire functional knowledge and skills of reasoning and critical thinking (Komenski, 1997). One of the concepts that have numerous positive effects on the development of competencies for the 21stcenturyis STEAM education (Belbase et al., 2022; Boice et al., 2021; Bush & Cook, 2019; Hoi, 2021; Yakmen, 2008; Li et al., 2022; Wu, Lui, &Huang, 2022).

The term STEAM is an acronym that unites the fields of science, technology, engineering, art, and mathematics in an integrated approach to topics related to everyday life situations. Georgette Yakman is believed to be a creator of this concept since he integrated arts into the existing STEM concept, emphasizing that arts enable a more comprehensive approach to learning. Yakman (2008: 17) presents the STEAM schematically as a pyramid (*Figure 1*). The foundation of STEAM education comprises a wide range of scientific disciplines within the five main areas. Hence, the approach to learning is not interdisciplinary but rather transdisciplinary. This is symbolically presented as *STΣ@M*, where the mathematical symbol Σ (sigma) stands for the sum of all values, and it is used here to emphasize the holistic character of STEAM.

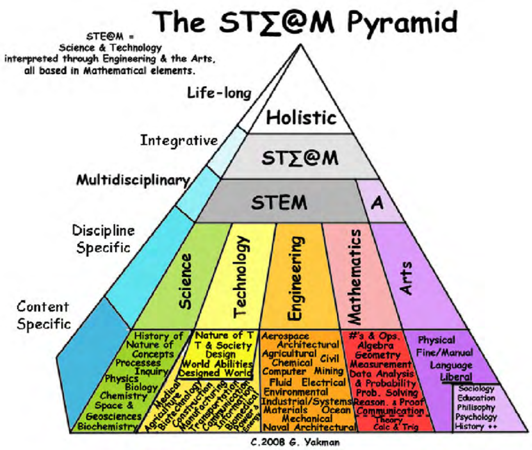

Figure 1: STEAM pyramid (Yakman, 2008:17)

By placing the pyramid in the context of the goals and outcomes that are achieved and the content that is studied within science teaching (*Table 1*), we can observe the study areas of the presented scientific disciplines and how they correspond to the basic intention that science teaching should aim to develop all spheres of a student's personality, whereby the boundaries between the studied topics "should be understood conditionally and flexibly" (*Pravilnik*, 2019:43).

Table 1: The STEAM disciplines in the science lessons for the 4th grade of elementary school

SCIENCE TEACHING		**THE REPRESENTATION OF THE STEAM SCIENTIFIC DISCIPLINES**
TOPICS	**CONTENTS**	
Natural and social characteristics of Serbia	Position, territory, borders, and symbols of Serbia and its national currency. Natural characteristics of Serbia – relief, water, forests. Typical, rare, and endangered species of plants and animals – importance and protection. National parks of Serbia. Social characteristics of Serbia (population, settlements, and activities). Citizens of Serbia (rights and obligations, democratic relations, and interculturality). Economic characteristics of Serbia (natural resources and activities in different regions). Sustainable use of natural resources	SCIENCE: The representation of the content from the fields of geography, geomorphology, ecology, biology, demography, and sociology TECHNOLOGY: The application of various digital research tools (Google Earth, Google Maps, VR and AR applications) ENGINEERING: The consideration of different ways of environmental protection, rationalization of natural resources, industrial engineering, mining engineering ART: Modeling relief forms, visual presentation of state symbols MATHEMATICS: Fractal presentation of demographic data, mathematical calculations related to the area and population
Man is a natural and spiritual being	Man – a natural, social, and conscious being. Physical changes in puberty. Digital security and consequences of excessive use of information and communication technologies; inappropriate contents.	SCIENCE: The representation of the content from the fields of biology, anatomy, physiology, medicine, anthropology TECHNOLOGY: Digital security ENGINEERING: Systems engineering, food engineering ART: The culture of living, the art of creation that distinguishes man from other beings

		MATHEMATICS: Quantitative data on the development of the individual, nutritional value of food
Materials	Mixture Separation of mixture components Electrification of objects made of different materials. Electrical conductivity – Conductors and insulators. Rational consumption of electricity and proper handling of electrical appliances in the household. Magnetic properties of materials Flammable materials Air – oxygen as a combustion factor. Fire hazard and protection.	SCIENCE: Representation of content from the fields of physics, chemistry, electrical engineering TECHNOLOGY: The use of software and measuring instruments for the study of the above contents ENGINEERING: Metallurgical engineering, food engineering, electronic engineering ART: Analysis of signs and symbols of flammable materials MATHEMATICS: The quantitative data on electricity consumption, interpretation of non-linear texts
Serbia's past	Life in the distant past The Serbian state during the Nemanjić dynasty's rule– rise and decline Life under Turkish rule The origin and development of the modern Serbian state (First and Second Serbian Uprising – cause and course; leaders of the uprising; culture, way of life). Serbia in modern times	SCIENCE: The representation of the content from the fields of geography, history, demography, ethnology TECHNOLOGY: The use of software and audio-visual traces from the past ENGINEERING: Construction engineering ART: Tangible and intangible goods MATHEMATICS: The interpretation and the creation of timelines

The successful implementation of such a complex concept in science teaching requires a carefully designed application and the combination of different strategies, procedures, and activities of students and teachers. Given that it is a concept that encourages students to solve complex problem situations so that they can develop personal competencies and qualities (Hoi, 2021; Mehta et al., 2019), some authors advocate for the STEAM approach with an emphasis on project learning. STEAM project-based learning involves students in designing, problem-solving, research, and decision-making. This allows students to work relatively autonomously for a long time and manifest the products of their work through various artifacts – realistic products or presentations (Liao, 2019). The focus of STEAM viewed through the prism of project-based learning is on the complete course of handling a project, that is, on a path (process) that students have to go through to gain new knowledge. That process includes mistakes, modifications, and a complete consideration of a particular problem. Similarly, there are authors who give priority to the application of research teaching, that is, the so-called *5E* model (*Engage*, *Exploration*, *Explanation*, *Elaboration*, *Evaluation*) within which students are in a position to ask questions, observe, predict, experiment, explain, research, apply knowledge, and verify their assumptions (Stroud & Baines, 2019).

When it comes to citing cooperative learning as one of the main STEAM strategies of education, the authors agree that when students are encouraged to cooperate and critically observe the different views on the same problem, we foster divergent thinking (Boice et al., 2021; Liao, 2019; Li et al., 2022). In addition to cooperative learning, the strategy of cooperative teaching has been also emphasized. As stated before, STEAM supports learning based on students' research work, and problem and/or project model. The very concept can be a challenge for teachers as well. They are required to take the role of facilitators who should teach students about topics that are not directly related to their formal education. In this sense, the cooperation between teachers and subject teachers should be established. This would be an excellent preparation for the subject teaching in the fourth grade of elementary school. Some authors recognize the importance of establishing cooperation with experts from different fields. This contributes even more to the pedagogical values of STEAM education. The application of digital technologies easily solves the problems of physical distance and provides opportunities for organizing visits in a virtual environment (Mehta et al., 2019).

In the literature aiming to explore the characteristics of STEAM education, there is an emphasis on the application of the Design Thinking method, which simultaneously encourages the development of analytical and divergent thinking in students through creative problem-solving (Liao, 2019; Henriksen, Mehta, & Mehta, 2019). The recommended stages in the method application are similar to the stages of the problem model and research teaching with minimal terminological differences. In the first stage, students examine the current state of the phenomenon being studied; followed by defining the problem, considering ideas, creating a prototype solution, and testing the proposed solution model (Henriksen, Mehta, & Mehta, 2019).

Other authors also attach importance to reflections (Bassachs et al., 2020; Wannapiroon, Petsangsri, 2020), emphasizing that reflective learning is closely related to STEAM education. Through reflection, students can develop and acquire competencies that will help them identify correlations between different scientific domains since reflection, inter alia, aims to examine, frame, and contextualize scientific questions to address the hypotheses during experimentation (Bassachs et al., 2020).

However, despite the frequent use of the mentioned keywords that determine STEAM (*Figure 2*), unanimously accepted instructions on structuring STEAM teaching practice do not exist. Ideas vary depending on the goals one wants to achieve, the nature of the integration of disciplines, and the role of art. There are guidelines regarding the insistence on students' practical work, cooperation, research work, and discussion, which is, on the one hand, a mitigating circumstance, because it leaves teachers with the opportunity to maximally adapt the teaching to the prior knowledge of their students and specific working conditions.

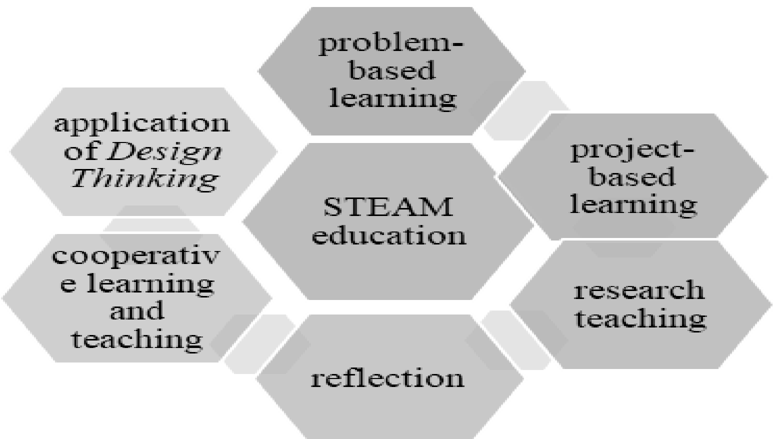

Figure 2. Recommended teaching procedures and activities in STEAM education

Depending on the level, the options for STEAM integration can be ordered as follows: the application at the level of individual tasks within partial lessons, the application of learning strategies, and the integration into the complete existing curriculum that can be reformed (Belbase et al., 2022). Based on the above-mentioned analysis of the compatibility of the contents within the science subject program with the areas of study included in STEAM (*Table 1*), we can point out that in this particular case, the integration is possible at the first two levels, i.e. in individual lessons. The last level of integration would require additional involvement and investigations of the expanded context, although there are theoretical foundations for it.

Students' roles in science teaching with STEAM

Based on a holistic approach, STEAM contributes to the expression of students' motivation and positive attitudes toward taking part in classes; hence, it reflects not only on their cognitive, but also on their psychomotor development (Wu, Lui, & Huang, 2022). By setting the characteristic STEAM requirements related to the application, analysis, creation, and evaluation of different conceptual solutions, students strive to reach higher levels of Bloom's taxonomy. This transforms their role as passive participants in the teaching process. Students assume the role of the agents in the investigation of a phenomenon, which changes the center of the teaching process. By providing additional information, encouraging, motivating discussion, coordinating, and monitoring the behavior and progress of students, the role of the teacher during the implementation changes to a different form compared to traditionally organized teaching, where the emphasis is on the activities of a teacher. Teachers become facilitators tasked with providing guidance and additional support, not offering ready-made knowledge and solutions.

By solving real-life problems through STEAM, students are encouraged to "blur the boundaries" between subjects. They focus on the transfer of knowledge from different fields that contribute to a comprehensive understanding of the problem while students are maximally engaged in solving it. Students are allowed to express their doubts, present their observations with arguments, and confront different opinions and attitudes in a polite narrative. Bearing in mind that the complexity of the problems the students deal with can vary, students are encouraged to be productive, persistent, self-initiative, flexible in accepting different points of view, and independent. All these qualities are very important for the skills of the 21st century.

As creators and researchers in STEAM, students strengthen their reading comprehension skills and the ability to adequately select facts by importance while recording their observations in written form. STEAM does not expect the mere memorization and reproduction of ready-made facts presented ex-cathedra; students are stimulated to research independently, draw conclusions, and confirm or challenge formulated assumptions (Belbase et al., 2022). Accordingly, students compare, contrast, and classify the similarities and differences between observed phenomena, connect knowledge of scientific concepts with different properties, present conceptual solutions using numerous visual means (illustrations, graphs, schemes, tables, diagrams, research diaries, photo-narratives), and interpret relevant information based on the independent generalizations previously made. By using technology, students are trained to critically search for the necessary information, observe cause-and-effect relationships, compare the obtained data, and present the obtained work products by citing new examples. According to STEAM, the idea of integrating art into a research process is precisely based on the fact that students are placed in a position to cultivate the ability to visually represent the experiences gained in real-time adequately so that in the following stages of work, they can use their discoveries, documents, sources, and forms of presentation of key data that will lead to new correlations, used for noticing mistakes, making modifications, designing new conceptual solutions, or presenting work results (Stroud & Baines, 2019).

The authors emphasize that students form a learning community in a STEAM classroom that continuously collaborates throughout the year to strengthen group cohesion by fostering individual and collective responsibility, thus encouraging students to work reflectively with peers and in a team (Stroud & Baines, 2019).

Traditional teaching methods differ from STEAM-oriented teaching in that the responsibility for learning is "shifted" to the student and depends fully on his active participation. Students are maximally mentally engaged and progress through their efforts. Of course, this does not necessarily imply that students are left to their own devices. It is about shifting the emphasis from their passive role in receiving knowledge to the role of collaborators in teaching. Depending on the needs of students and research goals, it is possible to negotiate the levels of responsibility placed on students and their teachers (Stroud & Baines, 2019). The changed status of students in the process of such designed teaching requires that both parties understand and respect partnership and cooperation, with clearly defined tasks, rights, and obligations.

STEAM application limitations in science teaching

Despite numerous advantages observed in the application of STEAM education, the authors agree that limiting factors cause incomplete realization of positive effects.

As the primary limiting factor, the authors cite the lack of experts who would deal with the design of teaching content according to the STEAM concept. In practice, there are widespread positive attitudes towards this type of work organization among teachers. However, there is a discrepancy between what teachers believe and how they implement it. Hence, Belbase et al. (2022) raise the issue of motivation and teachers' ability to apply this concept. Among teachers, there is often a fear of teaching a subject that is outside the scope of their formal education. Considering that there is still no consistent structure (model, template, copy) according to which STEAM teaching is conducted, there are teachers who feel this is a barrier to designing lessons, writing preparations, teaching organization, and its implementation (Boice et al., 2021). In Serbia, some recognize the importance of applying the concept, but who believe they need additional support: more literature in the Serbian language and the exchange of examples of good practice via various professional gatherings, forums, and conferences (Filipović, 2022).

An additional limitation is the evaluation of student achievements in STEAM classrooms. As STEAM combines several different disciplines, it is difficult to assess achievements based on the standards and outcomes set for each specific subject. Belbase et al. (2022) suggest student-centered assessment. Their participation in the joint assessments of tasks or projects through peer assessments and self-assessments is enhanced, concurrently enhancing the development of their reflection. An emphasis can also be placed on the connection of content, engagement, creativity, and originality through keeping a research journal and such evaluations can be diagnostic, formative, and summative. Some ideas promote a holistic approach to assessment and an approach based on success criteria. The difference in these approaches is reflected in the presence of already defined evaluation criteria. Holistic evaluation does not use a set of criteria for evaluating student performance. An evaluator observes the entire object, action, or process. It mainly depends on the holistic effect of the artwork or design and identifying the key features within such an object of assessment without using predetermined criteria. On the other hand, criteria-based assessment uses an established set of criteria with a systematic or predetermined formal structure (such as a rubric or assessment key) to be used during the assessment (Belbase et al., 2020).

The greatest degree of concern and conflicting opinions revolve around the number of disciplines covered by STEAM. While some advocate for the presence of art in its various forms, considering it a segment that contributes to the development of students' creativity, others, on the other hand, point out that by adding more disciplines, the intensity of the content is lost, and each discipline is approached superficially. In addition, many mathematicians believe that mathematics has been put on the back burner due to the dominance of science or engineering; its role in project/problem-based learning has been reduced to the function of a "tool" while its importance for the development of mathematical reasoning and thinking is neglected (Belbase et al., 2020).

CONCLUSION

The tendencies of modern education imply the need to design an educational system that will meet today's needs by developing 21st-century skills that will prepare students for future occupations and form them as self-directed and self-initiated individuals. For these purposes, it is necessary to encourage students to use knowledge functionally and to accustom them to be active participants in the teaching process: to collaborate, compare, classify, research, assume, try, verify, and evaluate to solve problems from the real world. It is necessary to encourage the transfer of knowledge by eliminating the barriers between subjects. When it comes to students' ability to use the acquired knowledge functionally in the field of natural sciences, there is a need to design a high-quality interdisciplinary approach to the contents of science lessons that will support students in the process of developing their cognitive, affective, and psychomotor domains.

The possibilities of applying STEAM to innovate science teaching are determined, first of all, by the theoretical-methodological framework and the results of adequate empirical research by foreign authors. The analysis of relevant scientific publications on the characteristics and effects of STEAM leads to a conclusion that there is a corresponding innovative potential, viewed through three essential aspects:

1) the need to change the traditionally organized science teaching with modern, transformative, and transdisciplinary STEAM since this approach interprets the nature and function of teaching differently and implies an essential connection of teaching with life, uniting knowledge and skills of five different areas (science, technology, engineering, art, and mathematics);

2) the transformation of the roles of students and teachers in a teaching process, whereby students are partner-oriented to the teacher in that they acquire the status of active participants who have the roles of researchers, creators, leaders, and evaluators; the focus of teachers' work shifts from ex-cathedra lectures to the role of coordinators, mentors, collaborators– facilitators who do not provide ready-made knowledge, but rather motivate students to reach the highest levels of Bloom's taxonomy independently; and

3) overcoming the limitations for the implementation of STEAM including insufficient motivation and training for planning, designing, implementing content, and evaluating student achievements in the fields integrated into STEAM. A high-quality structure design is needed since the standards and outcomes for all disciplines should be equally represented to eliminate the possibility of insufficient and incomplete study of any discipline.

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LEARNING TO MAKE, MAKING TO LEARN: STEAM MEETS MAKER MOVEMENT

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Abstract: In this paper, we examine the potential advantages of integrating principles and methods from STEAM education and the maker movement into the teaching and learning process. The transition of the maker movement from informal to formal education, such as schools and colleges, is encouraged by STEM, and even more so by STEAM education. The maker movement, characterized as a community fostering creation based on science, technology, art, and craft, along with STEAM education, is rooted in the tradition of learning by doing and has experienced significant growth in recent years, even within Serbian schools (13 makerspaces were opened last year). Why is this collaboration between makers and education so fruitful? It aims to cultivate creativity, problem-solving skills, communication, social, and other competencies that schools typically struggle to develop. Our main goal is to address the lack of theoretical discussions regarding the connections between the nature of learning and the nature of a making process. Thus, we explore how learning emerges from STEAM education and the maker movement from the perspectives of socio-constructivist theory, progressivism, and critical pedagogy. This analysis led us to propose seven principles of learning by making that, if employed, can serve as a foundation for bridging STEAM, makers, and everyday teaching practice. They are as follows: tinkering – active thought, transdisciplinarity, real-life problems and project-based learning, community of learners, playfulness, metacognition and a hacking mindset, and mistakes-based learning. Finally, we outline both potential pitfalls and resources for implementing the maker movement in Serbian schools.

Keywords: STEAM, teaching/learning, maker movement, makerspace, makers

INTRODUCTION: WHY IS IT IMPORTANT TO UNITE THE MAKER MOVEMENT AND STEAM?

The maker movement, as a community that fosters creation based on science, technology, art, craft, do-it-yourself home improvement, and similar endeavors,

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emerged within informal education at the beginning of this century but soon found a path into the formal learning environment (e.g., Martin, 2015). Besides recognizing the importance of making as an essential part of human evolution and a basic human need, other core principles of the movement, particularly from the perspective of formal education, include (Hatch, 2014): share, learn, tool up, play, and participate. People need to share what they make with others, and another aspect of sharing is sharing knowledge about the process of making (i.e., know-how). Making is inseparable from learning because we have to learn to be able to make, but making also brings about a natural interest in learning. Tools, both high- and low-tech tools, are an essential part of making. Play brings a positive mood, makes our cognitive processes more flexible (this is also the effect of a positive mood alone, as noted by Reeve, 2009), and ultimately increases productivity. The idea is to be playful with ideas and with what we are making. Finally, it is expected to participate in a community of makers/learners by working directly together, holding classes, attending makers' events, or in some other ways.

Although it has been constituted in recent times, the maker movement has long-standing theoretical roots—it has been an educational "revolution in waiting for 100 years" (Blikstein, 2018: 420). The movement is grounded in sound educational perspectives and a history of ideas about learning, including progressivism, socio-constructivism, and critical pedagogy (e.g., Blikstein, 2018; Libow Martinez & Stager, 2013). More than a century ago, Dewey wrote, "Only the already experienced can be symbolized" (Dewey, 1910: 166). He made a paradigm shift by proclaiming the maxim of *learning by doing*. Dewey not only framed learning as the product of practical activities within the context of authentic inquiry and experimentation but also emphasized that learning in school needs to be connected to the real world, to children's activities outside of school, thus gaining full meaning for learners (e.g. Pešikan, 2020). The fact that knowledge and understanding must be actively constructed (and not transmitted) links constructivism and socio-constructivism. However, the latter adds social interaction (i.e. co-construction) and cultural tools as the main means for shaping individual cognitive development. Critical pedagogy brings to the fore the importance of empowering learners against oppressive social structures maintained by the traditional school system and highlights the need to support students in perceiving themselves as agents of change.

STEAM, which stands for Science, Technology, Engineering, Arts, and Mathematics, is an educational approach that as many authors suggest offers a path toward significant educational improvements, particularly in developing competencies needed for the 21st century (Dryder & Vos, 1994; Trilling & Fadel, 2009; OECD, 2013). The STEAM approach is widely discussed and described as encompassing principles such as interdisciplinarity, collaboration, hands-on and inquiry-based learning, critical thinking, problem-solving, project-based learning, real-world applications, and technology integration (Henriksen, 2014). Additionally, it incorporates principles like transdisciplinarity, embodiment, and a critical approach (Sengupta, Shanahan, & Kim, 2019). Recent authors highlight the transformative potential of the STEAM approach in educational contexts (Williams, 2023). In this paper, we argue that the combined impact of the STEAM and makers approaches in educational settings is far more powerful than the changes they can bring individually.

METHODOLOGY

The main research question is what the potential advantages of integrating principles and methods from STEAM education and the maker movement into the teaching and learning process are. The paper aims to map concordances between STEAM tradition and maker movement tradition in an educational context by defining principles that can support teaching and learning processes into being more engaging and relevant for students.

Building upon five years of experience in STEAM and makers practices at the Center for the Promotion of Science in Belgrade, where one of the authors was involved in designing, coordinating, implementing, and evaluating 15 children's science camps, three maker labs, and numerous maker workshops, this paper explores reflections on these programs and their theoretical foundations. It examines the connections between socio-constructivist theory, critical pedagogy, and the practice of STEAM and makers programs in Serbia. Thus, the paper has two core foundations: practical work with children and theories of learning and teaching. The concept of bridging STEAM and maker approaches predates the popularization and formal naming of these categories in educational settings. Although these approaches have more similarities than differences, they have developed as relatively separate traditions, particularly in formal education in Serbia. Therefore, this paper aims to map the intersections of these approaches and ground them in educational sciences. This can help educators understand the role of maker tools, approaches, and principles in everyday teaching practice better, particularly in project-based learning, STEAM, and thematic teaching, all of which are becoming part of the official curricula.

The methodology of this paper involves a reflective practice approach, where practical experiences are critically examined through theoretical lenses to develop new principles. Practical experiences from STEAM and makers practices are revisited and reread by using established theoretical frameworks dominant in educational contexts in European and Western traditions today.

RESULTS: PRINCIPLES OF LEARNING BY MAKING

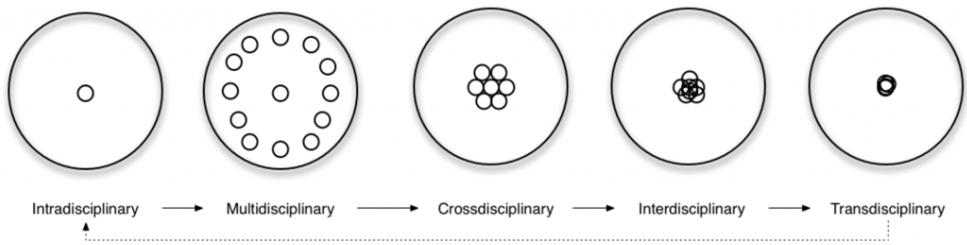
Tinkering – Active Thought

Tinkering is a term often used within the maker movement to designate a way to approach and solve problems in a creative and improvisational manner (like in a children's game) as well as a form of learning where both hands and mind are active (e.g. Bevan et al., 2015; Libow Martinez & Stager, 2013). It is a concept closely related to Piaget's constructivist theory and its notion of an active learner. It is also similar to the term *mentipulation* coined by Ivić and associates (Ivić, Pešikan, & Antić, 2003) to describe the mental processing of information about reality. Tinkering could be defined as "the generative process of developing a personally meaningful idea, becoming stuck in some aspects of physically realizing the idea, persisting through the process, and experiencing breakthroughs as one finds solutions to problems" (Bevan et al., 2015). As such, it is an iterative process (e.g. Bevan et al., 2015; Libow Martinez & Stager, 2013) during which learners set goals, develop strategies, try to overcome problems, feel frustration, seek social scaffolding, strive to understand, experience turn-taking, and feel joy (Bevan et al., 2015). Furthermore, it is the process of interdisciplinary inquiry, as seen in play and complex scientific investigation. In STEAM education, this is achieved by using a wide palette of concepts, tools, and procedures.

Transdisciplinarity

If you look outside your window and see a road with some vehicles on it, what would you think about this phenomenon? Can we classify traffic as an engineering issue? Or would you think about the noise and pollution and consider it an ecological issue? Perhaps you would see it as a sociological issue because some vehicles are more expensive than others, indicating the different social statuses of their drivers. Or would you think of all of these aspects? Traffic, like any other phenomenon, cannot be confined to any single discipline. Disciplines are merely human interpretative frameworks trying to grasp the phenomena that surround us. In STEAM and the maker movement, engineers, artists, craftspersons, and scientists from diverse backgrounds collaborate. This fosters the development of new methodologies and approaches, rooted in their own disciplines but expanding into new territories where their fields intertwine. As Jensenius (2012) wrote, transdisciplinarity is a new point of departure, where borderless and discipline-free phenomena are addressed through joint efforts and different, but equally valuable, contributions. (*Figure 1*).

Figure 1. Continuum of disciplinarities (Jensenius, 2012; based on an original drawing by Zeigler, 1990)



This approach brings more justice to everyone involved and to the phenomenon in question as well. This kind of teaching and learning transcends subject divisions and embraces a collaborative, multidimensional approach, opening students' mindsets to more complex ways of approaching the world.

Real-Life Problems and Project-Based Learning

Advocating for schoolwork to be focused on real-life problems or some versions of problems professionals encounter is a common theme in a number of educational approaches, including progressivism and constructivism. This is also advised from the perspective of neuroscience findings, i.e. brain-based education (e.g. Woolfolk, 2021). Working on problems with real-life relevance provides an authentic context for learning (Libow Martinez & Stager, 2013) and increases intrinsic motivation (a well-documented effect in handbooks of educational psychology, e.g. Vizek-Vidović et al., 2005 and Woolfolk, 2021).

A natural context for solving real-life problems is project-based learning, as they share a multiperspective approach (and build multiperspective understanding), collaboration, and interdisciplinarity, among other qualities. There are no disciplinary bounds in life or professional work—at the very least, we have to cooperate with other professionals. Not surprisingly, one of the outcomes of project-based learning is the transfer of knowledge and skills between subjects (e.g. Šefer, 2005). The unity of real-life problems and project-based learning is highly valued in the maker movement; therefore, guidelines for project ideas and how projects should evolve are provided (Gabrielson, 2015; Libow Martinez & Stager, 2013): is the project personally meaningful? Does it prompt intrigue? Is it challenging but doable? Is sufficient time provided? Will the product be shareable?

Community of Learners

Building on the foundation of socio-constructivism, Barbara Rogoff is probably the best-known proponent of the idea of a community of learners "where everyone plays active and often asymmetrical roles in sociocultural activities" (Rogoff, 1994: 209). The maker movement (as a type of community) emphasizes the importance of creating within a community through principles of sharing and participation. Makers form communities of practice within makerspaces, where they jointly "develop, negotiate, and share" their conceptual understandings (Sheridan & Konopasky, 2016). Community improves learning in various ways. On a group level, it provides gains in resources when people share knowledge and skills, offer new perspectives, and enable collaborative problem-solving. On an individual level, it provides important feedback in the form of encouragement, creative suggestions, or constructive corrections. The formative role of social interaction does not end with the development of higher-order mental processes nor in the realm of cognition (although this was a focus of Vygotsky and his successors). By learning in a community, children develop social and communicational competencies—skills that are essential to workplace success regardless of the profession. Moreover, making and learning in a community may unfold online (even through asynchronous communication), but current insights support the coexistence of physical and online communities (e.g. Litts et al., 2016).

Playfulness

The principle of playfulness is central to both STEAM education and the maker movement. Makerspaces look a lot like playgrounds. Makerspaces are a sort of playground for the body and the mind (Myers-Spencer & Huss, 2013). To draw a parallel, in deprived environments, children usually learn to make their toys and reconstruct their living spaces into playgrounds. Their play is riskier, deeper, and even more creative than the play of children from more advantaged backgrounds and in more structured environments (Brown & Patte, 2013). If we compare this with classrooms, play should become a necessary principle of didactical choices for children of all ages, from toddlers to adolescents. Yes, it will look and sound messy and might seem hard to manage (Crawford-Berniskis, 2014), but play always has a purpose for a child, even if at times it may appear purposeless to teachers (Smidt, 2011). Playful (Marten, 2015) and provocative, unstructured spaces that encourage self-expression are invaluable learning resources and are exactly what makerspaces provide (Rosefeld, Halverson, & Sheridan, 2014). They could also be called spaces of creation (Plemmons, 2014). Flexibility is perhaps the most important quality of these spaces (Helfrich, 2014). This implies that teachers should be able to work and remain comfortable in chaotic situations (Crawford-Berniskis, 2014). Curiosity is nurtured, promoted, and invited in these spaces which motivate more questions than answers (Kurti et al. a, 2014: 9).

Metacognition and a hacking mindset

Makerspaces are sometimes called hackerspaces and are often funded as cooperatives of programmers and hackers (Crawford-Berniskis, 2014). But, in the maker movement hacking[1] is less of a tool or programming practice and more of a mindset (Martin, 2015) that could be applied to understanding learning, education, and society. Technology and specifically coding are very important aspects of the maker movement. Coding became one of the literacies of a new age. BBC, in a project "Make it digital"[2], equipped every child of age 7 across the UK with a pocket-sized codable computer with motion detection, a built-in compass. and Bluetooth technology. With children's programs for coding (Scratch, Codeable, etc.), and the gadgets like Little bits, Arduinos, and Raspberry pies making the craziest things is rather easy. What kind of learning is this? First, coding itself is a very *metacognitive action* and it requires a clear division of the steps of a process, the organization of an algorithm of wanted action, and many adjustments of these steps along the way (Weizenbaum, 1976). Second, it is a *holistic process of solving a problem,* from the discovery of what is needed to the discovery of how it can be resolved, it is a path of inventing (Piaget, 1973). The same logic is applied in steps described in STEAM: identify the problem, identify criteria and constraints, brainstorm possible solutions, generate ideas, explore possibilities, select and approach, build a model or prototype, refine the design or for less formal learning environments it is, and ask-imagine-plan-create-improve (Myers-Spencer & Huss, 2013:43).

Mistakes-Based Learning

Mistakes are extremely unwanted elements in the teaching/learning process; the entire education is based on avoiding mistakes and prescribing punishments for mistakes. This practice is unfortunately rooted in many theoretical insights from traditional psychology in which mistakes were considered an aspect of learning that corrupted knowledge and should be avoided (Ausubel, 1968; Bandura, 1986; Skinner, 1953). However, there is an important aspect of making mistakes that can lead a learning process towards more flexibility,

[1] Hacking: a usually creatively improvised solution to a computer hardware or programming problem or limitation; a clever tip or technique for doing or improving something (Merriam Webster online dictionary)

[2] http://www.bbc.co.uk/programmes/articles/4hVG2Br1W1LKCmw8nSm9WnQ/the-bbc-micro-bit

risk-taking, and depth. Mistakes are probably the very boundary stone (Serbian: *međa*) between knowing and not knowing. They act as indicators of what is not learned or is supposed to be learned in a school context. This is how teaching transforms into a hunt for mistakes, and teachers constantly tend to create a mistake-free environment. This environment has clear authorities, i.e. those who can point out the mistakes made by students—knowledge holders. These authorities are teachers, scientists, textbooks, and other instructional materials, and they rule classrooms, making the story about mistakes a story about power relations as well. What is considered a mistake, who defines those criteria, and who is allowed to make mistakes? These questions bring us to the dominant ideologies in the curricula and the consequent social control (Apple, 2004). On the other hand, the entire history of science is also a history of mistakes, as Popper points out (1962: 25):

> The history of science, like the history of all human ideas, is a history of irresponsible dreams, of obstinacy, and of error. But science is one of the very few human activities—perhaps the only one—in which errors are systematically criticized and fairly often, in time, corrected. This is why we can say that, in science, we often learn from our mistakes, and why we can speak clearly and sensibly about making progress there.

Based on mistakes, theories are proven or rejected, paradigms are shifted, and society transforms. Therefore, what if mistakes, and our way of dealing with them, are instead treated as a lack of knowledge (Prodanović & Krstić 2021) treated as proof of knowledge, flexible mindset, and creativity? Moreover, substantial research evidence shows that mistakes play a role in building confidence, critical thinking, and a flexible, risk-taking mindset (Dweck, 2008; Keith & Frese, 2008; Metcalfe, 2017). As making is what makes us human (Hatch, 2014), so are mistakes; their quality distinguishes us from machines, and the status they hold in a classroom is a very good indicator of classroom freedom. The Makers movement and STEAM are spheres where mistakes are unavoidable. In tinkering and making "failure is something that you just figure out how to work with" (Crawford-Berniskis, 2014: 13) and you will refer to it many times since it is a process *of learning by mistaking* (Martin, 2015). This principle suggests that one does not create and learn *against* mistakes but *with*, *on*, *around*, and *from* mistakes. It shows openness toward the uncertainty about where your learning is taking you. Let us promote learning as a slow and patient (Biesta, 2012), mistake-embracing, iterative journey that is concurrently open-ended and uncertain (Biesta, 2013; Todd, 2016).

CONCLUSIONS AND IMPLICATIONS

More than 13 makerspaces are built mostly in schools in Serbia[3] opening opportunities for bridging STEAM curricula and project-based learning with the Makers movement. These schools are tooled. However, how to make a makerspace a learning space? First, we have to understand our learners, connect the existing curricula and STEAM projects with the community, consider global trends and best practices, develop themes, and order equipment and materials (Kurti et al. b, 2014). Educational makerspaces are based on student ownership of their learning, and it is not necessary to be a technical expert to start a makerspace in your school or library (Kurti et al. a, 2014: 11). The only thing necessary is our orientation toward collaboration, sharing, problem-solving, learning by mistaking, playing, and being capable of seeing everything in a classroom as potential material.

Every educational reform, as a change of familiar routines, faces some similar obstacles. Here, we will outline risks and potential pitfalls that are relatively specific to the transition of the maker movement into formal education, i.e., schools and faculties. By explicating the nature and importance of learning that takes place in the process of creating, this paper aims to overcome one of the challenges for the implementation of the maker movement – the traditional divide between hands-on activities and "mental" educational activities, where the former are regarded as inferior. However, there is still a risk of pure tooling-up (or a risk of a "tool-centric" approach, see Martin, 2015) if teachers lack the competencies to manage the process, the sensitivity to utilize unplanned/unexpected learning opportunities, the skills to support learning in a group/community, the courage to explore something new and unstructured, and the integrity to reflect on the process and identify the needs for improvement. Furthermore, the purchase of high-tech devices should not be considered sufficient or necessary, thus preventing the misinterpretation of the maker movement as appropriate only for schools in wealthy societies. There is also a risk of distributing tools and opportunities for making (and learning) unevenly among students: for example, giving more to excellent students or delegating tasks and activities in line with gender biases. Finally, making and tinkering – similarly to project-based learning – are inconsistent with regular school schedules and might deteriorate in quality when traditional grading is applied (Libow Martinez & Stager, 2013). Although there are some solutions and recommendations (e.g., Libow Martinez & Stager, 2013; Šefer et al., 2012), this could be the point of the biggest transformation of the educational system.

[3] https://mejkerslab.rs/otvoreni-mejkers-labovi/

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CURRICULUM POTENTIALS FOR THE STEM/STEAM APPROACH IN THE FIRST CYCLE OF ELEMENTARY EDUCATION IN SERBIA[1]

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Abstract: Serbia is in the early stages of introducing STE(A)M into the educational system. Although the STE(A)M approach is not clearly emphasized in strategic educational documents, some primary education goals that are complementary to this approach. The Erasmus Plus project STE(A)M in Primary School: *Mission Possible* (2023-2025) is underway in Serbia, Bulgaria, and Slovenia. This paper presents some of the results of this project that focuses on a content analysis carried out on the teaching and learning program for four subjects within the first cycle of primary education: The World Around Us/Nature and Society (Science), Mathematics (Mathematics), Digital World (Technology and Engineering) and Visual Arts (Arts). The project *STE(A)M in Primary School: Mission Possible* aims at targeting the educational standards, learning outcomes, and topics that allow for two or more subjects to be co-integrated and developing brief scenarios for teaching activities. The analysis shows that the knowledge and skills needed in everyday situations (not just in a school context) have the greatest STE(A)M potential based on the defined standards/learning outcomes/topics. Such themes include: Materials (Science), Measurements (Mathematics), Safe Use of Digital Devices, Algorithmic Way of Thinking (Digital World), and Communication (Visual Arts). These potentials are more noticeable in the first and second grades, while they are somewhat less conspicuous in the third and fourth grades. The time mismatch of complementary topics is one of the greater issues in using the STE(A)M approach since it disturbs the effective planning and implementation of STE(A)M activities. Thus, additional efforts are needed to harmonize the teaching and learning programs of STE(A)M subjects, i.e. their learning outcomes, topics, and time compliance, and to provide clearer teaching instructions.

Keywords: STEM, STE(A)M, teaching and learning programs, learning outcomes, topics

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STEM/STEAM EDUCATION IN SERBIA

STEM employs the skills that generally use the left half of a brain and is, thus, logic-driven, while research suggests that art expands the right hemisphere of the brain where creativity and innovation are fostered (Daugherty, 2013). STEM fields are focused on convergent skills, whereas art concentrates on divergent skills. Adding art to the STEM "equation" can further strengthen this concept, making it more accessible to a larger number of students and providing greater opportunities for self-expression (Land, 2013). STEAM education generates an arena for solving problems "outside the box" and thereby fosters innovative thinkers needed in the future (Areljung, 2023), which aligns with the demands of employers who "...prefer the creative employee with technical skills related to the job... Yet, there is a gap between understanding the need for creative employees and putting into place education and training systems that result in creative employees'' (Daugherty, 2013:11).

The integration of STE(A)M (Science, Technology, Engineering, Arts, Mathematics) education into primary schools in Serbia aims to enhance learning through an interdisciplinary approach to problem-solving and to encourage the development of various soft skills in students. These skills include critical thinking, practicality, creativity, innovation, collaboration, a propensity for research (curiosity), project management skills, and teamwork in problem-solving. The need to introduce the STEM approach also stems from the need to introduce STE(A)M education, which is also indicated by the results of international research (TIMSS) and scientific studies that point to conceptual misunderstandings of terms at younger school age that continue at older ages.

One of the goals of primary education in Serbia complements the STE(A)M framework: "Developing key competencies for lifelong learning, developing interdisciplinary competencies for the needs of modern science and technology" (*Rulebook*, 2017). The same document clearly states that teachers should be guided by an integrated approach with horizontal and vertical connectivity within the same subject and different subjects while planning lessons in the first cycle. According to the teachers, STEAM education serves cognitive, academic success, and permanent learning, but it also develops children's peer relationships directly or indirectly. Three themes were identified that are in line with the teachers' opinions: 1) opportunities for collaborative learning with friends, 2) values, and 3) opportunities for skill development (Erol & Erol, 2023).

Teacher education in Serbia is not based on the introduction of the STE(A)M concept. It is predominantly focused on the content of individual sciences and how they can be made understandable to students. The emphasis remains on the content of school subjects, with less emphasis on applying knowledge and reasoning in instruction. However, there are projects and professional development programs aimed at improving the competencies of STE(A)M teachers (for example, projects *Schools for Better Air Quality: Citizen Air Quality Monitoring, STEM Education, and Youth Activism in Serbia*[2], *Supporting STE(A)M Education in Serbia*[3], *professional development programs STEM education in the function of developing key competencies in students* and *STEM activities and challenges*[4]). These programs are supported by the Ministry of Education, the Center for the Promotion of Science, and the European Union. While there are suitable training programs for teachers in the STE(A)M fields, the long-term and systematic effects of these projects and programs are not monitored after their completion.

S. TEMPO PROJECT

The aim of the Erasmus Plus project *STEM/STE(A)M in Primary School: Mission Possible (S.TEMPO)* is to support the introduction of STE(A)M education at the primary education level in Bulgaria, Slovenia, and Serbia. The project partners are three faculties from Bulgaria, Slovenia, and Serbia that educate teachers (Sofia University, Ljubljana University, and Belgrade University) and three publishing houses (Klett Bulgaria – Project coordinator, Rokus Klett, Slovenia, and Klett Belgrade, Serbia).

The project runs from October 2023 to August 2025. The expected results of the project are developed and academically validated. They include the design methodology for STE(A)M /STEM activities, training 45 primary-school teachers (15 per country) to use the methodology, developing 45 STE(A)M / STEM activities, and developing 45 pilot STE(A)M activities in a real classroom environment. All activities will be published online and promoted across primary teachers' communities for further use in their classrooms. The project team will collect preliminary data on the first effects of implementing the methodology and based on it, draft policy recommendations for the future development of STE(A)M in the primary education context.

[2] https://decazavazduh.rs/o-projektu/

[3] https://www.divac.com/Vesti/2983/Kakva-je-buducnost-STEAM-obrazovanja-u-Srbiji.shtml

[4] https://zuov-katalog.rs/?action=page/catalog/all

METHODOLOGY

The goal of the conducted research is to analyze the potential of the curriculum for primary grades in Serbia for the realization of STE(A)M education. Curriculum refers here to educational standards and the teaching and learning programs for the first cycle of primary education in Serbia. A content analysis focusing on the teaching and learning programs for four subjects within the first cycle of primary education was carried out – The World around Us/Nature and Society (Science), Mathematics (Mathematics), Digital World (Technology and Engineering), and Visual Arts (Arts). We searched for the educational standards, learning outcomes, and topics that can connect at least two of the selected school subjects during the same school year. It was used as a basis for creating STE(A)M activities. The validity of the selected learning outcomes and content was checked within the S.TEMPO project by creating the scenarios for STE(A)M activities that will be published in the future.

RESULTS

A graphical representation of STE(A)M school subjects in the first cycle of primary education is shown in *Table 1*:

Table 1. STE(A)M school subjects

	S	T	E	(A)	M
School subjects	World Around Us/ Nature and Society	Digital World (World around Us/ Nature and Society)		Visual Arts	Mathematics
Number of hours per week	2	1		1 or 2	5
Educational Standards (for the end of the First cycle)	Yes	No		No	Yes
Learning Outcomes (for the end of each school year)	Yes	Yes	Yes	Yes	Yes

As a concept of teaching/learning, STE(A)M is not visible in the existing National Educational Standards in Serbia since they are subject-specific. What can be observed is a sporadic potential for connecting the topics across the subjects. We shall present below an example of such educational standards for Mathematics and Nature and Society:

- **Mathematics:** 2.4.2. Students know units of time (second, minute, hour, day, month, and year), can convert larger units into smaller ones, and can compare time intervals in simple/complex situations.
- **Nature and Society**: 1.4.4. Students know units of time measurement: day, week, month, year, decade, and century; 1.4.5. Students can read requested information from clocks and calendars.

The teaching and learning programs for each subject/grade include the learning outcomes. The learning outcomes for the corresponding grade/subject were used to determine possibilities for cross-curriculum integration (possible relation with other subjects) more precisely in a curriculum mapping.

The goals defined for the subject World Around Us (Nature and Society) are to get students acquainted with themselves and their natural and social environment and to develop the ability for them to live responsibly within them. The educational standards for Nature and Society at the end of the first cycle of primary education are grouped into six themes: *Nature –Living and Nonliving*, *Ecology*, *Materials*, *Movement and Space Orientation*, *Society*, and *Serbia and its History (Past)*. The themes in the curriculum for *World Around Us* (*Nature and Society*) are somewhat similarly formulated –*The Self and Others*, *Materials*, *Diversity of Nature*, *Natural and Social Characteristics of Serbia*, *The History of Serbia*, etc. Through the analysis of the educational standards for *Nature and Society*, we found that two of these themes are suitable for planning STE(A)M activities:

1. *Nature – Living and Nonliving* and
2. *Materials*.

The other themes can also be the core content of these activities, but they are somewhat more challenging to implement. Through the analysis of the program for World Around Us (Nature and Society), we also identified the themes that have the highest integrative potential in this context and are, consequently, particularly suitable for STE(A)M activities:

1. *Diversity of Nature*;
2. *Materials*;
3. *Movement in Space and Time*; and
4. *Health and Safety*.

Given that the themes addressed in World Around Us (Nature and Society) are directly connected to students' everyday lives, these themes often form the core around which STE(A)M activities are built in the first cycle of primary education and upbringing.

The goals defined for the subject Digital World are to develop students' digital competence necessary for the safe and proper use of digital devices for learning, communication, collaboration, and algorithmic thinking. As we have already emphasized, there are no educational standards for this subject, so we analyzed the learning outcomes. Across all four grades, the learning outcomes are achieved through three themes: *Digital Society*, *Safe Use of Digital Devices*, and *Development of Algorithmic Thinking*.

Based on the analysis of the content available in the teaching and learning program for the Digital World, we identified topics (from the second and third themes) that are particularly suitable for STE(A)M activities and interdisciplinary integration:

1. *Breaking down Problems into Smaller Units;*
2. *Designing Steps that Lead to the Solution of a Simple Problem;*
3. *Identifying and Correcting Errors in an Algorithm;*
4. *Identifying and Correcting Errors in a Simple Visual Program; and*
5. *Benefits and Risks Arising from Communication via Digital Devices.*

When it comes to algorithmic thinking, teachers should interpret the term *algorithm* as an instruction for solving a problem or carrying out a procedure. Students should be presented with problems to decompose and express their solutions in a series of steps, relying on their existing educational experiences. Among the problems that can be encountered are those that require repeating certain steps several times or consistently.

The primary objective of the subject Mathematics is to enable students to develop fundamental skills in abstract and critical thinking, cultivate a positive attitude towards mathematics, and enhance their proficiency in mathematical communication, both verbally and in writing. This educational process aims to empower students to utilize their mathematical knowledge and skills at higher educational levels and when addressing real-world problems, thereby laying a solid foundation for the continued exploration and understanding of mathematical concepts. The educational standards for Mathematics at the end of the first cycle of primary education are grouped into four themes: *Natural Numbers and Operations with Them*, *Geometry*, *Fractions*, and *Measurement and Measures*. The themes in the Mathematic curriculum are similarly formulated –*Numbers*, *Geometry*, and *Measurement and Measures*. Through the analysis of the educational standards for *Mathematics*, we found that the most suitable themes for planning STE(A)M activities are as follows:

1. *Measurement and*
2. *Geometry.*

Through the analysis of the teaching and learning program for all four grades, we identified the topics that are particularly suitable for STEM/STE(A)M activities:

1. *Geometric Figures, Symmetrical Figures*;
2. *Measuring Length (with Non-standard and Standard Measuring Units)*;
3. *Measuring Area*; and
4. *Measuring Time*.

There is a noticeable dominance of the topics within the theme *Measurement and Measures* since the knowledge and skills acquired are necessary for the activities found in other subjects, i.e. Science, Art, or Digital World.

The goal of the subject of Visual Arts is to encourage students to develop their creative thinking and appreciation of beauty through hands-on activities. This helps them become effective communicators and fosters a deep appreciation for the cultural and artistic heritage of their own and other cultures. As we have already emphasized, there are no educational standards for this subject, so we analyzed the learning outcomes. The learning outcomes, across all four grades, are achieved through the following themes: *Relations in the Visual Field*, *Shaping*, *Composition*, *Materials*, *Communication*, *Heritage*, *Scene*, etc. Based on the analysis of content available in the teaching and learning program for *Visual Arts*, we identified topics that are particularly suitable for STE(A)M activities and interdisciplinary integration:

1. Visual Characteristics of Plants and Animals, Signs, Symbols, Flags...
2. *Properties of Materials;*
3. *Ornament, Symmetry;*
4. *Shapes, Position of Shapes in Space and Plane;*
5. *Transformation;* and
6. *Reading Visual Information.*

Although the course *Visual Arts* provides numerous opportunities for expressing the results achieved through STEM activities, it is also an essential part of STE(A)M activities around which *Science* and/or *Technology and Engineering* and/or *Mathematics* are grouped. It is important to understand that the role of art is not only to serve as a visual representation of achieved results but also to support the creative process of students, respecting the goals of art education in primary school.

DISCUSSION

The curriculums in Serbia are discipline-oriented so there are separate teaching and learning programs for the Serbian Language, Mathematics, World Around Us (Nature and Society), Visual Arts, Digital World, Foreign Language, etc.

School subjects in primary schools that can be used with the STE(A)M approach are: 1) World Around Us (the 1st and the 2nd grade) and Nature and Society (3rd and 4th grade) (Science and Technology and Engineering – less dominant); 2) Digital World (Technology and Engineering); 3) Mathematics (Mathematics) and 4) Visual Arts (Arts). The World Around Us (Nature and Society)is specific compared to other school subjects, as it is interdisciplinary and, hence, has the greatest potential to become the core for creating STE(A)M activities. In other words, the contents of this subject come from various disciplines (biology, physics, chemistry, geography, history, traffic, technology, sociology) that are presented in the everyday life context. Thinking about STE(A)M learning, we had in mind that in primary schools, we should try the "true STE(A)M education (that) should increase students' understanding of how things work and improve their use of technologies" (Bybee, 2010).

Based on the analysis of the teaching and learning programs for the early grades of primary schools in Serbia, the cores that enable the realization of STE(A)M activities can be singled out – STE(A)M topics and STE(A)M skills.

STE(A)M topics:[5]

- **Nature***: Diversity of Nature (1); Visual Characteristics of Plants and Animals, Signs, Symbols, Flags... (3);*
- **Materials***: Materials (1); Properties of Materials; Transformation (3);*
- **Shapes, Figures and their Transformation***: Geometric Figures, Symmetrical Figures (2); Ornament, Symmetry; Shapes, Position of Shapes in Space and Plane; Transformation (3).*

STE(A)M skills (based on the competencies for the 21st century):

- **Problem-solving procedures**: Breaking Down Problems into Smaller Units; Designing Steps that Lead to the Solution of a Simple Problem; Identifying and Correcting Errors in an Algorithm; Identifying and Correcting Errors in a Simple Visual Program (4);
- **Communication**: Benefits and Risks Arising from Communication via Digital Devices (4). Reading Visual Information (3); Health and Safety (1);

[5] (1)World Around Us/Nature and Society; (2) Mathematics; (3) Visual Arts; (4) Digital World

- **Measuring** (as a procedure in science): Measuring Length (with Non-standard and Standard Measuring Units) (2); Measuring Area (2); Measuring Time (2); Movement in Space and Time (1).

These STE(A)M topics/skills are the segments of some of the STEM competencies – scientific concepts, scientific thinking, inquiry practice, information literacy competencies, and attitudes and accountability (Hu & Guo, 2021). The themes related to knowledge and skills applied in real-life problems (McDonald, 2016), not just in a school context, clearly stand out as the ones with the greatest STE(A)M potentials. Such topics include: *Materials* (Science), *Measurements* (Mathematics), *Safe Use of Digital Devices*, *Algorithmic Way of Thinking* (Digital World), and *Communication* (Visual Arts). We believe that the STE(A)M activities based on these topics can promote active learning that engages students in the learning process cognitively and emotionally while taking into account their experience.

These potentials are more noticeable in the first and second grades, while they are somewhat less in the third and fourth grade. Although it would be logical for more STE(A)M activities to occur at older ages (as students then have more knowledge and experience, making the potential for integration greater), the educational standards/teaching and learning programs in Serbia show the opposite. One reason for this discrepancy could be that there is more subject-specific content in the higher grades, i.e. the content belongs to specific sciences and is less related to everyday life skills.

Other factors limit the application of STE(A)M activities. This results from the inadequate time coordination of similar and complementary content across various school subjects. This disrupts the effective planning and execution of STE(A)M activities. For example, finding new uses for objects made of various materials is considered to be one way of demonstrating responsible behavior towards the environment in World Around Us during the second grade. A year earlier (first grade), students explore the possibilities of reshaping damaged objects and materials, discarded items, or packaging in Visual Arts.

CONCLUSION

Serbia is in the early stages of introducing STE(A)M into the educational system to adapt to societal and economic changes. The competencies for lifelong learning (adopted by the European Commission) represent the framework for defining educational standards and learning outcomes in Serbia. Although STE(A)M education is not essentially nor officially an integral part of the educational system in Serbia (which is based on relatively isolated school subjects), this curriculum analysis demonstrates the potential for creating STE(A)M activities in the lower grades of primary schools in Serbia through the subjects such as Mathematics, World Around Us (Nature and Society), Visual Arts and Digital World.

As shown in this paper, there is potential for applying STE(A)M activities with students aged 7–11, but there is no systematic support for integrating STE(A)M disciplines with different school subjects. Consequently, the implementation of these activities in the first cycle of primary education in Serbia is mostly reduced to individual ideas and initiatives. One such opportunity is the project-based teaching/learning approach. It is one of the recommended methods of learning in primary school as emphasized in the programs for teaching and learning various subjects and extracurricular activities. Unfortunately, there is no clear and systematic data on the implementation of this approach or STE(A)M activities in primary schools in Serbia.

Also, the STEM concept is more familiar to teachers in Serbia than the STE(A)M concept. The introduction of art into the field of the sciences has been only sporadically discussed in scientific and professional circles and it has become somewhat more intense in recent years. Only a few scientific papers published in Serbian, individual elective courses in the university programs for teacher education, and a few projects testify to this. Private schools and institutions for informal education promote the STE(A)M approach much more, while the state system, which includes a significantly larger number of children and teachers, needs more support in this regard.

Consequently, we believe that one of the key prerequisites for the wider application of STE(A)M activities is to implement changes in the current university teacher education, i.e. all faculties educating future teachers and the methodologies for teaching individual disciplines included within the STE(A)M concept. In addition, it is necessary to create integrative study subjects that would promote this approach. We believe that this could be one of the most effective ways to introduce STE(A)M education into primary schools, along with further supporting projects and professional development programs for teachers who are already employed.

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META-ANALYSIS OF THE EFFECTS OF THE STEM TEACHING APPROACH ON THE DEVELOPMENT OF 21ST-CENTURY COMPETENCIES RELATED TO LEARNING NATURAL SCIENCES[1]

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Abstract: Since the fast scientific growth has a profound impact on life in the 21st century, this research aimed to explore the effects of STEM teaching on the development of key 21st-century competencies for learning natural sciences. Consequently, four research hypotheses were formulated: the STEM approach promotes the development of creativity (H1), critical thinking (H2), problem-solving (H3), and science-processing skills (H4) to a greater extent than the traditional approach to teaching natural sciences. The validity of the hypotheses was assessed through a meta-analysis. The results of 21 studies that examined the effects of the STEM approach on the development of the above-mentioned competencies among both elementary and high-school pupils were used to calculate the corresponding mean Cohen's *d* value for each of the four hypotheses. The mean Cohen's *d* values for the hypotheses related to creativity and science-processing skills range between +0.500 and +0.800 which indicates a moderate positive effect. The mean Cohen's *d* values for the hypotheses referring to critical thinking and problem-solving skills were higher than +0.800, indicating a strong positive effect of the STEM approach on the development of these competencies in comparison to the traditional teaching approach. Consequently, it can be concluded that all four research hypotheses posed here are confirmed. Furthermore, the findings confirm the considerable potential of the STEM teaching approach to contribute to the development of key 21st-century competencies related to learning natural sciences.

Keywords: STEM approach, 21st-century competencies, learning natural sciences, meta-analysis

INTRODUCTION

Life in the 21st century is characterized by constant rapid changes in our social and professional environments (EURYDICE, 2011). Therefore, the competen-

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cies pupils need to be equipped with to promptly and successively adapt to these changes have been labeled 21st-century competencies (Partnership for 21st Century Learning, 2016). Since many of the above-mentioned changes are induced by fast scientific growth (EURYDICE, 2011), development of the 21st-century competencies such as creativity, critical thinking, problem-solving, and science-processing skills, which are also essential for learning natural science successfully, is of great importance. One of the novel teaching approaches that have the potential to promote the development of these competencies is known as the Science, Technology, Engineering, and Mathematics (STEM) approach (Binkley et al., 2012). This interdisciplinary teaching approach, which combines the knowledge from the four domains, is student-centered; it prioritizes collaboration and the use of active learning methods such as problem-solving and inquiry-based learning to tackle real-life problems; it is intended for all age groups from pre-school to university and, through facilitating the development of several 21st-century competencies, it also contributes greatly to lifelong learning (Bybee, 2010; Stehle & Peters-Burton, 2019).

By prompting pupils to acquire new knowledge through overcoming real-life problems, the STEM approach actively promotes the development of their problem-solving skills (Tan et al., 2023). To become successful problem solvers, pupils must also be equipped with critical thinking skills, which presuppose the ability to pose questions about the problems of vital importance for themselves and their environment, evaluate the credibility of various data sources, collect trustworthy and relevant information, detect cause-effect relationships, and communicate effectively with individuals in their surroundings while looking for ways to resolve these issues (Ennis, 2018). Successful problem-solving is also facilitated by creativity, i.e. the ability to overcome the challenges in our environment through the generation of innovative products (McWilliams, 2009). In the field of natural sciences, creativity is manifested as the ability to organize new experiments and produce novel theories to solve scientific problems (Hu & Adey, 2002). Hence, it is closely associated with the development of pupils' science-processing skills. The STEM approach teaches pupils how to act and think scientifically by encouraging them to observe various changes in their environment actively, formulate hypotheses that attempt to explain the occurrence of these changes, choose and conduct appropriate experiments to test the proposed hypotheses and use obtained experimental findings to conclude about their correctness (Raj & Devi, 2014). Aside from facilitating the acquisition of new scientific knowledge in educational settings, the development of science-processing skills also helps pupils solve daily-life problems in an organized and systematic manner and make responsible and well-taught decisions regarding complex issues that arise in their social environment (Hodosyova et al., 2015).

RESEARCH METHODOLOGY

The Aim of Research and Research Hypotheses

This research aimed to compare the effects of the traditional disciplinary and the STEM interdisciplinary teaching approach on the development of the key 21st-century competencies in learning natural sciences. By this aim, the four research hypotheses were posed stating that the STEM teaching approach is more effective in promoting the development of pupils' creativity (H1), critical thinking (H2), problem-solving (H3), and science-processing skills (H4) than the traditional disciplinary approach to teaching natural sciences. The correctness of the four research hypotheses was assessed with a meta-analysis.

The Principles of Meta-Analysis

A meta-analysis is a quantitative research technique that assesses the correctness of a research hypothesis by using the findings of the experimental studies that have already evaluated the correctness of that hypothesis (Guzzo et al., 1987). Furthermore, to be included in a meta-analysis, the results of one such study need to enable the calculation of the effect size value of Cohen's *d*. Experimental educational studies typically examine whether a novel, i.e. an experimental teaching approach, produces better results than the approach that has been traditionally applied. By calculating Cohen's *d* values, it can be determined whether, and to what extent, an experimental approach is more effective than the standard one in a certain respect (Guzzo et al., 1987; McGough & Faraone, 2009).

The Cohen's *d* value is obtained with the formula (McGough & Faraone, 2009):

$$d = \frac{\overline{Y}e - \overline{Y}c}{S_p}$$

, where $\overline{Y}_e$ represents the mean achievement of pupils from an experimental group, $\overline{Y}_c$ is the mean achievement of pupils from a control group, and S_p represents a pooled standard deviation of the given research sample. The pooled standard deviation is calculated with the formula:

$$S_p = \sqrt{\frac{(n_e - 1) \cdot S_e^2 + (n_c - 1) \cdot S_c^2}{n_e + n_c - 2}}$$

, where n_e represents a number of pupils in an experimental group, n_c is a number of pupils in a control group, S_e represents the standard deviation of the results of the experimental group, and S_c is the standard deviation of the results obtained for the control group.

The mean Cohen's *d* value for a hypothesis is obtained after the Cohen's *d* values for all studies focusing on the correctness of the given research hypothesis are calculated. Ultimately, based on the sign and numerical value of the mean Cohen's *d*, the proposed hypothesis is either confirmed as correct or rejected as incorrect (Guzzo et al., 1987; McGough & Faraone, 2009).

The mean values of Cohen's *d* can be positive or negative. Positive values imply that the experimental approach produces better results than the traditional approach, while negative values prove the opposite. Additionally, based on the numerical values of the positive mean of Cohen's *d*s, it can be determined to what extent a given experimental approach is more effective than the standard one(McGough & Faraone, 2009). The values between 0 and +0.200 indicate that the positive effects of the experimental approach are negligible and that they are likely to remain as such even after a prolonged period of application. The values ranging from +0.200 to +0.500 are considered low. Consequently, the positive effects of the application of the experimental approach are small, but not negligible. Also, they are expected to become more pronounced as the experimental approach is applied over time. The values ranging from +0.500 to +0.800 are labeled as medium. This implies that the positive effects are greater than in the previous instance and that they become apparent more quickly. The values surpassing +0.800 are labeled as strong and they indicate that the experimental approach produces considerably better results than the traditional approach. The effects are easily observable even after a very short period of application. Ultimately, a hypothesis stating that the given experimental approach is more effective than the traditional approach in a certain respect is confirmed as correct if a corresponding mean Cohen's *d* value is higher than +0.200 (McGough & Faraone, 2009). The identical principles of interpretation of the numerical values of Cohen's *d* apply when the obtained mean values of Cohen's *d* are negative. A hypothesis stating that the traditional approach is more effective than the experimental approach in a certain respect would be considered correct when obtained the mean Cohen's *d* values are lower than -0.200.

Literature Search and Data Analysis

The present meta-analysis includes only the research papers published in the English language in peer-reviewed journals between 2013 and 2023. They present the results of the experimental studies that compared the effects of the STEM approach and traditional disciplinary teaching on pupils' creativity, critical thinking, problem-solving, and science-processing skills. To find such papers, the citation databases Web of Science, Scopus, and Google Scholar were utilized. The search terms referred to the development of 21st-century skills (*development of creativity*, *development of critical thinking skills*, *development of problem-solving skills*, and *development of science-processing skills*) and the educational fields (*STEM education* along with *chemistry education*, *physics education*, or *biology education*). 21 research papers were eligible for the present meta-analysis. Following the computation of individual Cohen's *d* values for all the studies included in this meta-analysis, the mean Cohen's *d* values were calculated for each of the four research hypotheses by using the random-effects model in the JASP software for statistical analysis.

RESULTS AND DISCUSSION

An overview of the research papers included in this meta-analysis is provided in *Table 1* with a special emphasis on Cohen's *d* values calculated based on their finding for the H1–H4.

As can be seen in Table 1, this meta-analysis was conducted on the findings of 21 research papers. 16 papers were published after 2020, while the remaining 5 were published between 2013 and 2020. Their findings enabled the calculation of 24 Cohen's *d* values. Seven values refer to the H1 and H2. Five values are relevant for the H3 and H4. Two studies (P1 and P9) obtained the results that enabled the calculation of Cohen's *d* values for two hypotheses (H1 and H3).On the other hand, one paper (P6) enabled the calculation of two Cohen's *d* values regarding the H4 for two different educational levels. Overall, 12 Cohen's *d* values refer to students in elementary schools, 9 to those attending high schools, 2 to students at universities, and 1 to pre-schoolers.

Table 1 further shows that the mean Cohen's *d* values obtained for the correctness of the H1 and the H4 are +0.594 and +0.672, respectively. Both values are positive and they fall within the range labeled as a moderate effect size (between +0.500 and +0.800). This indicates that the STEM approach had a moderately strong positive effect on the pupils' creativity and science-processing skills in comparison to the traditional disciplinary approach to teaching natural sciences. Furthermore, the effects are expected to become more and more apparent if the application of this approach continues. The mean Cohen's *d* values obtained for the H2 and the H3 are +1.059 and +0.880, respectively. Both values are positive and they can be labeled as high effect size values (>+0.800). It can be concluded that the STEM approach had a very strong positive effect on the development of pupils' critical thinking and problem-solving skills. The effect will be easily observable even after a very short period of application.

Table 1: An overview of the research papers included in the meta-analysis

Paper No.	Author(s) of the paper	Publication year	Educational level	*d*(H1)	*d*(H2)	*d*(H3)	*d*(H4)
P1	Çalişici & Benzer	2021	Elementary school	+0.076	/	+0.882	/
P2	Cotabish et al.	2013	Elementary school	/	/	/	+0.479
P3	Dewi & Kuswanto	2023	High school	/	+0.780	/	/
P4	Doğan & Kahraman	2021	High school	+1.528	/	/	/
P5	Eroglu & Bektas	2022	High school	+0.781	/	/	/
P6	Gürsoy et al.	2023	Elementary & High school	/	/	/	+0.772; +0.814
P7	Hacioglu & Gulhan	2021	Elementary school	/	+0.470	/	/
P8	Hayuana et al.	2023	University	/	/	+0.870	/
P9	Hebebci & Usta	2022	Elementary school	+0.091	/	+0.920	/
P10	Majeed et al.	2021	Elementary school	+0.685	/	/	/
P11	Mater et al.	2022	Elementary school	/	+1.750	/	/
P12	Noufal	2022	High school	/	+0.435	/	/
P13	Parno et al.	2021	High school	/	+0.757	/	/
P14	Preca et al.	2023	High school	+0.355	/	/	/
P15	Retnowati et al.	2020	High school	/	+1.440	/	/
P16	Şahin	2021	Pre-school	/	/	+0.956	/
P17	Sari et al.	2020	University	/	/	/	+0.700
P18	Siregar et al.	2019	Elementary school	/	+0.720	/	/
P19	Strong	2013	Elementary school	/	/	/	+0.597
P20	Yesildag-Hasancebi et al.	2021	High school	+0.645	/	/	/
P21	Zengin et al.	2022	Elementary school	/	/	+0.774	/
The mean value of Cohen's *d* for each hypothesis				**+0.594**	**+1.059**	**+0.880**	**+0.672**

Following the calculation of a mean Cohen's *d* value for a certain hypothesis within a meta-analysis, it is customary to compare this value with those obtained by other meta-analyses that have addressed the same hypothesis. Given that the STEM approach has been applied in teaching science around the world for only 15 – 20 years, experimental studies and, consequently, meta-analyses regarding the effects of its implementation on the development of the 21st-century competencies are still scarce. Thus, the literature review produced no prior meta-analysis examining the effects of the STEM approach on the development of pupils' creativity, problem-solving, and science-processing skills. Only one previously conducted meta-analysis was found regarding the effects of this approach on the development of pupils' critical thinking. Putra et al. (2023) included 13 research papers published between 2015 and 2021. None of them is included in this meta-analysis since all of them were published in Indonesia in their authors' native language. This meta-analysis is, however, available in the English language. When it comes to the effectiveness of the STEM approach in developing pupils' critical thinking, the study reports the mean Cohen's *d* value of +0.880. This value is lower than the mean value of +1.059 obtained for the H2 in this study, but it still falls into the range of strong effect size values (>+0.800). This provides further confirmation that the STEM approach, compared to the traditional disciplinary teaching of natural sciences, has a considerably stronger positive effect on the development of pupils' critical thinking and that the effect is easily observable even after a relatively short period of application.

CONCLUSION

To examine the effectiveness of the STEM interdisciplinary teaching approach in teaching natural sciences in terms of the development of the key 21st-century competencies, the present study tested four research hypotheses stating that this approach promotes the development of creativity (H1), critical thinking (H2), problem-solving (H3), and science-processing skills (H4) to a greater extent than the traditional disciplinary teaching. The correctness of the hypotheses was assessed with a meta-analysis. 24 Cohen's *d* effect size values were calculated based on the results of the prior experimental studies focusing on the correctness of the given hypotheses. Since the mean Cohen's *d* values obtained for each hypothesis are positive and higher than +0.200, it can be concluded that all four hypotheses are correct. Furthermore, the mean Cohen's *d* values obtained for the H2 and the H3 are within the range of high effect size values (>+0.800). This indicates that the STEM approach promotes the development of critical thinking and problem-solving skills to a considerably greater extent than traditional disciplinary teaching. The effects are easily observable even after a very short period of application. Regarding the H1 and the H4, the mean Cohen's *d* values can be considered medium effect size values (between +0.500 and +0.800). This implies that while the positive effects of the STEM approach on the development of creativity and science-processing skills are not as strong as in the case of the H2 and the H3, they are still far from negligible and will become more and more pronounced as the approach is applied over time.

Given the relative novelty of the STEM teaching approach, the previous research about its effects on the development of the key 21st-century competencies in learning natural sciences is expectedly scarce. Thus, most of the research papers used in this meta-analysis have been published within the last four years. Despite these shortcomings, the mean Cohen's *d* values obtained for the four research hypotheses undeniably indicate that the STEM approach has a far greater potential to contribute to the development of pupils' creativity, critical thinking, problem-solving, and science-processing skills than the traditional disciplinary approach. Disciplinary teaching is dominant in schools throughout Serbia, and this can be linked to the low levels of students' scientific literacy (Putica & Ralević 2022). Consequently, more frequent application of the STEM approach is expected to positively contribute to the development of pupils' 21st-century competencies which are essential for learning natural sciences and the improvement of their scientific literacy.

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THE IMPORTANCE OF EARLY DIGITAL LITERACY OF PRESCHOOL CHILDREN THROUGH THE INTEGRATION OF THE STEAM APPROACH

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Abstract: This paper explores the integration of digital literacy into preschool education through the STEAM approach, focusing on practical examples and the challenges faced by educators and parents. It examines the implementation of digital education programs in preschool settings, emphasizing the importance of interactive and creative methods to develop digital skills in young children. A key example from Leskovac illustrates how digital literacy can be effectively introduced through play in a preparatory preschool group, showing the potential of STEAM to enhance early childhood development. The paper highlights the significance of teacher training and interdisciplinary approaches to successfully incorporate digital literacy into preschool curricula. The conclusion stresses the importance of preparing children for the digital world by fostering early digital competencies and setting a foundation for their future learning.

Keywords: STEAM, preschool education, early childhood development, digital skills, interactive learning

INTRODUCTION

Modern educational systems are subject to continuous changes and improvements to meet the challenges and demands of contemporary society. One of the most innovative approaches in education that is gaining increasing attention is STEAM (Science, Technology, Engineering, Mathematics + Arts) or STREAM (Science, Technology, Reading, Engineering, Mathematics + Arts). The introduction of STEAM into preschool education represents a significant step towards developing critical thinking, creativity, and problem-solving skills in young learners.

The goal of this literature review is to examine the opportunities and challenges of digital literacy in preschool children through examples of good practice and the integration of STEAM principles. Special attention is given to the importance of early digital skills development and strategies parents and educators can apply to prepare children for the challenges of the digital age.

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The analysis of challenges in digital literacy highlights issues such as internet security, screen time control, and access to quality digital content. This paper discusses strategies to overcome these challenges, including educational programs for parents and educators. Approaches to digital literacy in preschool institutions consider pedagogical methods and strategies that these institutions can implement, including the use of specialized Web 2.0 tools and digital didactic games adapted to the preschool age.

STEAM EDUCATION AND DIGITAL LITERACY FOR PRESCHOOL CHILDREN

Digital literacy, as defined by UNESCO (2018), encompasses the ability to use digital tools effectively, critically, and safely. In the context of preschool education, this definition extends to age-appropriate interaction with digital technologies for cognitive and socio-emotional development.

The use of STEAM technology in early childhood education offers a unique opportunity to enhance the formation of lexical skills in preschool children. By incorporating interactive and engaging digital tools, educators can create a dynamic learning environment that stimulates language acquisition and vocabulary growth (Yunusova, 2024).

Digital literacy encompasses the capacity to proficiently and critically access, assess, and produce information via various digital tools and technologies. It goes beyond simply knowing how to use devices and software; it encompasses the skills needed to engage with digital content, understand its implications, and use technology responsibly. In the context of early childhood education, digital literacy includes foundational skills such as using digital tools for communication, problem-solving, and creativity. If digital literacy is fostered from a young age, children can develop the skills necessary to thrive in an increasingly digital world.

STREAM education, which encompasses Science, Technology, Reading and Writing, Engineering, Arts, and Mathematics, represents an extension of traditional STEM education by incorporating arts as a key element. This extension enables a holistic approach to education, combining creative and analytical skills. In support of this, digital literacy becomes essential, particularly for preschool children who are already exposed to digital technologies in their everyday lives.

Collaborative STEAM projects promote communication skills and social interaction among preschoolers. Working together on tasks that require verbal exchanges, explanations, and discussions can support the development of vocabulary, language fluency, and interpersonal skills in young learners (Yunusova, 2024).

Recent research indicates that moderate use of digital technology can positively affect children's development, while negative consequences can result from excessive use or, conversely, from no contact with digital technologies at all (UNICEF, 2019).

The STEAM approach integrates disciplines to create engaging educational experiences, such as LEGO construction, robotics, and mathematical development, tailored to preschoolers' cognitive abilities (Kyyakbayeva et al., 2024).

One of the key ways STEAM education can be linked to digital literacy is through the integration of technology into play and learning. Using digital tools and resources can significantly enrich educational activities. For example, children can use tablet computers to draw and design simple projects, which fosters their creativity (arts) while simultaneously teaching them basic digital skills (technology).

STEAM includes the Arts with other STEM domains, recognizing that creativity and the arts are key elements of learning and pivotal to innovation. This integration offers children opportunities for individual expression and diverse communication, making STEM experiences more socially and culturally relevant (Johnston, Kervin, & Wyeth, 2022).

STEAM education promotes the development of critical thinking and problem-solving skills, which are crucial for digital literacy. Through activities that involve exploration and experimentation, children learn how to approach problems systematically, using technology to gather data, analyze it, and present results. For instance, children can use digital microscopes to explore biological samples, combining science, technology, and arts through the visualization and interpretation of data.

STEM and STEAM approaches in early childhood support inquiry and problem-solving, offering children opportunities to explore the world through systematic, authentic investigations that integrate design thinking and scientific processes (Johnston, Kervin, & Wyeth, 2022).

THE IMPORTANCE OF DIGITAL LITERACY IN PRESCHOOL AGE

Digital literacy prepares children for future educational challenges by promoting logical and systematic thinking and enhancing their competitiveness in the modern world (Purnamasari et al., 2020).

Digital literacy encompasses the ability to understand, use, and create digital content. In preschool, this means developing basic skills such as using digital devices, navigating simple apps, and fostering critical thinking in the context of digital media. Early exposure to technology can significantly influence later educational outcomes and prepare children for the modern digital world.

Digital literacy in the educational context plays a crucial role in developing a child's cognitive abilities by stimulating curiosity and creativity. It includes the ability to use digital tools to find, evaluate, utilize, create, and communicate content effectively (Hafizzaturroyani et al., 2024).

Digital technologies in learning allow children to satisfy their needs for exploration. Digital tools are employed in direct work with children to deepen their experiences, encourage richer play and interaction with others, stimulate their imagination, and contribute to the development of various forms of expression. In an environment where ICT is widely used, children are additionally motivated to collaborate in play, experiment with and combine different tools, exchange ideas, and enjoy joint activities, while making personal contributions.

The use of digital technology can also be seen as a social activity and a way to support children's learning. The equipment, located in a specific area and available to children throughout the day, allows them to search for answers together with their peers, find various solutions, and gain ideas for further research or project development.

Author Bolstad (2004) believes that the literature suggests at least three reasons why information and communication technologies (ICT) are important in the education of preschool children. First, ICT already affects the people and the environment in which children learn. Second, these technologies offer new opportunities to enhance many aspects of early childhood practice. Third, there is support and interest from the entire education sector for the development and integration of ICT in education policy. When used appropriately, ICT can be a valuable tool to support the learning and development of preschool children (Bolstad, 2004).

CHALLENGES AND LIMITATIONS IN THE USE OF DIGITAL MEDIA IN PRESCHOOL EDUCATION

The integration of digital media in preschool education, while promising, faces significant challenges and limitations, particularly in the context of implementing STEM (Science, Technology, Engineering, and Mathematics). One primary challenge is to ensure that digital tools are developmentally appropriate for young learners, as excessive screen time or poorly designed applications can hinder rather than help cognitive and social development.

Although the process of STEM education is dynamic, preschool educators find it difficult to innovate ways to integrate STEAM (Science, Technology, Engineering, Arts, and Mathematics) content and pedagogical methods into school-based curricula. The role of preschool educators is evolving from delivering knowledge through a teacher-centered approach to nurturing STEM-related learning in children. However, many kindergarten teachers lack sufficient professional training in STEAM teaching methods, resulting in weak teaching skills and poor understanding of STEAM education concepts (Leung, 2023).

STEAM learning activities often face challenges such as the lack of teacher training and appropriate guidebooks. Teachers must transition from teacher-centered to child-centered methodologies, which demand the integration of STEAM components with real-world projects suitable for children's developmental stages (Hafizzaturroyani et al., 2024).

Further research is needed to understand the professional learning needs of early childhood educators in implementing STEAM learning, as well as to refine assessment techniques that can accurately capture the development of early childhood literacy through STEAM (Karta & Rasmini, 2022).

Digital technologies can assist in overcoming various deficits and obstacles that parents alone cannot address to provide optimal developmental conditions for their children. It has become common for children to use the Internet, leading parents to try to increase opportunities for their children's advancement by using digital resources, while simultaneously considering the associated risks (Livingstone et al., 2017).

The STEAM learning model, supported by parental involvement, has been found to increase children's creativity and motivation, promoting an environment that encourages collaboration, critical thinking, and problem-solving (Karta & Rasmini, 2022).

Preschool children are particularly vulnerable to online dangers, including exposure to inappropriate content. Therefore, it is crucial for parents and educators to be well-informed and trained to protect children and guide them toward safe internet use (Livingstone et al., 2017).

ACCESS TO QUALITY DIGITAL CONTENT

The integration of STEAM (Science, Technology, Engineering, Arts, and Mathematics) education in preschools heavily relies on access to quality digital content, which can significantly enhance learning experiences and outcomes. High-quality digital content provides interactive and engaging ways for young learners to explore STEAM concepts, fostering creativity, critical thinking, and problem-solving skills.

Project-based learning within the STEAM model has been shown to effectively increase children's learning activities and outcomes, as it fosters involvement in multiple scientific disciplines and encourages the exploration of problems from various perspectives (Karta & Rasmini, 2022).

When selecting digital content for preschoolers, it is essential to consider its educational value and age-appropriateness. The content should support the specific developmental needs of children, offering relevant and appropriate information in a linguistically and cognitively comprehensible way. Additionally, the content must be interactive and engaging, encouraging active participation and exploration, while also ensuring the safety and quality of the information children consume.

Educators must be equipped with the necessary training and support to effectively integrate digital tools into their STEAM curricula. Bridging the gap in access to quality digital content is essential for maximizing the benefits of STEAM education and ensuring all children have the opportunity to develop essential skills for the future.

STRATEGIES FOR OVERCOMING CHALLENGES

Strategies for overcoming challenges in integrating digital media into preschool education are reflected in the development of educational programs, seminars, forums, and workshops that empower and educate parents and educators. These programs should cover a wide range of topics, starting with Internet security. Through these initiatives, parents and educators can learn how to protect children from online threats, recognize potential dangers, and take appropriate protective measures.

In addition, educational programs should encourage the selection of quality digital content that is adapted to the age and developmental needs of children. Through programs like these, adults can become more competent in guiding children through the digital world, providing them with a safe and stimulating environment for learning and exploration. This is not only a matter of technological literacy but also of responsible parenting and a pedagogical approach that will allow children to make the most of the advantages of the digital era with minimal risks and negative impacts.

One significant challenge is the need for developmentally appropriate, engaging content that can hold the attention of preschoolers while introducing complex concepts. To address this, educators can employ hands-on, interactive activities that blend digital tools with physical manipulatives, making abstract ideas more tangible. Additionally, providing teachers with robust professional development opportunities is crucial, ensuring they are well-equipped to incorporate STEAM principles effectively into their classrooms.

Research indicates that early childhood educators often lack confidence and skills in STEM domains, impacting curriculum implementation. Professional development is essential to empower educators and enhance their ability to integrate STEAM approaches effectively (Johnston, Kervin, & Wyeth, 2022).

Digital tools, such as educational software and didactic games, can enrich existing learning resources. The virtual world of computer games in which preschool children grow up is often perceived as the opposite of the traditional world of growing up through play (Marsh, 2010). However, computer games as new media have become a desirable tool in the learning process of preschool children.

Web 2.0 tools are a group of social programming tools in which users create content themselves, support collaborative learning, facilitate communication, collaboration, and evaluation, and can be used as a supplement to classical teaching and all forms of extracurricular activities (ZUOV, 2014).

Web 2.0 tools that educators can use in their daily work include:

- **Social networks as an information panel for educators**: Google, Gmail, Facebook, Instagram.
- **Tools for collaboration and sharing**: Viber, YouTube, Symbaloo, Zoom, Google Classroom, Google Docs, Pinterest, Padlet, Lino-it, WordPress, Blogger.
- **Tools for presentations, creating and editing photos, video, and audio content:** Animoto, Prezi, CapCut, PowerPoint.
- **Tools for creating digital didactic games**: Jigsaw Planet, LearningApps, WordWall, Story Bird, and Story Jumper (Krstić Radojković, 2023).

Digital technologies, such as computers and tablets, complement traditional tools in children's play, allowing for a combination of imaginary and non-digital technologies that help develop knowledge and skills about digital concepts (Johnston, Kervin, & Wyeth, 2022).

EARLY DIGITAL LITERACY OF PRESCHOOL CHILDREN THROUGH THE STEAM APPROACH – AN EXAMPLE FROM PRACTICE

The project *Computer and I*, implemented in the preparatory preschool group at PU Vukica Mitrović in Leskovac, aimed to introduce digital technologies to children at an early age. The project successfully integrated STEAM principles through interactive activities that enabled children to explore science, technology, reading and writing, engineering, art, and mathematics, thereby developing digital skills and creativity.

The project began by examining how children use computers and other digital devices, which served as a starting point for further activities. Through the creation of panels, interactive presentations, and quizzes, children explored the history of communication, from message transmission via *messengers* to modern technologies. Learning was supported by collaboration with the computer science teacher and parents, who brought old devices such as gramophones, typewriters, and tape recorders, allowing the children to compare old and new technologies.

The practical part of the activities included working on computers, where the children, with the help of school-aged peers, learned to draw in Paint, use Google, write in Word, and print their work. The children acquired digital skills engagingly and interactively. Although they initially wanted to play games, they were encouraged to create educational games using Web 2.0 tools. Through the WordWall program, they learned to create digital didactic games, add images, and change templates. Using the LearningApps tool, they created a dictionary, and with the help of JigSawPlanet, they made puzzles with their pictures and shared them with their parents via a Viber group. These activities allowed them to have fun and learn, even when they were at home.

They regularly visited the IT classroom where, through play, they learned about spatial relations, shapes, occupations, traffic, animals, and nature. By setting up an "office" within the kindergarten, the children applied their acquired knowledge through various roles and simulations of real professions. With the support of older school-aged children, they mastered PowerPoint and prepared a presentation for parents for the end of the school year.

This project is an example of good practice in integrating digital technologies into early education, encouraging creativity, exploration, peer learning, and collaboration among children, thus exemplifying the successful implementation of STEAM principles.

CONCLUSION

Interdisciplinary projects within the STEAM framework can provide children with the opportunity to develop digital skills in the context of solving real problems. In the modern educational context, where technological innovations dictate the dynamics of learning, research on the importance of early digital literacy in preschool opens new avenues for exploring how digital literacy can be integrated into curricula.

Early acquisition of digital skills enables children to develop the necessary competencies that will benefit them in the future. Through creative and interactive approaches, preschools can significantly contribute to children's digital literacy, ensuring they are ready for the challenges and opportunities of the digital age that the STEAM framework provides.

Interdisciplinary projects based on the STEAM approach offer children the opportunity to develop essential digital skills through play and exploration. Projects such as *Computer and I* demonstrate that the use of digital tools in education can significantly contribute to the development of creativity, collaboration, and critical thinking in children, enabling them to face future educational challenges with greater ease.

These experiences helped them approach new learning challenges more easily and with greater confidence. Becoming familiar with programs such as Paint, Word, Google, YouTube, Google Maps, WordWall, LearningApps, JigSawPlanet, and PowerPoint enabled them to actively participate in the educational process and master school material interestingly and interactively. They also showed exceptionally advanced digital competencies in Digital World in the first grade.

Through interactive methods and age-appropriate content, educators can shape positive learning experiences that motivate children for further development. It is essential to continue research on the significance of digital literacy in early childhood to ensure equal opportunities for all children in the dynamic world of the future.

Educators should prioritize structured STEAM activities that combine digital tools with hands-on learning to foster creativity, critical thinking, and problem-solving skills in preschool children. Professional development programs are essential to equip teachers with the necessary skills for effective implementation. Parents should be involved in the digital education process through workshops and collaborative activities to create a consistent learning environment at home and in preschool settings. Community initiatives can bridge gaps in digital literacy resources and foster collective engagement. Future studies should focus on the longitudinal impacts of early digital literacy interventions, particularly how STEAM methodologies influence children's academic and socio-emotional development in later stages of education.

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TEACHING HISTORY WITH THE AID OF EDUCATIONAL ROBOTICS

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Abstract: S.T.E.M. (Science, Technology, Engineering, and Math) describes a curriculum that combines science, technology, engineering, and math with theoretical knowledge through real-life practice. This paper focuses on promoting educational robotics in primary and secondary education due to its pedagogical benefits. The activity designed here was invented to teach history to students in primary and secondary schools. The paper aims to engage students in creating historical timelines based on their school curricula, and the robots they are to construct with the aid of their teachers use the same timelines as guides. The robot is then programmed to follow a black line (i.e. a timeline) until it finds a marker with a historical date based on its distance sensor. The robot then stops moving and the robot plays the historical narration recorded by the pupils. With this exercise, students can be divided into groups. They can build robots with materials, motors, and sensors with the Lego Education Spike Prime pedagogical package. They can record all the historical facts about a certain period. The period we used as a case study is the "Great Revolution" (1821–1830) presented in Appendix C of their sixth-grade textbook. The Spike Prime software was selected for these purposes.

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The impressions of the students and teachers who participated in the project are very positive. It was a fun and easy way for the students to learn about the topics presented in their textbook. They could also gain a better understanding of the historical facts that they had recorded. Other positive features of this assignment include the ease of adapting the timelines to different primary and secondary school lessons.

Keywords: Educational Robotics, STEM, STEAM, robotics, history, school

INTRODUCTION

The term S.T.E.M. [Science, Technology, Engineering, and Mathematics] stands for a curriculum combining science, technology, engineering, and mathematics with theoretical knowledge through real-life practice. Recently, the letter "A – Arts" has been added to the acronym S.T.E.M., creating S.T.E.A.M.

S.T.E.A.M. programs aim to cultivate students' critical thinking and develop their skills for solving various problems. Through hands-on learning, children learn about the disciplines that make up S.T.E.A.M. in a different and fun way, unlike traditional learning.

S.T.E.A.M. education is inextricably linked to educational robotics. Students become builders of their robots using building materials, motors, and sensors. In addition to learning how to build robots, students also learn to program them by giving them motion through special software. Hence, they also enter the world of computing.

Lego Education is considered the father of educational robotics as it has contributed greatly to its popularity by creating many educational packages for all ages. At the same time, it has also created many well-known educational platforms. Until recently, Mindstorms EV3 was the most widely used educational robotics education package for students aged 10–17 while Wedo 2.0 is the most popular for the ages 5–8. A new educational package called Spike Prime was created in January 2020 to expand students' options. Its software has almost nothing to do with the existing ones and the programming can be implemented in 3 different ways (Icon blocks, Word blocks, Python).

The objective of the project is for sixth-grade students to create a robotic construction that can move autonomously on a "timeline." In addition, a robot can be used to teach historical events of the modern world. Here we shall focus on the Great Revolution in Greece (1821–1830), which is presented in section C of the history textbook.

METHODOLOGY

First, a suitable educational robotics package had to be selected. There are two educational packages appropriate for the given age: Mindstorms EV3 and Spike Prime. The methodology for the implementation is presented in *Figure 1*. Although it is a new educational package, Spike Prime has been introduced in many primary and secondary schools. Hence, this specific educational robotics package was selected.

The historical content was taken from the sixth-grade history textbook, i.e. section C entitled "The Great Revolution in Greece (1821 – 1830)."

A significant effort was made not to make the robot and the programming code too difficult and demanding, so that all students, even those who have never been involved with educational robotics before, can create them.

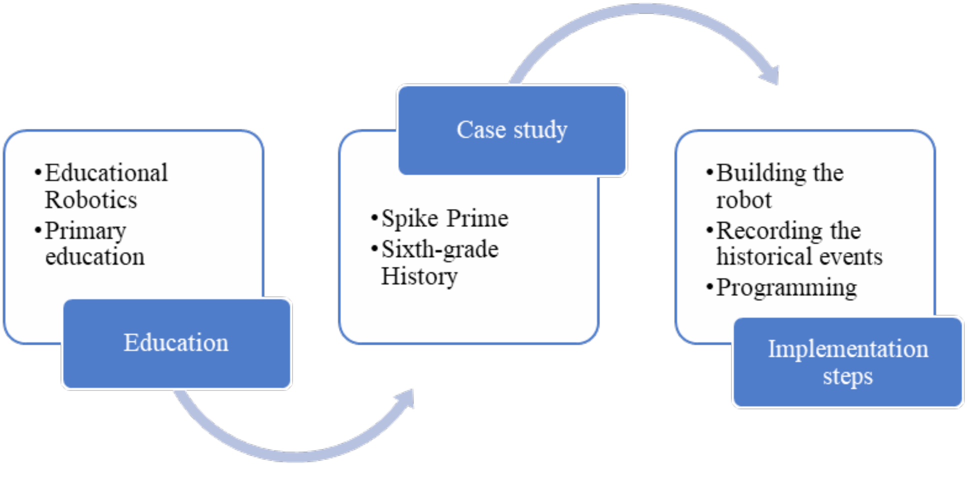


Figure 1: Implementation methodology

Benefits of this approach

Through experiential learning of history via educational robotics, students can gain significant benefits in educational robotics and in a history lesson.

- Benefits of educational robotics include:

1. the development of social skills (teamwork and cooperation, self-confidence, diminishing the feeling of failure, etc.), and
2. the development of technological skills (computational thinking, programming, creativity, etc.).

- Benefits for the history lesson:

1. Students are not mere readers, but rather narrators. This promotes meaningful learning rather than mere memorization.
2. The teaching changes from formal to playful learning, providing students with the interest that such an important course requires.
3. It allows students with learning difficulties (e.g. dyslexia) to follow the lesson with more ease and enjoyment.

Proposed Teaching Course

Students have to follow specific steps to be able to implement their project:

1. create groups (2–4 people),
2. construct a robot (e.g. Driving Base) within Spike Prime Software,
3. record the narration on the historical events via Spike Prime Software,
4. program a robot to move on the black line,
5. unify the historical events by creating the final historical timeline, and
6. execute the program.

Practical Part

Creating robots

Figure 1 shows all the steps that each team has to follow to build their robot using Spike Prime Software.

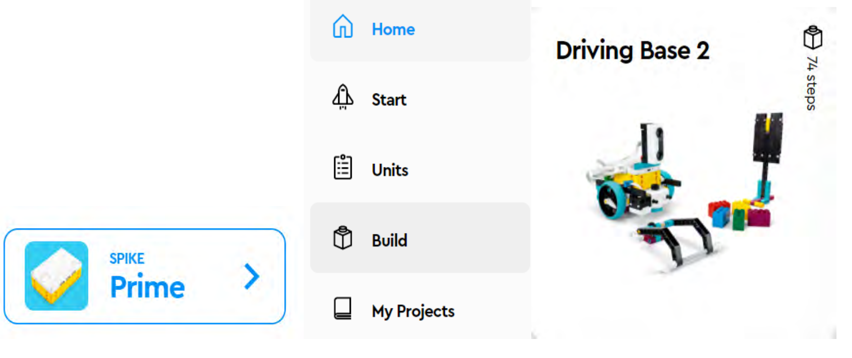


Figure 2: Robot construction implementation steps

Recording the historical events

The detailed steps for students to begin programming by recording the historical events are presented below:

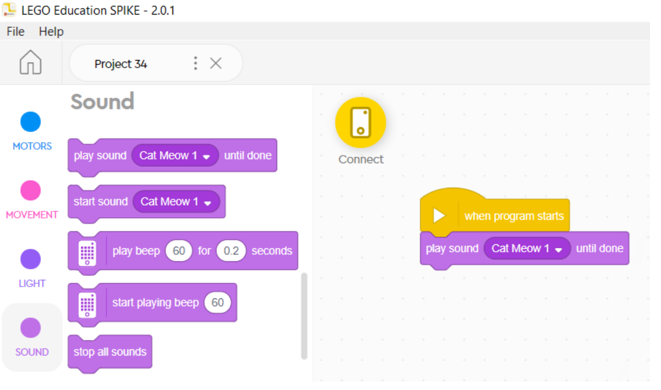


Figure 3: Insert audio block

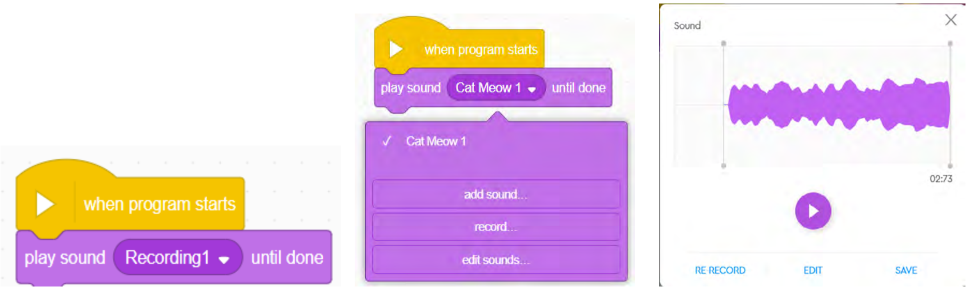


Figure 4: Recording steps

Spike Prime has no limitations on the number of audio recordings; instead, the only limitation is that the recording time cannot exceed 9 seconds.

Line Follower Programming

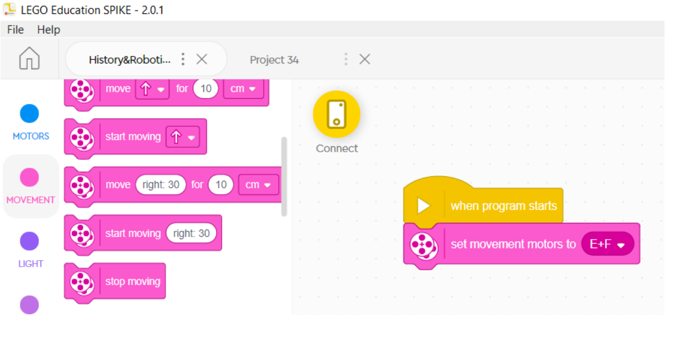


Figure 5: Declaration of engines

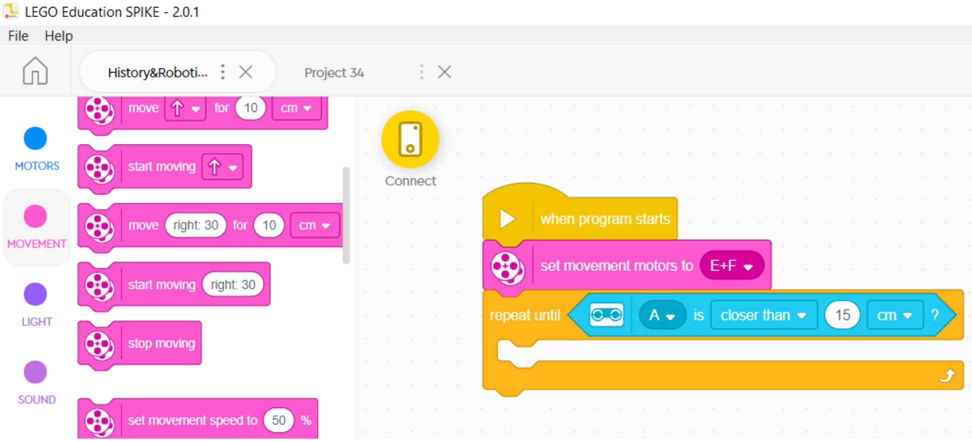


Figure 6: Repeated code segment until the "distance" sensor detects an object at a distance of less than 15cm

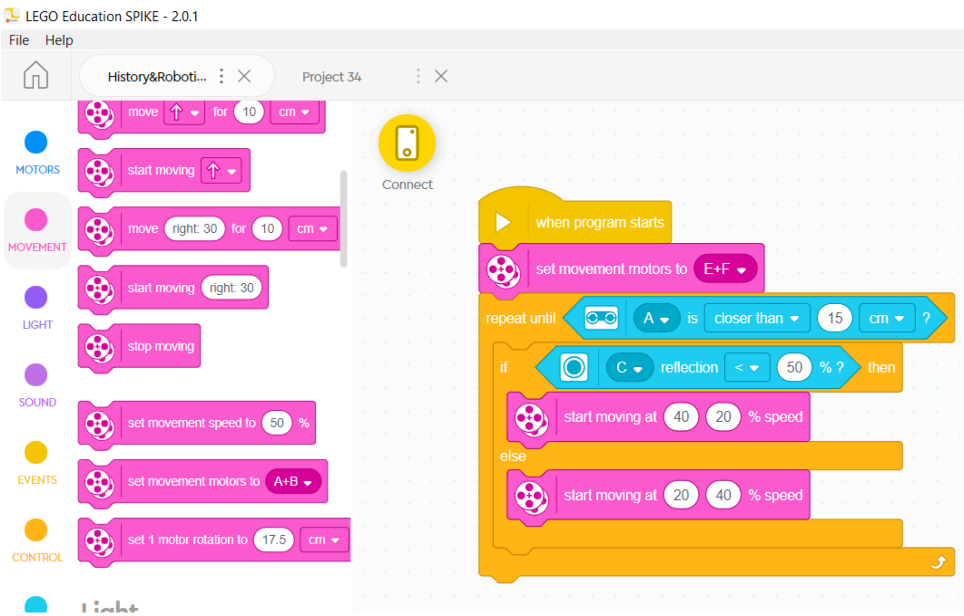


Figure 7: Advanced selection structure

When the light sensor reflection drops below 50% (i.e. detects black color), the left motor has a speed of 40%, and the right motor has a speed of 20%. When the light sensor reflection rises above 50% (i.e. detects white color), the right motor has a speed of 40%, and the left motor has a speed of 20% to get back on the black line.

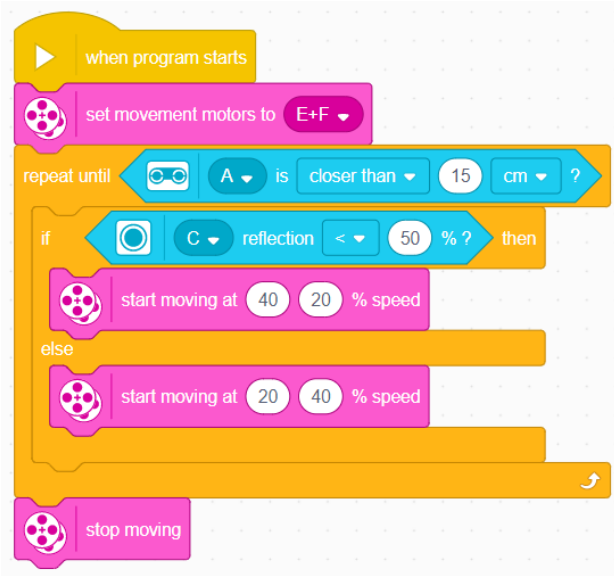


Figure 8: Motor stop / Final programming code

Indicative worksheets per chapter

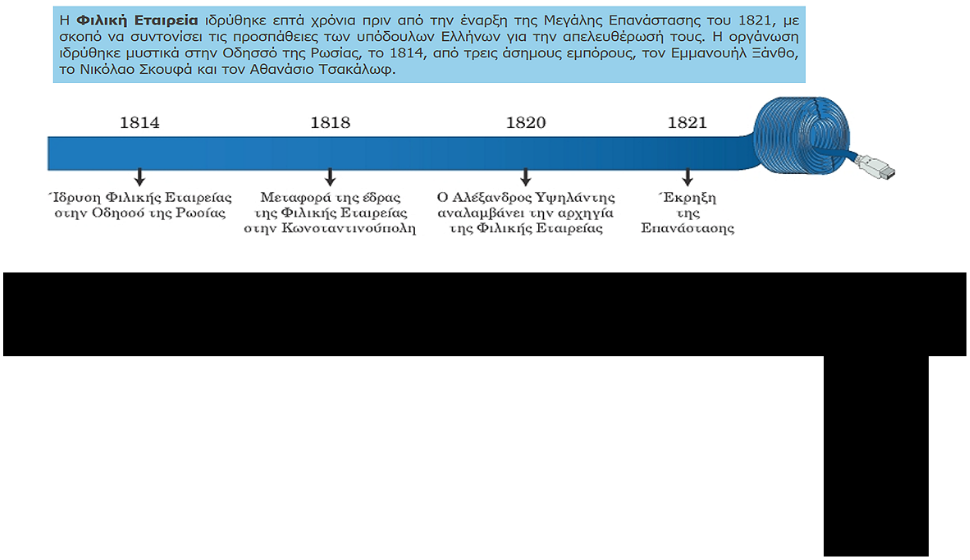
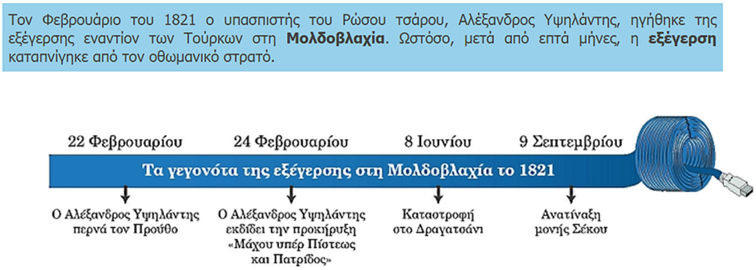
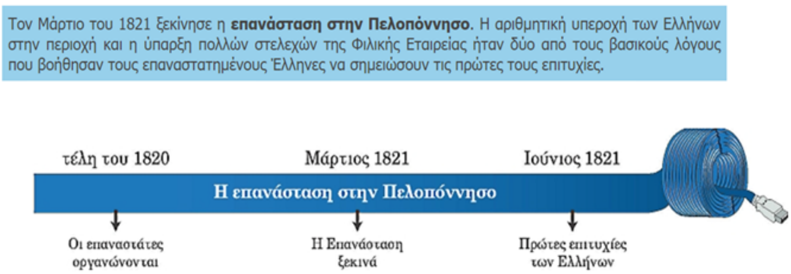


Figure 9: "Filiki Eteria" (Chapter 1)



[redacted]

Figure 10: "The Moldovan Uprising" (Chapter 2)



[redacted]

Figure 11: "The Revolution in the Peloponnese" (Chapter 3)

The main innovation is that by printing and aligning the black lines on an A4 piece of paper, we can create complex timelines that a robot can follow. At each arrow/cross, the robot stops and plays the recording on the specific historical event.

CONCLUSIONS

The combination of educational robotics with the sixth-grade history lesson allows students to learn about the magical world of educational robotics and its benefits, experiment by building a robotic vehicle, and program it. It also helps them learn the content found in the textbook chapters in an easy and fun way and have a better understanding of the presented historical events. Students cease to be mere receivers in the transmission of knowledge, just as teachers are no longer mere transmitters. Teachers have an opportunity to create timelines for different subjects by simply printing A4 pieces of paper and adapting the procedures to their own needs.

The aim of the project is to combine educational robotics with all basic subjects in primary and secondary education and gradually integrate it into schools as a basic skills course. Through robotics, students can deepen their understanding of the material, fill the gaps through experiential learning, and at the same time, get acquainted with educational robotics and its benefits. Also, with the appropriate educational material, students with learning difficulties can follow each lesson more easily through an experiential approach.

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SOME REFLECTIONS ON STEAM EPISTEMIOLOGIES: SYNKRASIS, MIXIS OR SYNTHESIS?

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Abstract: The introduction focuses on the ancient Greek concepts of *synkrasis* and *mixis*, linking them to modern interdisciplinary frameworks and STEAM education methodologies. It emphasizes the importance of evaluating the integration quality among STEAM subjects, highlighting a tendency among educators to oversimplify these relationships. The historical emergence of disciplines in the 19th century and their implications for knowledge production is discussed, noting critiques of rigid boundaries that limit inquiry. Interdisciplinarity, while a contemporary focus, has roots in ancient understandings, yet it now often struggles against the fragmentation of knowledge. The distinctions between interdisciplinary, multidisciplinary, and transdisciplinary approaches are clarified, with transdisciplinarity positioned as a more collaborative and integrative method that transcends traditional boundaries. Transdisciplinarity is identified as a vital research principle that fosters holistic integration, essential for addressing complex global challenges. It contrasts with temporary interdisciplinary collaborations by advocating for sustained change in scientific inquiry structures. The conclusion underscores the need for a nuanced understanding of disciplines and their historical context, advocating for a revival of coherent disciplinary concepts within transdisciplinary frameworks.

Keywords: interdisciplinarity, transdisciplinarity, synkrasis, mixis, STEAM.

INTRODUCTION

In initiating this discussion on a complex subject, we will first examine the ancient Greek concepts of *synkrasis* and *mixis*, before linking these ideas to contemporary frameworks of interdisciplinarity. This connection will subsequently inform our exploration of STEAM education methodologies. A critical aspect of this inquiry involves assessing the quality of integration among the diverse subjects within the STEAM paradigm, both in practical implementation and epistemological coherence.

To provide a context, the ancient Greeks offered valuable insights into the relationship between parts and wholes, which can illuminate the complexities

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modern science introduces. Galen, along with pre-Socratic thinkers, articulated the interconnectedness of elements as constitutive of a cohesive whole. Aristotle's contributions further enriched this discourse; however, it was Werner Jaeger (1959) who provided a clear distinction:

> The Greek term translated as “proper mixture” is *krasis*, signifying a specific kind of blend, contrasting with mere juxtaposition (*mixis*). S*ynkrasis*, derived from *krasis*, underscores a profound interpenetration, suggesting a “blend” that results in a harmonious unity among elements. Initially employed in Greek medicine to denote an indissoluble unity, it later found relevance in political philosophy to describe an ideal synthesis of social elements within the polis, and was also applied to the cosmos.

Moving forward, we will explore the relationships among subjects within the STEAM framework, questioning whether these connections are primarily interdisciplinary—facilitating easier integration—or transdisciplinary, necessitating more complex interrelations and thereby presenting greater challenges. Our focus will predominantly center on the epistemological implications of these connections.

Moreover, evidence suggests that educators often oversimplify the relationships among subjects within the STEAM framework, viewing them as additive associations rather than as integrative or blended interactions.

Disciplinary classifications emerged in the early 19th century, aiming to organize diverse fields of knowledge within European academia, with further refinements occurring in the 20th century (Stichweh, 2001). Each discipline possesses unique methodologies and epistemic practices tailored to specific objectives, leading to the theorization of disciplines as structures of power that classify and prioritize certain forms of knowledge while marginalizing others (Foucault, 1977; Moran, 2001). Critics have highlighted the limitations inherent in establishing boundaries that constrain the epistemological breadth of inquiry (Fam et al., 2018; Gibbs, 2017; Ingold, 2010). Consequently, the delineations between disciplines may be both distinct and ambiguous (Osborne, 2015).

Examining the interactions among the disciplines involved is imperative to effectively analyze the boundaries within and across science, STEM, and STEAM. Interdisciplinary interactions can be conceptualized in various ways: as efforts to create a unified knowledge framework that links disciplines, as challenges to traditional knowledge production, or as means to transcend the limitations of individual disciplines (Moran, 2001). For instance, interdisciplinary curricula may promote culturally responsive approaches to teaching mathematics (Zaslavsky, 1993) or encourage innovative methods for navigating rigorous student assessment standards (Kaufman et al., 2008). Conversely, transdisciplinarity emphasizes a holistic integration of approaches, prioritizing the co-equal blending of disciplines (Choi & Pak, 2006; NASEM, 2018; Osborne, 2015). Peter Galison posits that interdisciplinarity facilitates “trading zones” for collaboration, whereas transdisciplinary approaches foster new ways of knowing through deeper integration of knowledge and methodologies (Galison & Stump, 1996).

Scholars have increasingly argued for the necessity of interdisciplinary and transdisciplinary approaches to address complex global challenges and enhance higher education to prepare future generations for a globalized world better (Fam et al., 2018; Gibbs, 2017). Others suggest that transdisciplinary strategies can highlight and connect core cognitive skills across disciplines, thereby enhancing creativity as a pedagogical goal (Henriksen & Deep-Play Research Group, 2018). Within the STEAM context, the “nexus of practice” (Scollon, 2001) serves as a useful theoretical framework for understanding the integration of practices across disciplinary boundaries, emphasizing unique outcomes arising from the intersection of STEM and the arts (Peppler & Wohlwend, 2018). This exploration of disciplinary boundaries and interactions informs our understanding of STEM and STEAM, revealing the complexities of interdisciplinary and transdisciplinary work that are often overlooked when defining STEAM. Additionally, prior research underscores the latent power dynamics intrinsic to transdisciplinary efforts, highlighting the critical role of communication and power in shaping these collaborative spaces (McGarr & Lynch, 2017; Weinstein et al., 2016).

Recent scholarship on STEM and STEAM has begun to frame inter- and transdisciplinary work in terms of the shared epistemic practices between the arts and sciences (Bevan et al., 2019, 2020; Costantino, 2018). For instance, Costantino (2018) advocates for a mutually engaged transdisciplinary curriculum model focused on creative inquiry, encompassing iterative processes of problem definition, multimodal exploration, critique, design, refinement, and exhibition. This model emphasizes epistemic practices across arts and sciences, fostering exploration, meaning-making, and critique. Costantino posits that such an approach cultivates a "third space" that generates hybrid content and epistemology for arts and engineering.

At this juncture, it is essential to delineate significant distinctions: The terms interdisciplinary and multidisciplinary, while often used interchangeably, hold distinct meanings. Interdisciplinary refers to the integration of two or more academic disciplines to examine a problem or topic from multiple perspectives, leading to insights unattainable through a singular discipline study. The goal is to synthesize and integrate methods and knowledge for a comprehensive understanding. Conversely, multidisciplinary involves multiple disciplines addressing a project while maintaining their distinct methodologies and perspectives, without necessarily integrating their insights.

Transdisciplinary research transcends these boundaries by bringing together experts from various fields and including stakeholders directly affected by the issue at hand. This approach aims not only to generate new knowledge but also to apply it in ways that address real-world challenges, emphasizing collaborative, inclusive processes among all participants.

In summary, transdisciplinary approaches are characterized by their focus on collaboration, co-creation, and practical application, distinguishing them from both interdisciplinary and multidisciplinary methodologies.

INTERDISCIPLINARITY

Interdisciplinarity, despite its contemporary popularity, is rooted in ancient concepts of science. Historically, the interconnection of knowledge across disciplines was paramount, with figures like Aristotle embodying a holistic understanding where science and philosophy were inseparable. The prevailing unity of science was a lived reality rather than an abstract ideal. Today, interdisciplinarity lacks a distinct epistemic and organizational status; it often appears merely as a way to bridge the gaps created by specialization, where diverse knowledge exists within disciplinary silos, diminishing the Aristotelian universality.

Assuming that reviving thinkers such as Aristotle could restore interdisciplinarity to its former prominence is unrealistic given the vast expansion and diversification of scientific knowledge. Modern science increasingly transcends its internal inquiries, addressing real-world issues that intertwine scientific and societal questions. This interconnectedness reflects both organizational and epistemic dimensions, complicating the differentiation between scientific problems and broader societal challenges.

A significant issue lies in defining interdisciplinarity, which has emerged as a buzzword without a consensus on its precise meaning (Hoffmann et al., 2013). Scholarly literature typically distinguishes between multidisciplinarity (the coordinated efforts of distinct disciplines), interdisciplinarity (the theoretical or methodological integration of disciplines), and transdisciplinarity (which challenges traditional disciplinary boundaries) (Choi & Pak, 2006; Holbrook, 2013; Klein, 1990, 2010). The concept of integration is often considered central to distinguishing interdisciplinarity, as emphasized by Klein, who argues that true interdisciplinarity involves the contributions of one discipline to the theories and problems of another.

However, not every interdisciplinary interaction leads to successful integration (Grüne-Yanoff, 2016). Many collaborations may yield "model templates" or similar constructs rather than achieving genuine integration (Knuuttila & Loettgers, 2016; Ankeny & Leonelli, 2016; Bradley & Thébault, 2017). Thus, it is posited that multidisciplinarity, interdisciplinarity, and transdisciplinarity might be viewed as stages within a singular process, evolving from initial disciplinary involvement to potential boundary-breaking integration.

Interdisciplinarity is not a recent phenomenon; several scientific disciplines, such as biochemistry, originated from interdisciplinary interactions across overlapping fields. Recent discussions underscore its potential to tackle urgent global challenges, suggesting that it can foster new methods of knowledge production and generate "mutual knowledge" through novel insights and integrative frameworks (Klein, 2008; Frodeman et al., 2010). This perspective indicates that interdisciplinarity can catalyze significant transformations in scientific paradigms, akin to Kuhn's notion of scientific revolutions.

Despite some successful interdisciplinary initiatives, the lack of a universally accepted methodology raises concerns about its overall effectiveness. Researchers often struggle with clarity regarding the methodologies they employ (Robertson et al., 2003). Analysts remain divided on the existence of a coherent interdisciplinary method; some propose prescriptive frameworks (Newell, 2007), while others advocate for understanding interdisciplinarity through case studies (Krohn, 2010).

Frodeman (2014) argues against rigid methodologies, emphasizing the importance of scientists' virtues, such as openness to new perspectives and adaptability. This viewpoint challenges the establishment of fixed rules for interdisciplinarity, which could contradict its very nature. Ultimately, without a consensus on methodologies or a clear definition of problems, assessing the outcomes of interdisciplinary practices remains complex and ambiguous, complicating our understanding of when and if a problem has been successfully resolved.

TRANSDISCIPLINARITY

Transdisciplinarity is best conceptualized as a specialized subset of the broader interdisciplinary framework, having evolved its distinct discourse (Klein, 2009). This discourse often conveys the notion that transdisciplinarity signifies a radical departure from traditional disciplinary paradigms in research and pedagogy.

Transdisciplinary research encompasses a collaborative effort that integrates both academic and non-academic contributions, placing participants or subjects of study on equal footing with researchers. This approach is particularly applicable to complex issues—such as global climate change, nanotechnology, and conflict resolution—that transcend the capabilities of disciplinary or even interdisciplinary methodologies. Indeed, complexity serves as a central criterion for transdisciplinary research, as highlighted by Nowotny, Scott, and Gibbons (2001) and others.

While conventional interdisciplinarity focuses on the analysis, synthesis, and harmonization of existing disciplinary insights into a cohesive framework, transdisciplinarity aims to reconstruct knowledge from foundational elements. It seeks to recombine the content knowledge of various disciplines into innovative formations that facilitate a comprehensive understanding of multifaceted problems (Madni, 2007; Pop & Mathies, 2008; Wallerstein, 2004). The etymology of "transdisciplinarity" suggests a movement "across and through the disciplines," thereby questioning the fundamental assumptions that underpin the segmentation of knowledge.

This approach has emerged in response to a growing recognition among scholars and educators of the limitations and misaligned priorities inherent in traditional disciplinary frameworks. By adopting the term "transdisciplinarity," we assert that this approach transcends the constraints of conventional disciplinarity, fostering new methodologies and paradigms that integrate insights derived from prior discipline-based studies. The exploration of knowledge is particularly well-suited to transdisciplinary methodologies, especially considering the evolving social, economic, and political contexts of knowledge production, as identified by Gibbons et al. (1994). This framework necessitates an examination of various dimensions—including psychological, epistemic, social, and cultural—as well as different perspectives, such as idealistic, semantic, bibliographical, service-oriented, and results-oriented.

Much of the literature on transdisciplinarity continues to utilize terminology from the earlier frameworks, such as "interdisciplinary" or "multidisciplinary," which can lead to conceptual ambiguities. Kline's work (1995) is particularly relevant, as it discusses concepts of hierarchy, complexity, and dimensionality to elucidate the relationships among disciplines. The analytic features he describes as fundamental to multidisciplinary thinking are grounded in the principles of the Category Theory (Ehresmann & Vanbremeersch, 2007; Goguen, 1999).

Transdisciplinarity is gaining traction in educational settings, particularly in the realms of science, technology, and planning, as well as in addressing pressing global challenges. This approach is timely and pertinent for reinterpreting the meaning of knowledge in contemporary society, with the potential to invigorate both the humanities and social sciences.

The increasing complexity of the scientific landscape presents challenges not only due to the exponential growth of knowledge—rendering comprehensive understanding of any single field increasingly difficult—but also concerning the institutional structures that govern scientific inquiry. The capacity to think beyond narrowly defined disciplinary boundaries is diminishing, raising concerns that these boundaries may confine the pursuit of knowledge itself. It is essential to recognize that the delineations between disciplines are not intrinsically natural or fixed; rather, they are historically constructed and often influenced by specific research subjects, theories, methodologies, and objectives that may not conform to traditional disciplinary frameworks.

There is a notable asymmetry between the evolution of problems and the development of disciplines, a situation exacerbated by the trends toward increasing specialization. When problems do not conform to predefined disciplinary categories, addressing these challenges often necessitates efforts that transcend such boundaries, a principle central to both interdisciplinary and transdisciplinary approaches. However, transdisciplinarity signifies more than a mere terminological shift. While interdisciplinary collaborations tend to be temporary, transdisciplinarity promotes a sustained scientific paradigm that fundamentally alters the structure of disciplines. It serves as a principle of research, addressing real-world challenges—such as those related to environmental sustainability, energy, and health—while simultaneously reshaping the organization of scientific inquiry itself.

In essence, transdisciplinarity operates as an integrative concept that seeks to dismantle the isolation that often characterizes scientific practice. It addresses the historical shortcomings that have arisen due to excessive specialization within disciplines, yet it does not aim to replace these traditional frameworks. Transdisciplinarity rather functions as a research and organizational principle that prioritizes problem-solving, extending beyond conventional disciplinary boundaries. It does not constitute a transscientific principle that supersedes scientific inquiry; rather, it is a scientific perspective directed toward a world increasingly shaped by scientific and technological reasoning.

Ultimately, transdisciplinarity is primarily a research principle, with theoretical implications emerging secondarily from transdisciplinary research endeavors. This distinction is crucial, as the nature of the problems addressed—whether they originate from internal scientific inquiries or external societal challenges—shapes the character of transdisciplinarity, which encompasses both theoretical and practical dimensions.

CONCLUSION

The interaction among disciplines, inter- and transdisciplinarity—akin to Karl Popper's "game of science" (Popper, 1959)—is a crucial endeavor that reshapes both scientific and institutional frameworks. The past reliance on lecture series or general studies as mere supplements to promote interdisciplinarity is outdated; such initiatives have often lacked genuine engagement with redefining boundaries.

Transdisciplinarity represents a robust form of collaboration that transcends disciplines, emphasizing that they remain essential. Disciplines provide foundational knowledge; without them, transdisciplinary efforts risk superficiality. Furthermore, the distinctions between disciplines cannot be oversimplified; they require complex justifications.

Recognizing that disciplines are historically constructed enhances their significance and underscores the need for systematic approaches. While the role of disciplinary knowledge remains vital, transdisciplinary tasks elevate the demand for clarity in understanding disciplinarity and its forms. The phrase "from disciplinarity to transdisciplinarity and back" reflects this need to restore a viable disciplinary concept in a transdisciplinary context. Ultimately, navigating scientific inquiry is a complex endeavor, even when it pertains to the discipline of science itself.

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APPLICATION OF THE STEAM CONCEPT IN A FLIPPED CLASSROOM

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Abstract: The interdisciplinary STEAM concept enables a learning experience by implementing a set of different skills (problem-solving, critical thinking, creativity, etc.) with the use of technology. Considering that hybrid teaching models are becoming more prevalent at all levels of education, our interest was the application of the STEAM concept in a flipped classroom (FC). Our theoretical research aims to present the possible ways and effects of applying the FC to the STEAM concept. By reinterpreting and critically analyzing several scientific research papers (theoretical and empirical) on the application of this model in the STEAM concept, we conclude that the FC can be applied effectively. Compared to the usual ways of realizing the STEAM concept by applying the FC, the potential of ICT is used more, time is used more rationally, and the development of various student skills is achieved more intensively. By using technology in the preparatory phase of the FC, before coming to school, students acquire knowledge at the level of memorization and understanding, according to Bloom's taxonomy of knowledge. This enables students to be engaged in acquiring knowledge at higher levels of Bloom's taxonomy through a variety of more complex tasks in the interdisciplinary STEAM concept. The importance and pedagogical implications of the application of a FC in the STEAM concept are particularly reflected in the possibility of increasing the efficiency of teaching.

Keywords: STEAM, interdisciplinary approach, flipped classroom, hybrid learning, effective teaching

INTRODUCTION

The use of new technological tools represents a global challenge in various aspects of everyday life. As technology and artificial intelligence continue to develop, their importance in society is increasing. Educational systems around the world face the important task of ensuring the development of specific skills and

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knowledge that will enable students to successfully cope with the challenges of the rapidly advancing technological environment. Most countries have already revised their educational goals, moving towards competency-based standards. The interdisciplinary STEAM approach to education is focused on acquiring student competencies necessary for the 21st century. This approach encourages the integration of multiple disciplines (science, technology, engineering, art, and mathematics). This contributes to a better understanding of complex problems and the development of innovative solutions. Besides a different approach, today's educational trends require the improvement or change of traditional teaching methods. How a teacher communicates knowledge unilaterally to students is less likely to make an educational impact on students, who are already familiar with the culture of acquiring various pieces of knowledge from the internet and communicating with people in various communities online (Jung & Hong, 2020:42). Using the potential of using technology in teaching and learning comes to the fore, especially by organizing blended and hybrid classes. The innovative FC teaching model has been used in the world for years, and in Serbian educational practice it represents the most recognizable concept of hybrid teaching (ZVKOV, 2021: 12).

This work was created with the desire to investigate the application of the STEAM concept in an FC based on the available literature. There is no data on this kind of research in Serbia. Most of the research in the world relates to the application of STEM concepts in an FC. Not wanting to limit ourselves only to STEM, the paper explores the application of the wider STEAM concept, which, in addition to the interdisciplinary connection of science, technology, engineering and mathematics, also includes art. The STEAM approach can achieve a more interesting and realistic learning experience because the creativity of students is included through art, which contributes to increasing the motivation of students to learn scientific content (Irwanto & Ananda, 2022). The importance of this topic is reflected in the need to make the application of the STEAM concept even more efficient, using the most modern communication and technological achievements by applying hybrid teaching models, such as an FC. We expect that the findings and results we have reached will help practitioners in applying the STEAM concept of learning, and give theorists and researchers guidelines and material for further theoretical research on this topic.

METHOD

In accordance with the main goal of the research – determining the possible ways and effects of applying the flipped classroom to the STEAM concept, the following research tasks were formulated:

1) to explore how the STEAM concept is applied in the FC; and

2) to explore the effects of applying the STEAM concept in the FC.

The research was carried out using a descriptive method and a content analysis procedure. After searching the databases of scientific papers on this topic, a reinterpretation and critical analysis of several research papers (theoretical and empirical) on the application of the STEM/STEAM concept in a FC was performed.

STEAM CONCEPT AND FLIPPED CLASSROOM

The transformation from the acquisition of scientific knowledge (through various subjects) to the STEM concept (interdisciplinary connection of science, technology, engineering, and mathematics) began in the USA, where it was identified as a significant national reform in the curricula at all educational levels to prepare students for the global economy of the 21st century (Yakman & Lee, 2012: 1072). The STEM/STEAM concept is successfully applied in some European countries, and over time it has become an integral part of the educational programs of the 21st century (Erkan & Duran, 2023: 2177). Interdisciplinary connection was extended to art and the next step was the integration of language, that is, the expansion of the concept into STREAM (Science, Technology, Reading, Engineering, Art, and Mathematics).

The interdisciplinary approach represents a holistic approach to learning that enables students to face problems that require multiple and overlapping solutions and apply everyday situations knowledge. Learning is organized on significant topics and problems, without taking into consideration the boundaries (and equal representation) of subjects (Blagdanić & Banđur, 2018: 279). Students are enabled to experience and apply real learning, they not only acquire knowledge but are also able to apply that knowledge in their everyday lives (Widya et al., 2019: 335). It is of great importance because it provides an approach relevant to real-life situations, during which students need to connect knowledge from different areas to adequately approach solving different problems in personal, professional, and social life. Communication, cooperation, critical thinking, solving complex problems, and creativity are considered key competencies of the 21st century (Hwang et al., 2015: 457). Their development is largely possible in this kind of the learning concept. A large comprehensive analysis of 225 research papers on the STEM concept of education (Freeman et al., 2014) showed that the exam results are about 6% better with the application of active learning by applying the STEM concept than in classes where active learning was applied via the traditional teaching.

During the implementation of the STEM approach, according to Erkan and Duran (2023), certain problems were observed, such as the quantity of the existing curriculum, situations when a class size is too large, the time allotted for implementation is not enough, problems related to communication between groups of students during teamwork, etc. The mentioned problems and the difficulties caused by these problems indicate that STEM education cannot be implemented effectively enough in many learning environments so there is a need for new teaching environments. Within these goals, one of the models being discussed and whose development is studied is the FC model (Erkan & Duran, 2023). In an FC, with the help of technology, online teaching and face-to-face work in school are combined. Activities, that traditionally took place in a classroom, now take place outside a classroom and vice versa (Bergmann & Sams, 2012; Bishop & Verleger, 2013). In this model, students first learn new content at home, often using online resources such as videos, multimedia presentations, or texts, and then use the time at school to apply what they have learned through discussions, projects, experiments, and other activities that allow deeper understanding and engagement. Lower levels of cognitive activities (according to Bloom's taxonomy – memory and understanding) happen at home, while at school attention is directed to higher levels of knowledge (application, analysis, evaluation, and creation) (Plageras et al., 2022; Widya et al., 2019). Instead of explaining new curricular content, teachers point students to different sources of information and encourage them to think critically about what they learn. Even an experiment a student performs according to (video) instructions from a teacher, and then records the results and tries to explain what he or she observed, can be a way of preparing students at home (Blagdanić & Banđur, 2018). The essence of the FC is to create a stimulating environment for learning by one's own abilities and interests, outside of classic classrooms (Bojović & Stojkanović, 2022).

Research confirms the successful application of the FC when learning the STEAM subjects (Bergmann & Sams, 2012; Hwang & Lai, 2017; Chaipidech & Srisawasdi, 2017; Milovanović, Cekić-Jovanović, & Ristanović, 2022). As the number of courses taught in blended/hybrid learning environments increases, researchers recommend more research on the best methods of combining technology-assisted learning with face-to-face instruction (face-to-face learning) (Dori et al., 2020). According to Bergmann and Sams (2012), the FC is not only about using online tools but also about interactive activities during learning. The student is at the center of an active learning process, while the teacher provides support where needed. The teacher's role is collaborative and mentoring, providing support through an individualized approach to students (Bishop & Verleger, 2013). The STEAM concept, which is applied in an educational environment where a student is at the center, with the effective use of technology, can be considered today as an example of educational models that lead to the change in educational systems, just like the FC. In the same way, it can be said that the FC model and STEAM education overlap in terms of giving great importance to the use of technology and activating students in the learning process, as well as developing students' competencies for the 21st century. Physics teachers (86%) and students (78%), in the course of research in Indonesia (Puspitasari et al., 2020:179), stated that they need a STEM integrated FC e-module because it benefits the improvement of critical thinking skills. Primary school teachers, according to the research by Cekić-Jovanović and Gajić (Cekić-Jovanović & Gajić 2022: 194), realize the importance of connecting related content of different subjects for the overall development of students' personalities and the acquisition of high-quality knowledge. They have positive attitudes about STEAM education and often apply modern technology and mathematics in STEAM for the preparation of materials, research activities, and the individualization of the teaching process.

WAYS OF APPLYING THE STEAM CONCEPT IN A FLIPPED CLASSROOM

Learning scientific content is most often carried out through research and experimental teaching, where students observe phenomena and draw conclusions based on the results of experiments. This type of research experimental teaching, with interactive lectures, in a study with high school students in Thailand, was compared with the traditional learning (via textbooks and PP presentations) and with research-based teaching in the FC (via videos and computer simulations on mobile phones). The results showed that the students who studied in a traditional way had the worst results on the test, followed by students who were taught through research and experimental teaching. The best results were achieved by students who studied in an FC while using technology and research and experiment. According to the authors, the integration of the FC in inquiry-based teaching, with the technological assistance of mobile devices and simulations as learning tools, can help students understand scientific content best (Chaipidech & Srisawasdi, 2017).

Nowadays, different models of the FC (Puthanveedu, 2022) are applied in the world, and some of them are particularly suitable for using the STEAM concept: the classic FC (learning lessons at home, working on assignments in a class); discussion-oriented (assigning content for learning at home, discussions in a class); demonstration-focused (demonstration principles in content, practice in classes); group-oriented (students look at materials and teach each other in class) and others. Even a false-flipped classroom model (where students watch video lessons in class) was studies at a STEM high school in the US.

The findings indicated that teachers used an expanded understanding of the FC model by allowing their students to watch videos in class. One of the biggest challenges these teachers faced was finding and creating videos to use in their classrooms (Kirklin, 2019).

We noticed that during the experimental programs, the integration of project learning and FC with the STEAM concept was most often applied (Aydın & Mutlu, 2023, Dori et al., 2020, Plageras et al., 2022, Sholahuddin et al., 2023). In project learning, students perform a series of activities needed to solve problems, with the application of appropriate strategies. Project-based learning often involves exploring a real-world problem that does not have a single solution. The process of project learning takes place through the joint work of teams of students through the analysis and search of possible solutions, the selection of the optimal solution, the defense and explanation of the chosen solution, and the intellectual product or artifact related to the aspect of real life. A key advantage of project-based learning is that the students themselves must actively acquire the knowledge they need to acquire related to the concepts being covered, rather than simply summarizing the material from the class. (Dori et al., 2020: 3). The FC complements project-based learning by allowing students to acquire background information with educational videos presented as homework before coming to the classroom, so they can focus on applying the basic concepts from the videos in school. Students become active participants during class, improving cooperation and communication skills as they work together to solve problems, discuss ideas, and present their findings, all in line with the higher levels of Bloom's Taxonomy (Aydın & Mutlu, 2023:823). Through the STEM approach in the FC, individualized teaching can be achieved and at the same time collaborative activities can be organized.

THE EFFECTS OF APPLYING THE STEAM CONCEPT IN THE FLIPPED CLASSROOM

The research on the application of the STEAM concept in the FC took place at different levels of education by analyzing the various effects achieved. The study conducted in four elementary schools in Indonesia was inspired by students' high motivation to use devices and low motivation to learn (Kurnianto et al., 2019: 282). The FC model provided stimulation with the help of illustrative and contextual scientific video content and had a positive effect on students' motivation and inspiration for learning. (Kurnianto et al., 2019: 286; Wibawa & Kardipah, 2018: 1008). The use of technology as a learning support affects the motivation of teachers and students (Puspitasari et al., 2020:182) and helps them implement teaching and learning more effectively (Rahman et al., 2015).

Students are also motivated by the active application of knowledge in solving practical problems. This is the key in the STEAM concept so a classroom becomes a space for creative problem-solving and collaboration.

Authors Güliz Aydın and Osman Mutlu (2023: 823), conducting a quasi-experiment, compared the results of learning the science content of the 6th-grade students using project learning and project learning supported by the FC model with the results of students in the control group, who learned according to the traditional science curriculum at school. The results showed that there was a significant statistical difference between the experimental groups and the control group in the academic achievements and the durability of knowledge, but without a significant difference in student innovation (Aydın & Mutlu, 2023: 823). A STEAM-based learning approach can provide a boost to students in learning activities by improving students' scientific, technological, engineering, artistic, and mathematical skills. It is expected that using a STEAM approach to learning will prepare students to face future challenges (Albar et al., 2021: 130). The scientific literacy of students in a class that applied project-based learning in an FC was better than with students who only applied project-based learning (Sholahuddin et al., 2023: 239). All research indicators reach the high to very high category, except for the possibility of proposing a hypothesis, which is in the middle category, so it can be concluded that such teaching takes place more efficiently and effectively. The effectiveness and efficiency of the FC, with the use of the Edmodo application in teaching science and promoting active and independent learning among elementary school students, was confirmed by Sze Yean (2019: 331).

The experimental application of the FC did not show better learning outcomes in all studies. A quasi-experimental study in Turkey (Taş, et al., 2022: 335) showed no significant statistical difference between using the FC in learning the science content among the 5th-grade students on science procedural skills and student academic achievement. Applying STEM education in an FC demonstrated a contribution to the development of students' competencies for the 21st century (Fung et al., 2022: 7). According to Plageras (Plageras et al., 2022: 1), it affects the ability to learn and understand scientific concepts, cognitive skills, and promotes students' creativity. By applying STEAMification as a specifically developed model of the STEAM approach in an FC, positive effects were achieved on the development of creative thinking skills and creative innovation (Wannapiroon & Petsangsri, 2020:1654). In one study, it was determined, based on the opinion of the teachers, that students' critical thinking skills were improved by receiving the e-module, which uses the STEM integrated approach of the FC (Puspitasari et al., 2020: 182). As the most significant conclusion of the research, Dori and her colleagues (2020: 11) emphasize the strengthening of cooperation among students, which is reflected in teamwork to solve problems during class through project learning in an FC.

The results of the analysis of STEM students' perceptions of the FC show that the main advantages for students (according to their perception) are: the flexibility of learning from videos (77%), better understanding of the content (73%), advantage due to previous knowledge in the class (34%), and the motivation to study (29%). Among the disadvantages mentioned by the students are: technical problems (34%) (related to the Internet, software, etc.), the lack of immediate feedback, and that they prefer shorter videos (Ramírez et al., 2014: 121). The study conducted in China on the application of the STEAM concept in a combined online and offline teaching environment showed a significantly positive effect on student learning satisfaction, although online teaching resources showed a positive, but insignificant, effect on learning satisfaction (Cai, 2023:72). The qualitative research results (Erkan & Duran, 2023: 2175) revealed that students found the activities useful, educational and fun. According to the results obtained from the study, the use of STEM activities supported by the FC model is recommended at all levels of education (Erkan & Duran, 2023: 2175).

CONCLUSION

The STEAM concept in the FC is most often applied through project-based learning globally. For the application of the STEAM concept, the application of other FC models is suitable, such as: classic FC, discussion-oriented, demonstration-focused, group-oriented, and even the false-FC model. Applying the STEAM concept in an FC increases students' motivation and enables engagement and good cooperation between students. The results of the presented research on the application of the STEAM concept in the FC confirm greater success in student achievement on test than with the traditional teaching. The same applies to the application of research, experimental, and project teaching in STEAM without the use of a FC. Students understand the content better and achieve better results on knowledge tests in a flipped classroom, and the teaching is more effective compared to the usual methods of STEAM teaching (Cf. Aydın & Mutlu, 2023; Dori et al., 2020; Freeman et al., 2014; Sze Yean, 2019; Sholahuddin et al., 2023). An exception is the study in Turkey which did not show a significant statistical difference between the experimental groups (Taş, et al., 2022: 335). The application of the STEAM concept in an FC affects the development of students' competencies for the 21st century, especially the development of critical thinking, solving complex problems, and creativity.

Through the theoretical analysis, we came to the conclusion that the STEAM concept can be successfully applied in an FC. We can assume that its application in teaching practice would lead to positive teaching effects and learning outcomes. Also, it would be useful to organize empirical research, with the aim of examining the effects of the implementation in schools in Serbia.

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II

STUDENTS' AND TEACHERS' ATTITUDES AND THEIR EDUCATIONAL NEEDS WITHIN THE STEM/STEAM/ STREAM APPROACH

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PRIMARY SCHOOL STUDENTS' ATTITUDES AND INTEREST IN AFTER-SCHOOL STEAM ACTIVITIES

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Abstract: STEAM represents an educational approach that integrates the "arts" into the existing STEM framework. Studies suggest that STEAM education positively affects students' learning, problem-solving skills, creativity, attitudes, and motivation. The research aims to analyze primary school students' perceptions of an after-school STEAM workshop. A quasi-experimental design was used. The instrument used in the study was a questionnaire developed by the authors. The sample consisted of 93 third-grade students. All students participated in the workshop about tessellations using the STEAM approach. The results showed that, in general, students expressed highly positive attitudes toward the STEAM workshop and increased interest in participating in after-school STEAM activities. It was determined that girls favored activities related to the arts more than boys, but there were no statistically significant differences in overall attitudes. However, there were statistically significant differences in two items in favor of boys. The boys expressed stronger interest in using digital tools and interactive boards and learning new, unknown things compared to girls. Students' responses imply that they can recognize tessellations, but frequent repetition of this topic is necessary. The findings also suggest that more school and after-school STEAM activities should be organized as they positively influence students' attitudes and enhance their interest and motivation for STEAM which might be important when choosing future careers in these fields.

Keywords: STEAM, after-school activities, primary school students, attitudes, interest

INTRODUCTION

In recent years, the share of STEAM education has been growing in the contemporary educational system. This holistic approach to learning not only fosters

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an interdisciplinary understanding of problems but also promotes the development of "Four Cs" skills: communication, creativity, critical thinking, and collaborative problem-solving, which are essential skills for the 21st century (NEA, 2012). Elementary school students, in particular, are at a crucial point where early educational experiences can significantly influence their future academic interests and career paths. The current social and economic context underscores the urgency of equipping young students with STEAM competencies. The global economy increasingly demands a workforce capable of handling technology and innovation, with industries constantly evolving toward automation and digitalization. The Fourth Industrial Revolution has accelerated the pace of technology adoption and blurred the boundaries between humans and machines across various sectors and geographical areas. Technology is only changing the way we work, but it is also altering job content, the skills required, and which jobs are being replaced (World Economic Forum, 2023). According to the World Economic Forum's report on the future of jobs, by 2025, 85 million jobs could be displaced due to shifts in the division of labor between humans and machines, while 97 million new roles may emerge that are more adapted to the new division of labor among humans, machines, and algorithms (World Economic Forum, 2020). This dynamic economic landscape requires a strong educational foundation that STEAM education can provide.

STEAM education, which integrates Science, Technology, Engineering, Arts, and Mathematics, evolved over time through the contributions of various educators and institutions. The concept of STEAM as we know it today was popularized by Georgette Yakman, an educator and researcher, in the early 2000s. Yakman developed the framework to include the arts in the traditional STEM (Science, Technology, Engineering, and Mathematics) model, recognizing the importance of creativity and design in fostering innovative thinking and problem-solving skills (Yakman, 2008).Yakman's STEAM framework emphasizes the interconnectedness of these disciplines and aims to provide a more holistic education that prepares students for the complexities of the modern world. Her work has been instrumental in promoting STEAM education and influencing educational policies and curricula worldwide.

Including Art in the traditional STEM framework relies on numerous studies of creative processes and the role of Art in fostering innovation. Scholars such as Howard Gardner, known for his theory of multiple intelligences, argue that creativity and Art play a vital role in cognitive development and should be an integral part of educational curricula (Gardner, 1983). Gardner's research suggests that incorporating artistic elements into STEM education can enhance students' ability to think divergently and approach problems from multiple perspectives. Elliot Eisner, an American professor in the fields of Art and Education and a vocal advocate for integrating arts into the education system, believed that Art education should not be viewed as a separate subject but as a complementary component to other subjects (Eisner, 2002). He considered that arts education should be integrated into other subjects to make learning more engaging and meaningful. Eisner's approach to arts education emphasized the importance of observation, experience, and communication in the learning process. Education expert Ken Robinson, an advocate for radical changes in education and the role creativity plays in it, argued that creativity is as important in education as literacy and should be treated with the same status (Robinson, 2006). Robinson's support for creativity in education underscores the importance of nurturing students' creative capacities alongside their academic abilities and technical skills.

This implies the necessity of incorporating the creativity inherent in Art into the traditional STEM framework of education. When properly and accurately taught, Art develops creativity and other cognitive competencies that benefit students in every aspect of their education and prepare them for the demands of the 21st century (Sousa & Pilecki, 2013). Therefore, the key contribution of Art to STEAM education is the development of creativity. Art inherently involves a creative approach to solving or exploring a problem. There are numerous definitions of creativity based on different scientific disciplines, indicating the complexity and multidimensionality of the phenomenon. However, we can generally say that creativity includes the ability to think outside the established frameworks and to find new solutions to existing problems. The presence of Art and creativity in education is associated with better results in PISA tests, problem-solving skills, critical thinking, teamwork, change management, collaboration, and other personal qualities highly valued in today's job market (Christopoulos, et al., 2024). Skills and abilities practiced and developed through art, when applied in STEM fields, contribute to knowledge transfer, contextualization of scientific findings, synergy of ideas, and communication of discoveries with the environment (Sousa & Pilecki, 2013). Moreover, STEAM education expands students' learning experiences by connecting skills and abilities from Art with STEM fields, combining divergent and convergent thinking processes that are otherwise considered separate and belonging either to Art or science (Sousa & Pilecki, 2013). Equally important, the collaborative nature of STEAM activities reflects real-life scenarios where interdisciplinary teamwork is essential. The collaborative aspect encourages students to work together, share ideas, and learn from each other, thus preparing them for future professional roles.

In other words, STEAM education provides students with creativity as a means of connecting content areas that were previously considered distinct or separate. It serves to enhance students' interest in exploring these areas from an interdisciplinary perspective. This increased student engagement is particularly important in primary education, where fostering a love of learning and curiosity can significantly influence students' further education.

Teachers and mathematics educators know that many students struggle with learning mathematics. Integrating the arts into math lessons helps students recognize the practical and real-world applications of mathematical concepts. This can be achieved both in regular classroom teaching and through after-school activities. Engaging students in after-school STEAM activities provides a unique opportunity to complement traditional teaching practices with hands-on, investigative learning that can enhance their interest in these fields. Research shows that such extended learning programs and after-school activities positively impact student achievement (Peterson, 2013). It has been found that STEM afterschool activities have influenced students' attitudes toward STEM fields and consequently their long-term academic trajectories (Peterson, 2013), highlighting the potential benefits of more comprehensive STEAM after-school activities.

RESEARCH METHODOLOGY

The aim of the research was to determine primary school students' perceptions of after-school STEAM activities (STEAM workshop). Based on this aim, three research tasks were defined:

1. to investigate whether pupils have positive perceptions about STEAM workshop activities and contents;
2. to investigate whether there are differences in perceptions based on gender; and
3. to investigate whether pupils recognize tessellations[1].

The research was conducted during the 2023/2024 academic year and included a sample of 93 third-grade students from Boško Djuričić primary school in Jagodina. All students attended afterschool STEAM workshop about tessellations held in May 2023. The gender structure of the sample is given in *Table 1*.

Table 1. Gender structure of the sample

Gender	N	%
Girls	40	43.0
Boys	36	38.7
No answer	17	18.3

[1]"Tessellation is an arrangement of closed shapes that completely cover the plane without overlapping or leaving gaps." (Deger & Deger, 2012)

The workshop included five activities. Four of these activities were implemented using a station rotation model, while the fifth activity engaged all students simultaneously. A brief description of each activity is given in *Table 2*.

Table 2. Description of STEAM workshop activities

Activity	Description of activity
A1. Tessellations in Art	Students were introduced to the artist Escher and some of his most famous paintings. They had a task to solve jigsaw puzzles where the pieces were parts of Escher's artworks.
A2. Geometry and tessellations	Students were introduced to different types of tessellations (regular, semi-regular, and irregular). Through a hands-on activity, they used pattern blocks to create tessellations and to solve puzzles which involved completely covering given shapes with the pattern blocks.
A3. Tessellations in games	Students were introduced to the game of Tetris, including information about its creator and the rules. They then played an offline version of Tetrisin pairs competing against each other.
A4. Interactive board tessellations	Students created tessellations using an interactive board and Mathigon polypad (interactive digital manipulatives).
A5. Designing tessellations	Students were divided into groups and each group created their tessellation pattern using cardboard. Their task was to design a section of a 10-meter-long art paper roll using the created tessellation.

The instrument used was a questionnaire created by the research authors. It consisted of three parts. The first part collected background information about the pupils. The second part contained 16 five-point Likert-type items that related to pupils' perceptions of workshop activities and content. In the first 5 items, pupils indicated how interesting and appealing they found each activity. The remaining 11 items asked pupils to rate their agreement with statements about workshop contents and organization of activities (*Table 3*).

The third part of the instrument contained four closed-ended questions that investigated whether students knew what tessellations were before and after the workshop, as well as whether they could identify tessellations in given examples (presented as two groups of images).

The statistical analysis was conducted using SPSS for Windows, version 23.0. P-values lower than 0.05 were considered statistically significant. The normality of data was assessed using the Shapiro-Wilk test of normality. For the quantitative data analysis, descriptive statistics methods were employed (frequency, percentage, mean, standard deviation, and mean ranks), while the Mann-Whitney test was used for non-parametric variables.

Table 3. Perception of workshop activities and content items

Item code	Item
T1	The whole tessellations workshop was interesting.
T2	I liked that we learned new, unknown things (what tessellations are, where they are, how to create them).
T3	I like that we could try everything on our own (put together a picture, play Tetris)
T4	I like that we were making different things (stacking plastic geometric shapes, making pictures from parts).
T5	I like that I worked together with my friends.
T6	I like that we used the interactive whiteboard to create different figures.
T7	I like that we connected math and art.
T8	I like that we connected math with games like Tetris for example.
T9	I like that we made and colored our own tessellations.
T10	I would like to have such classes at school.
T11	I would like to participate in more such afterschool workshops.

RESULTS AND DISCUSSION

The first research task was to determine pupils' perceptions of afterschool STEAM workshop activities and contents. Students rated all individual workshop activities as very interesting and appealing (see *Table 4*).

Table 4. Descriptive statistics

Activity	M	SD
A1. Tessellations in Art	4.43	0.85
A2. Geometry and tessellations	4.61	0.72
A3. Tessellations in games	4.72	0.59
A4. Interactive board tessellations	4.51	0.82
A5. Designing tessellations	4.52	0.88

However, they perceived activities that contained game elements to be the most interesting (activities A3 and A2). This was followed by activities that engaged elements of their personal creativity (A5 and A4). As the least interesting activity, students recognized activity with standard tessellations patterns (A1).

As part of the same research task, we wanted to determine the pupils' perceptions of the workshop in general, including their evaluation its content and organization. *Table 5* shows the arithmetic means and standard deviations for eachitem assessed in the instrument.

Table 5. Descriptive statistics

Item code	M	SD
T1	4.62	0.81
T2	4.69	0.53
T3	4.74	0.63
T4	4.70	0.76
T5	4.86	0.46
T6	4.68	0.75
T7	4.63	0.74
T8	4.81	0.49
T9	4.59	0.84
T10	4.61	0.88
T11	4.74	0.70

Based on the obtained results, we can conclude that the pupils express strong agreement with the given statements. They had positive perceptions of the whole workshop including its contents and organization. The organizational features rated highest were the opportunity to work in groups with peers (T5) and hands-on work (T3 and T4). Regarding the contents, students particularly enjoyed making connections between mathematical contents and games (T8).

Students expressed interest in participating in more STEAM activities, both during school and in after-school programs.

The second research task was to determine if there were differences in perceptions based on gender. The findings of the descriptive statistics are shown in *Table 7*. The girls evaluated A1 and A5 as more interesting activities in comparison to the boys. On the other hand, boys found A2, A3 and A4 as more interesting activities. This suggests that they preferred the activities involving elements of games and digital technology. Interestingly, the girls favored the activities related to the Arts more.

Table 7. Descriptive statistics

Item code	Girls			Boys		
	N	M	SD	N	M	SD
A1	40	4.48	0.88	36	4.44	0.73
A2	40	4.65	0.62	36	4.72	0.51
A3	39	4.67	0.58	32	4.78	0.55
A4	39	4.36	0.87	32	4.72	0.63
A5	39	4.62	0.88	33	4.33	0.92

However, the results show that there were no statistically significant differences in perceptions of boys and girls about activities: A1 (U=671.500, Z=-0.588, p=0.556), A2 (U=694.000, Z=-0.352, p=0.725), A3 (U=551.500, Z=-1.151, p=0.250) and A5 (U=512.500, Z=-2.146, p=0.068). As for activity A4, we found a statistically significant difference in favor of boys (U=468.000, Z=-2.146, p=0.032). The boys expressed stronger interest in using digital tools and interactive boards than girls.

As for the perceptions about the workshop contents and organization of work, similarly to previously described findings, girls expressed more positive attitudes about those workshop features which involved art (connecting mathematics and art, i.e. creating and designing tessellation patterns). It is interesting that the girls also expressed stronger readiness to participate in more school and after-school STEAM activities in comparison to boys. On the other hand, boys evaluated the features such as the possibility to learn new and unknown things more positively. The same applies to working in groups with peers and hands-on work. Nevertheless, we found a statistically significant difference in the perceptions of boys and girls only in item T2 (U=1391.500, Z=-1.982, p=0.048). The boys liked learning new, unknown things in comparison more than girls. There were no statistically significant differences in other items (*Table 8*).

Table 8. Descriptive statistics and results of the Mann-Whitney test

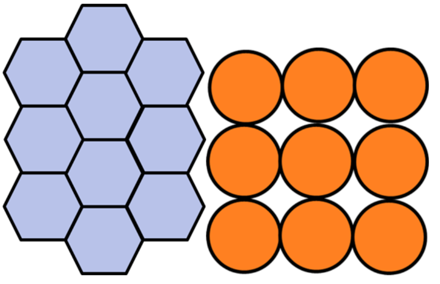
Item code	Girls			Boys			Mann-Whitney U	Z	p
	N	M	SD	N	M	SD			
T1	40	4.58	.813	36	4.53	.941	715.000	-.066	.947
T2	40	4.58	.594	36	4.81	.467	571.500	-1.982	**.048**
T3	40	4.73	.506	36	4.78	.637	648.000	-1.082	.279
T4	39	4.67	.772	36	4.72	.815	645.000	-.948	.343
T5	40	4.83	.549	36	4.89	.398	690.500	-.577	.564
T6	39	4.59	.910	36	4.69	.668	676.500	-.378	.705
T7	40	4.63	.540	36	4.61	.803	659.500	-.792	.428
T8	39	4.79	.469	36	4.75	.604	700.500	-.024	.981
T9	40	4.60	.778	36	4.44	1.027	711.000	-.121	.904
T10	39	4.69	.731	36	4.44	1.107	656.500	-.659	.510
T11	39	4.77	.627	36	4.67	.862	687.500	-.241	.809

The third research task was to investigate whether students knew what tessellations were before and after participation in afterschool STEAM workshops.

The first two items pertained to students' self-assessment of their knowledge of tessellations. While 2.15% did not answer the first item, 92.31% of the remaining students responded that they knew what tessellations are even before the workshops. The students largely demonstrated their ability to assess their understanding of the concepts. On the second item, 36.36% stated that they had forgotten what tessellations are after the workshops but were reminded by the images provided in the first part of the questionnaire.

As a part of the same research task, we wanted to determine if students could correctly identify examples of tessellations given in two sets of images. The first set contained purely geometrical objects while the second set contained real-life examples.

It is interesting to consider how students perceive tessellations in the images provided in the questionnaire. The first set of images pertained to tessellations with geometrical figures. Students exhibited a good perception of tessellations. As many as 89.25% of students correctly identified the tessellation depicted in one of the four images (*Picture 1*). However, a notable issue is the students' misunderstanding of the concept of tessellations, specifically that the figures must cover the entire plane without gaps. Due to this misconception, a significant percentage of students (38.71%) selected the image that shows a regular pattern of geometric figures but does not cover the entire plane (*Picture 2*).



Picture 1. Correct and wrong answer, respectively

Identifying tessellations in photographs depicting real-world examples proved to be a significantly more challenging task for the students. Four out of eight pictures presented examples of tessellations. The students' responses are given in *Table 6*.

Table 6. Students' responses

Type of answer	% of students
Correctly completed task	18.28
Selects some images of tessellation but not all	38.71
Selects images of all tessellations, but also some which are not tessellations	16.13
Selects some images of tessellations and some images which are not tessellations	26.88

By examining students' responses, we found that 31.18% identified a picture containing fractals as a tessellation and 4.30% of the students equated symmetry with tessellation. Interestingly, on average, 76.88% of the students correctly selected images depicting "pure" tessellations, i.e., tessellations without any visible noise (for example, the image of arranged bricks in a wall or paving stones on the street). However, fewer students (61.83%) recognized a tessellation image when another object was present along with the tessellation (for example, a bee on a honeycomb or a chess piece on a chessboard).

Considering these responses comprehensively, we can conclude that students are able to recognize tessellations, but frequent repetition of this topic is necessary.

CONCLUSION

STEAM represents an educational approach that positively affects students learning, achievement, problem-solving skills, creativity, attitudes, and motivation. It fosters creativity as a means of connecting different content areas and enhances students' interest in exploring these areas from an interdisciplinary perspective. Since many students struggle with learning mathematics, integrating the arts into math lessons might help them recognize the practical and real-world applications of mathematical concepts. While this can be achieved in regular classroom teaching, after-school activities have some advantages. After-school STEAM activities engage students in hands-on, investigative learning that can improve their understanding and enhance their interest and attitudes in these fields. The main aim of this research was to investigate primary school students' perceptions about after-school STEAM workshops. The obtained results showed that students expressed highly positive attitudes towards the workshop and increased interest in participating in after-school STEAM activities. Students evaluated the features such as the possibility to work in groups with their peers and hands-on work, as well as integrating mathematical contents with other content areas, with the highest grades. The girls favored activities and features related to the Arts more than the boys, but there were no statistically significant differences in their attitudes. However, we determined that there were statistically significant differences in two items in favor of boys. They showed stronger interest in using digital technology and learning new, unknown things. Overall, students' responses pointed out that they were able to recognize tessellations, but some misconceptions implied that frequent repetitions of this topic may be needed. The findings of this study suggest that afterschool STEAM activities have positive impact on students' interest and engagement. Since students' interest and motivation in STEAM are important factors when choosing future careers, we believe that more attention should be given to the design and organization of these activities.

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THE VIEWS OF FOREIGN LANGUAGE TEACHERS ON STEM/ STEAM/STREAM CONCEPT IN EDUCATION

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Abstract: The STEM concept is an educational model that integrates science, technology, engineering, mathematics, and more recently arts (STEAM) and reading skills (STREAM). It is a widespread belief that STEM and its derivates encourage creativity, critical thinking, and innovation. Considering their great importance and popularity worldwide, this paper aims to determine knowledge levels, application practices, and teacher's perceptions of STEM/STEAM/STREAM in Serbia. A questionnaire with open- and closed-ended questions was used as the instrument of this survey. The respondents are foreign language teachers in primary and secondary schools in Jagodina. The data obtained through this survey were analyzed quantitatively and qualitatively. The former was carried out with descriptive statistics. Striving to provide guidelines for further education of teaching staff, the paper has a practical value. In addition, it has significant theoretical implications in that the STEM/STEAM/STREAM concept is clearly defined and delimited from related concepts in teaching.

Keywords: STEM/STEAM/STREAM, foreign language, foreign language teachers, attitudes

INTRODUCTION

The rapid development of new technology, as well as social changes in the world, have led to the emergence of a new era, whereby the changes are also reflected in teaching methods and approaches in institutionalized education. Accordingly, and in order to develop students' competencies for the 21st century, the integration of different subject areas is necessary to create opportunities for innovation in teaching and learning. Therefore, the STEM[1] concept has attracted a lot of attention from various researchers in the field of education around the world (Yakman, 2008; Bal & Bedir, 2021; Bažant, 2022; Setyo Uta-

[1] STEAM and STREAM are advanced approaches to STEM. STEAM and STREAM incorporate arts or both arts and reading skills into the existing STEM, which integrates science, technology, engineering, and mathematics.

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miningsih et al., 2023), since it represents an interdisciplinary approach and has many advantages because it facilitates memory, stimulates the learning process, increases cognitive intelligence, enables better time management, and encourages the development of creativity.

The results of this study also provide information about the advantages of implementing STEM/STEAM/STREAM in foreign language teaching and learning, based on emphasizing on the question of which teaching concepts can be developed to fit students' needs.

Current global challenges and socio-political changes require innovations in pedagogic-educational approaches. Therefore, the research also examines the importance of foreign language teacher training in implementing the STEM/STEAM/STREAM approach and the current deficits. Namely, the study highlights the aggravating circumstances that teachers in Serbia perceive as obstacles to STREAM implementation.

Each STREAM subject affects a unique set of skills and expands the spectrum of perspectives in a learning process. Given that the Reading component serves to promote literacy and communication skills (Crum, 2022), it is necessary to determine foreign language teachers' knowledge about the STREAM approach and to analyze their observations on its implementation in foreign language teaching so that future professional support aiming at developing professional competences and improving the foreign language teaching can appropriately target the key deficiencies.

PREVIOUS RESEARCH

The acquisition of literacy and communication skills in a foreign language is essential for solving complex challenges and for meeting professional demands in students' future careers.

The "R" in STREAM stands for Reading, which is an essential component of education but is often neglected in STEM or STEAM (Yakman, 2008; Margot & Kettler, 2019; Bal & Bedir, 2021; Bažant, 2022; Setyo Utaminingsih et al., 2023). Reading is a fundamental skill that supports learning in all subjects and disciplines, promotes critical thinking, improves vocabulary and language skills, and improves understanding and communication skills. Reading is also necessary to promote creativity and self-expression through literary and artistic works. By emphasizing reading as a core component of STREAM education, students can develop the literacy skills necessary for success in school and beyond.

Crum (2022) believes that educational policy-makers and foreign language teachers should take into account the awareness of students about what language learning is and what it means to be linguistically and interculturally competent and that languages are crucial for improving every aspect of STEAM professions. Advanced language proficiency would pave the way to more lucrative careers for individuals connecting them through target languages, which would require blending STEAM content into the foreign language curriculum. Since communication is the key to learning a foreign language, and its effectiveness is based on the ability to function in a multitude of situations, the goal of language skills within this concept is to integrate language skills into other subjects to provide students with a more comprehensive and engaging learning experience. For example, students may read and analyze scientific articles, technical manuals, or engineering diagrams in the target language to support their understanding of STEM concepts (Crum, 2022: 2).

Previous research has confirmed that the STEM/STEAM/STREAM approach is gaining momentum globally. The attitudes of educators and teachers on the implementation of the approach and its derivates are fairly positive (Trechow, 2013). In addition to the acronym STEM, which is recognized around the globe, the acronym MINT (*Mathematik, Informatik, Naturwissenschaften und Technik*) is confined to the borders of the German-speaking countries (Kucharz et al., 2020). Several studies conducted in Turkey have focused on examining the opinions of teachers who use STEM. Highlighting the necessity of STEM education in contemporary societies, they indicate numerous advantages of this approach, especially for employment opportunities and advocate for the introduction of STEM education even in preschool age (Bakırcıa &Kutlu, 2018; Bal&Bedir, 2021; Akgunduz et al., 2022; Akcan, 2023).

Margot and Kettler (2019) from the USA conducted a thematic analysis of 25 articles on the attitudes toward STEM approaches. The criteria for inclusion in the study were specific research questions, availability of the publication in the English language, and that the study had been published between 2000 and 2016. The results show that teachers have a positive attitude towards STEM education, but a multitude of barriers was also reported such as pedagogical challenges, curriculum challenges, structural challenges, and student concerns (Margot & Kettler, 2019: 4–12).

Research conducted in Croatia also shows that teachers, as well as future teachers, are open to innovations in teaching and are aware of the importance of using the STEM approach in teaching; hence, they have a positive attitude toward its implementation (Bažant, 2022).

METHODOLOGY

As can be deduced from the aforementioned, teachers' opinions about STEM/STEAM/STREAM education and its implementation in teaching are of great importance for increasing the quality of their education and training. It is essential to determine the attitudes of foreign language teachers about STREAM education so that they can encouraged and supported to effectively use it in practice. Therefore, the main goal of this study is to determine the foreign language teachers' knowledge about this interdisciplinary approach and their attitudes toward its implementation in teaching to determine the needs and opportunities for improving the support provided to them. Such support is needed when they implement the given approach to strengthen their professional competence and confidence in carrying on STREAM activities. Therefore, we formulated research tasks to determine whether teachers have appropriate knowledge of what the STEM/STEAM/STREAM approach is, what their opinions on its implementation are, and what they consider as (dis)advantages of implementing the approach within the Serbian context.

For the purposes of this research, a mixed-methods research was chosen, that is, a questionnaire with closed- and open-ended questions was formulated to obtain both quantitative and qualitative data. The qualitative analysis was conducted with the data obtained via open-ended questions in which the respondents were allowed to express their opinions freely.

Sample and Questionnaire

The criterion for the selection into the research study group was the employment status of foreign language teachers. The research was conducted with 30 foreign language teachers who have been predominantly teaching German or English for over 10 years in primary (from 5th to 8th grade) and secondary schools in Jagodina. The survey was conducted between the 20th and the 30th of March, 2024. Participation was anonymous and voluntary.

The questionnaire contained 16 questions that examine the foreign language teachers' knowledge about the STEM/STEAM/STREAM approach and their attitudes toward its implementation, including the advantages and disadvantages.

It was important to formulate the questions understandably and to rely on the experiences of the respondents. One of the imperatives was to provide enough room for respondents to express their ideas subjectively and without any constraints. The first four questions (Q1 – 4) inquire about the gender, workplace, seniority, and foreign language in question. Hence, the study can differentiate the attitudes by gender and professional groups. The fifth question (Q5) is open-ended, and it asks the respondents to freely elaborate on their knowledge of the STEM/STEAM/STREAM approach. The responses may also manifest whether teachers unequivocally distinguish this approach from the related concepts, such as correlation in teaching. The sixth and seventh questions (Q6 and 7) aim to record whether the textbooks contain tasks or contents that can be used through the STEM approach. The following set of questions (Q8 to Q16) aims to record the attitudes toward the implementation of the STEM/STEAM/STREAM approaches in foreign language teaching and perceived advantages and disadvantages.

RESULTS AND DISCUSSION

The fidnings are presented in this section in the following manner: the questions are presented, explained, and the results are interpreted and processed in percentage terms.

Q1 – 4. The study group consists of 28 female and 2 male foreign language teachers. 67% teach German as a foreign language, and 33% teach English. Also, 60% of respondents are employed as foreign language teachers in the second cycle of primary education, while 40% teach in secondary schools.

Q5. Even though the replies varied, a great emphasis on the positive outcomes of the STREAM approach and its effectiveness can be observed:

> *A useful addition to the teaching…*
>
> *Use of multimedia in the form of audio or video recordings in teaching…*
>
> *Multidisciplinary approach to solving problems from everyday life through the development of critical thinking.*
>
> *A multidisciplinary approach to teaching that combines knowledge and skills from different subjects and areas, and develops students' abilities that are important for everyday life in the modern world.*
>
> *I am not very familiar with the program.*
>
> *STEM stands for Science, Technology, Engineering and Math*
>
> *I positively evaluate the approach, as it encourages the application of linking different subjects; it is the approach to solving tasks, enhancing thinking, and working together.*
>
> *I am not informed so much.*
>
> *Excellent approach…*
>
> *STREAM is an interdisciplinary concept in teaching that requires a purposeful connection between the learning objectives of the curriculum, standards, assessment, design, and implementation of a teaching unit.*

"R" (reading) means reading as a skill for learning and improvement in various fields.

A non-traditional approach to learning…

STEM skills are the skills and practical knowledge of the key subjects for today's age listed above and the correlation between them.

An innovative interdisciplinary approach in teaching at the preschool, elementary, and high school levels that enables quality learning by applying acquired knowledge to solve tasks that are very similar to situations and problems in real life, whereby students acquire new knowledge, skills, and values in a way that is close to them, motivates them and instills confidence. Working in a group to solve interesting problems, students improve their knowledge in the STEAM field and at the same time, acquire skills necessary for modern life and success in the profession, such as critical thinking, creativity, cooperation, successful communication in native and foreign languages, empathy and reflection on their progress.

Integration of science, technology, engineering, and mathematics when learning and concrete and clear application of what has been learned by solving real problems…

In addition to the fact that 47% of respondents define the STEM/STEAM/STREAM approach as an integrative approach in teaching, in which students connect knowledge from different subjects and use them to solve problems, 33% confuse it with the introduction of multimedia in teaching or correlation with some other subject(s) and 20% confess they are not fully familiar with the approach.

The respondents generally believe that the mentioned approach represents a positive incentive for foreign language teaching, but the answers indicate the need for professional support in the form of additional training on the application of the STEM/STEAM/STREAM approach in foreign language teaching.

Q6. 73% of the respondents gave an affirmative answer on the question inquiring whether the textbooks used by teachers contain tasks or content that can be taught via STEM/STEAM/STREAM. This means that foreign language textbooks are quite well equipped and provide some material for including the STEM/STEAM/STREAM approach. However, there is room for improvement.

The following textbooks have been mentioned as predominantly used in STEM/STEAM/STREAM activities: *Prima Plus* (Jin & Rohrmann, 2021) for the German language and *English Plus* (Wetz & Pye, 2013) and *Kid`s Box* (Nixon & Tomlinson, 2017) for the English language.

Q 8 – 10. Three statements were tested with a Likert-type scale. 67% of the respondents answered with *I strongly agree* to the first statement (*I am interested in using the STEM/STEAM/STREAM approach in foreign language teaching*). The remaining group claims that they *neither agree nor disagree* is the answer that best describes teachers' attitudes.

33% of the respondents agree with item 9 (i.e. *I am familiar with STEM/STEAM/STREAM activities that can be applied in foreign language teaching*). The rest of the subjects either have no opinion or disagree with this statement.

73% agree with item 10 stating that the STEM/STREAM/STREAM approach improves language skills in a foreign language. This means that 27% of foreign language teachers do not have an opinion about the potential benefits of STEM/STEAM/STREAM activities. This is in line with the aforementioned findings. The respondents are not equally familiar with STEM/STEAM/STREAM activities so it is reasonable that they do not have firm opinions about the positive impacts such activities can have.

Q 11. The question was optional in that only teachers who had had previous experience with STEM/STEAM/STREAM activities could answer. They were required to evaluate their experience as *very positive*, *positive*, *neutral*, *negative*, or *very negative*. 24 teachers replied. The experience in applying the STEM/STEAM/STREAM approach is considered *very positive* by 25% of the surveyed teachers and *positive* by 33%. 42% remained neutral. Although the majority of the surveyed teachers have a positive experience, one should not ignore the large number of teachers who do not think that this teaching approach has any positive effect on teaching foreign languages.

These data indicate a lack of motivation and awareness of the importance of using the STEM/STEAM/STREAM approach, which is again an indication that systematized professional training of teachers related to the mentioned approach is necessary.

Q 12 and 13. This question was also optional since it referred to those with prior STEM/STEAM/STREAM experience. The question inquired whether teachers preferred using the ready-made materials or choosing and preparing the materials themselves. 22 teachers answered. 82% confessed they prepared materials for their STEM/STEAM/STREAM lessons. This may also be one of the reasons why the respondents do not implement this approach regularly. Namely, Q13 (*How often do you use the STEM/STEAM/STREAM approach in teaching?*) reveals that 67% of the surveyed teachers *sometimes* use the approach, while only 13% use it *often*. Others confessed that they never use the approach.

Q 14. The teachers were asked whether they would use STEM/STEAM/STREAM activities if there was more professional training available for them. 67% of the surveyed teachers gave an affirmative answer, while 33% of them had no opinion about it. These results also illustrate the level of teachers' motivation to apply and to work on STEM/STEAM/STREAM topics.

Q 15 and 16. The last two questions focus on the respondents' insights about the advantages and disadvantages of applying the STEM/STEAM/STREAM approach in foreign language teaching. The obtained responses were diverse. However, most teachers agree that the approach equips the students with the skills and competencies needed to analyze and solve problems during class, but also in their everyday lives. There is a certain consensus that the approach can facilitate the development of technological literacy and critical thinking.

For the respondents, the largest drawback is the inconsistency with the foreign language curricula for elementary and high schools. They also highlight the lack of training on the possibilities of applying the STEM/STEAM/STREAM approach in teaching.

Based on the results presented above, it can be concluded that it is necessary to integrate STEM/STEAM/STREAM content into the curriculum thematically for foreign languages. In addition, training for foreign language teachers should be mandatory in order to raise awareness of the importance of this approach.

CONCLUSION

This study aimed to determine the level of knowledge about the STEM/STEAM/STREAM approach among foreign language teachers and their views and motivation toward the application of the approach. The analysis of the received answers reveals that the views towards the application of the STEM/STEAM/STREAM approach in foreign language teaching are mostly positive.

The respondents define the STEM/STEAM/STREAM approach differently and confuse it with multimedia and correlation in teaching. This is an indicator that training and professional support for foreign language teachers is needed when it comes to the mentioned approach.

The participants have different opinions about the benefits of STEM/STEAM/STREAM education, ranging from helping students to gain a deeper understanding of the importance of logical-semantic concepts, to developing technological literacy and critical thinking. Most importantly, teachers seem to be aware that the approach is highly beneficial for developing problem-solving skills in students.

The results indicate some difficulties that hinder the implementation of the given approach to foreign language teaching, such as the inconsistencies with the curriculum for the foreign language subject for elementary schools and high schools in Serbia, as well as the lack of training on the possibilities of applying the STEM/STEAM/STREAM approach in teaching.

Although the results of the research show that the emphasis is mainly on the positive incentive that the approach has for foreign language teaching, some respondents who have a neutral attitude towards the implementation of STEM/STEAM/STREAM in their teaching should not be ignored. Their attitudes indicate a deficit of personal motivation for the implementation of a given approach. The reason for this is the fact that views or attitudes are deeply rooted in our belief-system, that is very stable and rarely changes by itself. Therefore, tailored training is necessary so that teachers can develop further their beliefs and be encouraged to apply the approach. From the point of view of professional competence and development, this work suggests that teacher training is needed when it comes to the STEM/STEAM/STREAM approach.

However, there are also certain limitations regarding the research itself, and they concern a small number of respondents. Since this research is just the beginning of efforts to investigate the field of STEM/STEAM/STREAM and foreign language teaching in Serbia, we hope that similar research will follow, which, in addition to this work, can contribute to the development of the national plan and program for foreign language teaching in Serbia by introducing STEM/STEAM/STREAM content and prepared materials.

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HOW HIGH SCHOOL STUDENTS ASSESS THE IMPORTANCE OF STEM WORKSHOPS FOR ACQUIRING NEW KNOWLEDGE[1]

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Abstract: Striving to support students in choosing to study STEM subjects more intensively, one of the challenges for a teacher is to create an educational environment in which students can acquire new theoretical and practical knowledge and improve and enrich their competencies. Within the implementation of the STEM workshop *Mission (Im)possible*, first and second grade high school students, aged 15 and 16 (N = 108), were introduced to the basic cryptography concepts, lasers, sensors, various electronic components, their connections, and programming. Through group work, within a supportive environment and competitive atmosphere, students created an alarm system to protect a document with a previously encrypted message. After the workshop, participants took part in a survey, through which they expressed their agreement using a five-point Likert scale regarding statements related to the educational nature of the implemented workshops. The focus of the research is to determine to what extent students agree with the three statements: 1) I acquired new knowledge in mathematics, physics, and computer science during the workshop; 2) I believe that this way, I can learn more compared to traditional teaching methods; and 3) I believe that the activities during the workshop are significant for my education. Since the mean scores for all three statements were higher than 4.2, it can be concluded that students completely agree with all three statements on average. The results support the idea that STEM workshops can be

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designed and implemented to be accessible to students and that they can recognize their educational character.

Keywords: STEM workshops, non-formal education, high school students, students' opinions

INTRODUCTION

Encouraging students' interest and motivating them to become more involved in studying content in the field of natural sciences is one of the most current topics among researchers and practitioners in education, as well as educational policy-makers globally (Committee on STEM Education, 2018; Japan Society for STEM Education, 2018; Japashov et al., 2022; John et al., 2022; Luo et al., 2021). However, certain paradoxes have been observed**:** although modern social, economic, and technological circumstances indicate the need for more experts in STEM fields, research shows that students' interests in subjects within these areas have been continuously declining (OECD, 2008). For instance, in Australia, students' interests, particularly in mathematics, but also in biology, chemistry, and physics have significantly declined over the past 20 years, accompanied by a loss of students' confidence in engaging with these subjects (Thomson et al., 2017).

In that context, the question arises regarding the approach to teaching STEM subjects and the possibilities of using an integrated approach to engage and empower students to further participate in these fields. Over the past few decades, in Western countries, there has been an insistence on the functional use of knowledge from the teaching of natural science subjects and the creation of an integrated curriculum in these areas. The term "Integrated STEM education" is defined as an approach that combines teaching and learning from: a) two or more STEM subjects or b) one STEM subject and one or more subjects from other areas (Sanders, 2009). With the idea that real-world problems are rarely solved using knowledge from a single subject, teaching and learning based on specific connections between natural science subjects are promoted (Chiriacescu et al., 2023; Kelley & Knowles, 2016; Sanders, 2009; Stohlmann et al., 2014; Wieselmann et al., 2020).

Students' participation in STEM workshops significantly enhances their interest, knowledge, and practical skills in STEM fields, supporting their academic and personal development. For instance, students who attended computer science workshops reported an increase in interest of nearly half a point on a five-point Likert scale, with more than two-thirds expressing a desire to continue learning programming (Bruckhaus et al., 2024). In addition to better interest, students demonstrated substantial gains in domain-specific knowledge, with average scores improving from nearly 64 to 88 points (out of 100) after participating in the workshops (Bruckhaus et al., 2024).

Beyond acquiring new knowledge, STEM workshops emphasize learning through practical activities and projects, strengthening students' conceptual understanding and enhancing their problem-solving and critical-thinking skills. Such hands-on experiences are particularly beneficial for students who demonstrate talent in STEM fields, as they foster the ability to apply acquired knowledge to real-world challenges (Wu, 2019).

Research also highlights the effectiveness of STEM learning through projects and workshops in supporting students with lower performance in mathematics, as these students show greater progress in mathematical competencies compared to their peers with higher and medium achievements (Han et al., 2015). Additionally, integrated STEM education allows teachers to better observe and support individual student progress (Priatna et al., 2020).

Active learning, which is present in STEM workshops, leads to greater effectiveness in promoting long-term retention of knowledge and encouraging positive emotional responses from students compared to traditional teaching methods. This approach to learning through active participation not only enhances cognitive understanding but also fosters a positive attitude toward STEM fields (Mateos-Núñez et al., 2020). STEM programs and workshops that emphasize the application of knowledge in real-world settings and engaging activities have shown significant increases in students' motivation, engagement, and intentions to pursue STEM careers (Chittum et al., 2017).

In summary, STEM workshops, especially those focused on active learning, play a crucial role in improving students' academic achievements, increasing their interest in STEM careers, and enhancing their ability to apply acquired knowledge.

This research focuses on promoting an integrated approach to knowledge in mathematics, physics, and computer science, as essential areas for acquiring the knowledge and skills necessary for successful engagement in numerous activities in modern society, but also as a foundation for motivating students to further engage in related fields and possibly consider a career in the STEM fields themselves (Smith, 2011; Shwartz et al., 2021)

RESEARCH QUESTIONS

The research question is whether and to what extent students in the first two years of high school consider STEM workshops, designed, and implemented so that students learn about cryptography, lasers, sensors, and their integration and programming through play and collaboration, to be significant for their education.

Within this research question, three research tasks are distinguished:

1. to determine to what extent students believe they have acquired new knowledge in mathematics, physics, and computer science during the workshop;
2. to determine to what extent students believe that participating in the workshop can help them learn more compared to traditional teaching; and
3. to determine to what extent students believe that the activities they conducted during the workshop are significant for their education.

RESEARCH METHODOLOGY

STEM workshops titled *Mission (Im)possible* were implemented as part of an eponymous project that was approved for funding by the Center for the Promotion of Science of the Republic of Serbia and was the highest-rated project in the K1 category competition out of 85 proposed projects in 2020. The workshops were conducted in the fall of 2021 due to delays caused by the COVID-19 pandemic. Namely, in collaboration with the Science Club Kragujevac and the Science Club Užice, first and second-year high school students actively participated in the workshops. During the workshops, students first learned from the facilitators, who are also co-authors of this paper, about the basic concepts of cryptography, its historical development, and its applications of cryptography, with a special focus on the use of computers for (de)ciphering messages. They were then introduced to the laws of optics, the operation of sensors and lasers, and how these components are connected with others. Subsequently, the students were divided into two teams. The representatives of one team left the room while the representatives of the other team first encrypted a message of agreed length using a previously established rule, wrote it on paper, and placed it in the part of the classroom farthest from the entrance. They then assembled an improvised alarm system, using their newly acquired theoretical and practical knowledge, by connecting sensors, lasers, and other electronic components in various locations in the classroom to make it as difficult as possible for the other team members to reach the encrypted message. After setting up the alarm system, the second group, through negotiation and collaboration, tried to discover where the alarm system components were placed, to avoid them skillfully through incessant communication, and to reach the message together, which they then had to decipher. Afterward, the groups switched roles – the first group encrypted the message and set up the alarm system, while the second group overcame obstacles and deciphered the message. This created a competitive atmosphere that stimulated students to collaborate and communicate intensively to complete the common task successfully.

The sample consisted of students randomly selected from high schools in Užice (by the Science Club Užice) and Ćuprija (by the Science Club Kragujevac). Immediately after each workshop, printed questionnaires were distributed to the students. Before the students began filling out the surveys, it was explained to them that the survey was anonymous and that the results would be used exclusively for planning new, similar projects, as well as for scientific research purposes. Among other things, the survey included questions about the students' gender, the grade, and their grades in mathematics, physics, and computer science. Students were then asked to indicate their level of agreement with three statements regarding the significance of the STEM workshop they participated in for their education on a five-point Likert scale.

The sample included 58 boys and 50 girls, with 59 first-year and 49 second-year high school students. 12 students had a D, 19 students a C, almost a quarter (25 students) had a D, and nearly half (52 students) of them had an A in Mathematics. 9 students had a D, 8 students had a C, 36 students had a B, and nearly half (55 students) had an A in Physics. In Computer Science, the lowest grade was C (only 5 students); 14 students had Bs and more than four-fifths (89 students) had the highest grade.

RESULTS

The data obtained from the survey were processed with SPSS software for statistical data analysis.

Based on the responses on the first statement, students believe they acquired new knowledge in mathematics, physics, and computer science during the workshop; only 1 student somewhat disagreed, and there were no students who completely disagreed with the statement. There were 17 undecided students, while the remaining six-sevenths agreed with the statement to varying degrees: 40 students somewhat agreed, and 50 students completely agreed.

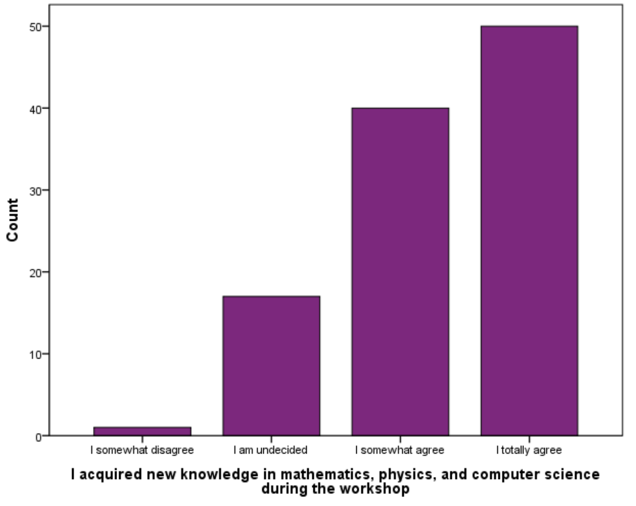

Figure 1: Students' agreement with the first statement

Analyzing the degree of agreement among students with the second statement, it can be concluded that high school students believe they can learn more through this method compared to traditional teaching. 4 students somewhat disagree with this statement, while 11 students are undecided. Furthermore, 39 students somewhat agree with this statement. Exactly half of the students (54 of them) completely agree that through active participation in these structured STEM workshops, they can learn more than in classes where teaching is conducted traditionally.

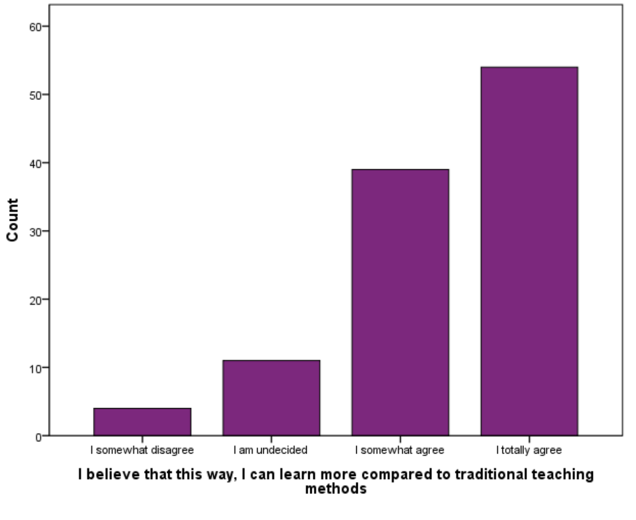

Figure2: Students' agreement with the second statement

It is easy to observe that no student has stated that he or she absolutely disagree with the previous two statements (*Figures 1* and *2*). Furthermore, by analyzing the degree of agreement among students with the statement that they believe the activities implemented during the workshop are significant for their education, it can be determined that not only is there no student who completely disagrees with this statement but there is also no student who partially disagrees with it (*Figure 3*). Specifically, slightly more than 10% of students (11 of them) are undecided; all others agree. Among them, 37 students somewhat agree, while a remarkable number of 60 students (55.55%) completely agree that by participating in STEM workshops, they acquired new knowledge from various subjects, interconnected and integrated into a meaningful whole.

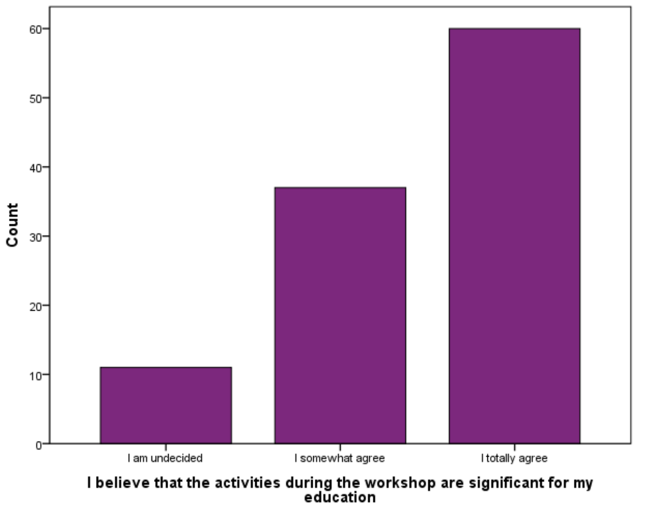

Figure 3: Students' agreement with the third statement

Table 1: The results of the descriptive statistics

Statements	N	Mean	SD	Skewness	Kurtosis
I acquired new knowledge in mathematics, physics, and computer science during the workshop	108	4.29	0.76	-0.67	-0.53
I believe that this way, I can learn more compared to traditional teaching methods	108	4.32	0.81	-1.10	0.70
I believe that the activities during the workshop are significant for my education	108	4.45	0.68	-0.85	-0.42

To determine the extent to which students generally agree with three statements provided, we calculated ranges for each of the five degrees of agreement. The determination of these ranges was proposed by Narli (2010), and they are determined by dividing the total range from 1 to 5 into 5 parts. Therefore, for average degrees of agreement from 1 to 1.8, students generally completely disagree with the statement; from 1.81 to 2.6, students generally disagree to some extent; from 2.61 to 3.4, students are undecided; from 3.41 to 4.2, students generally agree to some extent; and finally, from 4.21 to 5, students generally completely agree with the statement. Based on the arithmetic means of the degrees of agreement with three aforementioned statements (*Table 1*), as the arithmetic means for all three degrees of agreement are greater than 4.2, we can conclude that students generally completely agree that they acquired new knowledge in mathematics, physics, and computer science, believe that they can learn more in this way compared to traditional teaching methods, and consider the activities they conducted to be significant for their education. It is worth noting that the degree of agreement with the last statement is the highest (*Table 1*).

CONCLUSION

The results of this study indicate that students involved in the workshops have assessed that by implementing an integrated STEM approach and workshop-based teaching methods, they have made progress in understanding the content of subjects in the fields of mathematics, physics, and computer science. The results align with the findings from previous studies, which demonstrated an increase in students' interest and competencies in learning subjects such as mathematics (Han et al., 2015), physics (Astuti et al., 2021), and computer science (Bruckhaus et al., 2024) after participating in STEM workshops. Although the sample of students is insufficient for making generalizations, based on the obtained findings, we can raise questions related to promoting a research approach to teaching and learning natural sciences and creating conditions in which students can improve and enrich the competencies needed for a research approach (Sotiriou et al., 2017). In this context, the possibilities for developing interest in STEM fields involve reforming education in a way that content in natural sciences is closely linked to everyday life situations and actively guiding students on how knowledge from these subjects advances society (Trna et al., 2012). To meet these needs, it is significant to improve communication among teachers, establish interdisciplinary connections between teaching contents, and design, create, and implement project activities together with students (Anić & Pavlović Babić, 2015; Golubović Ilić & Mihailović, 2015; Popović

& Beara, 2022). Additionally, it would be desirable for collaborative activities to be multidisciplinary, so that students can connect acquired knowledge from different subjects and use it to solve specific problems (Antonijević & Vujisić Živković, 2015; Vujisić Živković et al., 2016).

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STUDENTS' PERCEPTIONS OF THE STEAM APPROACH IN UNIVERSITY TEACHER EDUCATION

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Abstract: Constant technological changes require generations of students able to solve problems in newly emerging circumstances quickly and efficiently. Nowadays, it is crucial to concurrently promote the skills for the 21st century among our students, get them actively involved in the social flows, and develop an interest in arts (including music) and natural sciences. The STEAM approach to university teaching allows students to draw conclusions about the phenomena covered by natural sciences through creative thinking developed by music education. This paper aims to investigate the attitudes of the final-year undergraduate students attending the Faculty of Education in Jagodina toward the STEAM approach in a university setting and their perceptions of the advantages and disadvantages of the STEAM approach. Furthermore, the paper examines the students' perceptions of the significance of teacher collaboration in STEAM activities/projects. The sample (N=89) was surveyed via a questionnaire. The findings indicate that university students have positive attitudes about the STEAM approach and the professor's initiative to combine different fields by promoting the active participation of all participants in the teaching process. The results demonstrate that the STEAM approach encourages students to think creatively and reason logically by enabling a unique symbiosis of "the mind of the scientist" and "the mind of the artist." One of the main disadvantages of the STEAM approach in university teaching stems from the impossibility of using it constantly. Consequently, combining STEAM with other innovative approaches is a requisite.

Keywords: STEAM approach, university teaching, students, music education, natural sciences

INTRODUCTION

Incessant and rapid technological changes in the world require new generations of students who will be able to solve newly-emerging problems swiftly

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and efficiently. Consequently, it is very important to equip students with the skills and competencies needed to solve real-life problems, follow current social trends, and develop an interest in art (music) and natural sciences. University education needs to follow global business trends which demand competent students who will be capable of responding to the demands imposed by the contemporary world and participate in the exchange of information about scientific achievements, while constantly strengthening their capacities (Wahyuningsih et al., 2020; Milić & Mladenović, 2022).

According to Dyer (2011), certain music-based activities can enhance their literacy skills, increase engagement, and improve memory during literacy instruction. According to other research (Davidova & Zavadska, 2019), the STEAM approach in the music curriculum allows the integration of music education with natural sciences and humanities and it enriches students' experience based on three pedagogical principles – personalization, participation, and productivity. Numerous studies confirm that children become more adept at communicating with peers through musical activities, such as playing musical instruments, creating music, and musical games, (Pitt, 2020) and they become more confident since speech is not the only medium of communication (Denac, 2022). Moreover, the positive impact of music on the intellectual, social, and personal development of children and adolescents has been confirmed in many studies that also highlight that musical activities influence language development, literacy, creativity, fine motor skills, coordination, attention, self-confidence, emotional sensitivity, and social skills (Hallam, 2010; Aguilera & Ortiz-Revilla 2021).

STEAM (Science, Technology, Engineering, Arts, and Mathematics) aims to foster creativity, critical thinking, collaboration, and problem-solving skills by bridging the gap between traditionally segregated subjects (White, 2014). In STEAM education, students are encouraged to explore increasingly complex, real-world problems and challenges holistically, drawing upon the principles from each area to develop innovative solutions (Sanders, 2009). One of the key strengths of the STEAM approach is its ability to cultivate technical proficiency and creative expression. Also, by incorporating arts (music), STEAM acknowledges the importance of imagination and aesthetics/emotional intelligence in problem-solving (Aguilera & Ortiz-Revilla, 2021). Such integration enriches the learning experience; more importantly, it facilitates the development of communication and critical thinking (Wahyuningsih et al., 2020; Belbase et al., 2021) and prepares students for the complexities of the modern world that requires interdisciplinary collaboration and adaptability (Morales et al., 2021).

Cekić-Jovanović and Gajić (2022) prove the positive attitudes about the STEAM education and the importance of integrating modern technology and mathematics. Their findings confirm that primary school teachers have positive attitudes toward the STEAM approach, confess willingness to prepare the materials for the STEAM research activities, and claim that they apply it often in teaching Digital Technologies and Mathematics. However, they point out that professional development training sessions and seminars dealing with integrative teaching and STEAM are much needed. On the other hand, most students consider that they have the competencies to cooperate with their colleagues to organize integrative activities (Milić, Mladenović, & Spasić, 2020). These competencies can be crucial for improving and modernizing university teaching.

The results of the research conducted among students of the Faculty of Mathematics and Natural Sciences and the Faculty of Engineering and Technology (Elabuga Institute of Kazan Federal University) showed that the problem of teacher education in general education institutions is a challenge of the modern world and is now relevant more than ever. The findings demonstrate that only 18% of students are familiar with existing global/state STEAM education programs; only 15% believe they are prepared to implement STEAM activities, and only 10% are confident in their readiness to lead project activities (Anisimova, Sabirova & Shatunova, 2020). These data indicate several issues, inter alia, teachers' readiness to implement new educational programs and preparing future teachers to execute practice-oriented educational activities for forming design and research competencies.

The utilization of the STEAM approach in university teacher education and, subsequently, the implementation in kindergartens and elementary schools through our students, depends on various factors. First, it includes curriculum design, possibilities for interdisciplinary linking of different fields, teacher education and training, resource availability, and student developmental levels (Carrier at al., 2011). The STEAM approach aims to integrate multiple areas to promote holistic learning experiences (Belbase et al., 2021). Because of all the above, future teachers need to be familiar with this approach during their university education.

All these researches and results of theoretical and empirical research, which we have looked into, showed that there are advantages and several disadvantages of the implementation of the STEAM approach. The analysis (Margot& Kettler, 2019) of empirical articles published between 2000 and 2016 indicate that while teachers value STEM education, they reported barriers such as pedagogical challenges, curriculum challenges, structural challenges, concerns about students, concerns about assessments, and lack of teacher support.

For that reason, the authors of this paper wanted to investigate the attitudes of final-year students of the Faculty of Education in Jagodina towards the implementation of the STEAM approach in university teaching, the importance of collaboration of professors in STEAM activities/projects, and their attitudes about the advantages and disadvantages about the implementation of the STEAM approach in university teaching.

RESEARCH METHODOLOGY

The research objective is to examine students' attitudes on implementing the STEAM approach to university teaching. In accordance with the objective, the following research tasks have been formulated: determine students' views on the advantages and disadvantages of the STEAM approach to university teaching; determine students' views on the possibilities of applying the STEAM approach in university teaching; determine students' views on the professor's initiative to methodically model STEAM activities in classes through music and ecology.

A descriptive method and techniques of surveying and scaling were applied. The research instrument was a questionnaire with a five-point Likert-type evaluation scale, designed by the paper's authors.

The questionnaire consists of three parts: the first part examined students' attitudes on the advantages and disadvantages of the STEAM approach to university teaching; the second part examined students' attitudes on the possibilities of applying the STEAM approach to university teaching; and the third part examined students' attitudes on the professor's initiative to model STEAM activities in university classes through music and ecology methodically. The questionnaire consisted of both closed- and open-ended questions.

The research sample consisted of 89 third- and fourth-year students of the Faculty of Education, University of Kragujevac in Jagodina. Students attending academic studies on programs Class Teacher Education and Preschool Teacher Education were surveyed. The students were surveyed after the STEAM class/workshop in the field of natural sciences and music education.

The survey was conducted *in vivo* in March 2024. The acquired data were processed using the SPSS program.

RESULTS AND DISCUSSION

Considering the subject of the research, our starting point was the research task to determine the students' attitudes on whether there is potential for the implementation of STEAM activities at the faculty, as well as the advantages and disadvantages of this approach. The findings show that the STEAM approach in university teaching contributes to the fulfillment of several advantages that are in line with the needs and requirements of modern education and the future jobs of class teachers and preschool teachers. Students from both programs agree to the greatest extent, that there are numerous advantages. It is encouraging that the majority of students believe that a large material investment in teaching materials is not necessary to implement STEAM in teaching. Also, they believe that it is possible to apply this approach in university teaching and that it is necessary to apply STEAM more. Findings show that students have stronger sense of community and a broadened worldview and problem-solving when faced to the challenges of real life situations, and with real colleagues (*Table 1*).

Table 1. Students' attitudes

I part ITEMS	Class Teacher Education		Preschool Teacher Education	
	Mean	SD	Mean	SD
The STEAM approach contributes to students acquiring more functional and quality knowledge	4.48	0.653	4.54	0.582
The STEAM approach allows students to connect science and music	4.6	0.645	4.85	0.368
The biggest advantage of implementing the STEAM approach is divergent thinking and encouraging creativity among students	4.4	1.000	4.54	0.647
The STEAM approach enables the holistic development of each student as an individual	4.16	0.987	4.04	0.774
The STEAM approach enables students to realize exploratory music activities in nature or through outdoor learning	4.48	0.770	4.58	0.504
The STEAM approach combines time for processing similar contents of several different areas/subjects	4.44	0.712	4.85	0.368
II part ITEMS	**Class Teacher Education**		**Preschool Teacher Education**	
	Mean	SD	Mean	SD
The STEAM approach can be successfully applied in university teaching	4.36	0.860	4.62	0.496
It is necessary to apply more STEAM approach to university teaching	4.48	0.770	4.69	0.471
Certain contents of the course Natural Sciences and Methodology of Music Education are suitable for the implementation of the STEAM approach	4.12	0.833	4.50	0.707

Certain contents of natural science, and contents in music teaching like listening or performing music, provide the most opportunities for integration	3.92	1.038	4.23	0.710
For the successful implementation of the STEAM, large material investments are necessary for the acquisition of teaching materials	2.36	1.114	3.08	1.383
There are no suitable contents in university teaching that can be successfully connected through the STEAM approach	2.08	1.115	2.46	1.392
Future Teachers/educators are not sufficiently trained in the STEAM approach	2.76	1.234	3.23	1.451

The STEAM approach in university teaching enables the acquisition of practical knowledge and logical conclusions, which, through creative thinking and including music, can be achieved in natural sciences (Milić & Mladenović, 2022). Although students believe that it is possible to connect the contents of different subjects, most of them were hesitant when asked for a specific example, in this case listening to music with specific topics covered by natural sciences. It is possible that they do not have enough experience, even though they are students of the final year, or they did not see the possibility for this kind of content linking. Anyway, their answers to the open-ended questions showed that the STEAM approach opens up new possibilities and ideas for the implementation of teaching. Some of the students' responses showed their enthusiasm for professors' collaboration in integrating two different areas, and confirm that learning through music and with music encourages creativity and increases their practical experiences:

> *Connecting music/art and science is very encouraging.*
> *It is easier to absorb some facts and it is more fun. But, it cannot be applied all the time and not everything can be processed in this way.*
> *I realize that there is a connection between certain contents of different subjects that I had not studied before.*
> *I did not believe that subjects such as science and music could be connected.*
> *This approach helps me understand the lessons more easily and have a better interaction with my students.*
> *STEAM activities and workshops are very interesting.*

Findings show that there are many possibilities for how university teachers and future teachers can apply the STEAM approach. Therefore, we can agree that the university practice represents an appropriate and applicable environment for the implementation of STEM activities. To ensure successful implementation teachers should work together, do collaborative planning, be an effective team, plan lessons, identify learning objectives, and align instructional strategies. These results confirmed the findings of other studies, e.g. Malinović-Jovanović & Ristić (2017), who highlighted the need to demonstrate various possibilities of integrating teaching materials of different areas and subjects through specific examples, explore them from different angles, and present the appropriate instructions for their design.

The results indicate that students consider STEAM activities to be entertaining, highly motivating, more perceptible, more remarkable, and specific and that they provide active participation of all participants:

> *We learn interactively.*
> *I would like to contribute to the development and progress of my students in different ways.*
> *I would teach like the professors who gave us practical solutions for connecting different areas and showed good cooperation.*
> *I would like to encourage children.*

Other research on the attitudes of future teachers show similar trends – students are more motivated to present different subjects to their future students in this way (Berlin & White, 2010; Erdogan & Ciftci, 2017; Kocakaya & Ensari, 2018). Our research findings show that there are opportunities for integrated teaching, by interrelating and unifying the subjects frequently taught in separate academic subjects in the curriculum. We discovered that interdisciplinary learning breaks down the barriers between different areas, allowing students to see connections and overlaps between separate academic subjects. By connecting and combining similar, suitable content from different areas, university teachers gain time for learning. The STEAM approach must encourage a holistic understanding of complex real-world problems, preparing students for the interdisciplinary challenges they will face in their professions.

Results suggest that students' understanding of the roles in the STEAM should be increased for them to teach more content. Hence, the STEAM professional development can be perceived as an effective initial way to change practice, citing the importance of collaboration and team teaching integrated directly into the learning process.

Also, implications from this study offer other university teachers significant and valuable considerations towards to successful implementation of STEAM teaching.

CONCLUSION

The research conducted among final year students at the Faculty of Education in Jagodina showed that students have positive attitudes towards the application of the STEAM approach in university teaching. Students believe that the STEAM approach in university teaching has more advantages than disadvantages. In addition, students have positive attitudes about the professor's initiative to methodically model STEAM activities in class, especially through music and natural sciences/ecology.

Nevertheless, there is a need to improve knowledge about the STEAM approach. It is necessary to enable more training and attendance at seminars, workshops, and professional development projects focused on STEAM teaching and the application of modern technology in STEAM, because good cooperation and integrative teaching are important segments, not only of university education but also of education in kindergartens and schools, for which our students are preparing.

This further implies the need to modernize university teaching by encouraging and increasing the motivation, education, and training, creating interest in further enriching the acquired levels of knowledge and competencies and creating specific, professional competencies for the application of innovative approaches.

There is a need to further direct student competencies through university teaching, and this is the reason why the application of innovative approaches, such as STEAM, is necessary.

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FUTURE PRESCHOOL TEACHERS' ATTITUDES TOWARDS THE INTEGRATION OF THE STEM LEARNING APPROACH IN EARLY CHILDHOOD PRACTICE

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Abstract: The research aims to assess the attitudes of future preschool teachers toward the integration of the STEM learning approach in early childhood practice before and after the introduction of the Conceptual PlayWorld model (CPW). The sample of the research is future preschool teachers (N=46) who attended the obligatory course Methodical Practicum of Getting to Know the Environment (MPGKE) and the optional subject Children's Play and Creativity (CPC) during which they developed the CPW, as a model of the integration of the STEM learning approach in early childhood practice. The attitudes of future preschool teachers were examined using a five-point Likert-type scale. The findings indicate that this model can create conditions for a positive shift in the attitudes of future preschool teachers towards the application of the STEM learning approach in preschool age, that it can be one of the models for the application of the STEM learning approach in early childhood practice, aligned with the understanding of learning and development of preschool children and that it needs to be further studied and developed in our educational context.

Keywords: STEM learning approach, Conceptual PlayWorld (CPW), future pre-school teachers, early childhood practice

INTRODUCTION

The concept of a STEM learning approach (science, technology, engineering, and math) has grown in popularity in recent years. When the STEM learning approach is used for addressing education curriculum, it typically refers to an integrative approach to teaching and learning (Zendler, Seitz, & Klaudt, 2018). The STEM learning approach is considered to enable meaningful learning. Teachers and preschool teachers believe that such learning will contribute to students'/children's better activity and their ability to participate critically in knowledge acquisition (Tippett & Milford, 2017). Young children are curious, creative, and collaborative; the same characteristics are needed for STEM education, and these characteristics in young children make them naturally

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interested in the STEM approach (Banko et al., 2013). The STEM learning approach encourages children to build knowledge about the world around them through observation, research, and questioning (Ata Aktürk, Demircan, Şenyurt & Çetin, 2017). Children are interested in STEM learning (DeJarnette, 2018). They are deeply engaged in the learning process (Tank, Rynearson, & Moore, 2018; Tippett & Milford, 2017). STEM serves children by improving their vocabulary, encouraging their collaboration, and transmitting their learning into their future experiences (Moomaw & Davis, 2010).

Research points to the increasing importance of applying the STEM learning approach in working with preschool children but, at the same time, it is emphasizes that educators' competence is insufficient to integrate the mentioned learning approach in early childhood practice because models for its application are mainly developed for school practice and applied in the school context (Stephenson, Fleer, Fragkiadaki, & Rai, 2021) which is not completely in accordance with the understanding of learning and development of preschool children. In addition, preschool teachers' views of STEM learning approach in the early childhood context can be illustrated as follows (Wan , Jiang, & Zhan (2020): considerable number of teachers (62%) perceive STEM as separate disciplines while only a small part of them (6.79%) illustrated STEM as an integrated approach to teaching (Simoncini & Lasen, 2018); part of teachers (30%) worried about the appropriateness of STEM education in the early childhood context (Park, Dimitrov, Patterson, & Park, 2017); various challenges were perceived by preschool teachers for STEM approach in the early childhood context, including practical constrains (such as time, instructional resources, administrative support, and support of colleague), preschool teachers' capacity (such as understanding and handling the curriculum developed by researchers, subject content knowledge, and lack of professional development) and concerns about children (such as interest, developmental differences, and safety) (Baigiati & Evangelou, 2015; Jamil,Linder, & Stegelin, 2018); John et al., 2018; Park, Dimitrov, Patterson, & Park, 2017); although preschool teachers had a positive attitude toward professional training program, they hesitated to implement STEM lessons with their young children (DeJarnette, 2018).

When preschool teachers feel inadequate in certain areas of work, they usually do not engage enough in working with children in that area, which leads, in this particular case, to insufficient practice of the STEM learning approach in working with children.

The positive impact of the CPW on the preschool teachers' professional development emerged as an important finding (Fleer, 2022). While most studies on preschool teachers' competencies focus on what they do not know in the domain of STEM learning approach integration (Gomes & Fleer, 2017; 2018), the CPW draws on preschool teachers' strengths in designing play-based programs where program goals are oriented toward learning as well as the overall development of children (Fleer, 2022). Integrated and exciting experiential learning enhances children's interest in the STEM concept and helps them develop skills that they need in the 21st century. A study (Stephenson, Fleer, Fragkiadaki & Rai, 2021) found that through participation in the CPW professional development, preschool teachers: positively experienced STEM teaching and gained new tools; gained self-awareness for transforming their STEM teaching practices; increased their motivation and competence; devoted more time to STEM experiences; and shifted their professional identity as teachers of STEM.

Based on these findings, the idea of our research is to enable future preschool teachers to practice the STEM learning approach through the CPW model during initial education in order to, at least partially, prevent the above-mentioned findings.

THEORETICAL BASIS OF THE CPW

The CPW was created by Professor Marilyn Fleer based on many years of research and search for the STEM learning approach in preschool education. One can ask why it is so important to have models of teaching STEM built on research undertaken in play-based settings in the early childhood contexts. First, in conceptualizing this problem, we have to understand the unique nature of the early childhood contexts (Fleer, Fragkiadaki, & Rai, 2021), where "learning takes place in social, mainly play-based situations and is formed on the basis of children's daily experiences and interests" (Barenthien, Lindner, Ziegler, & Steffensky, 2020: 338). Second, we need to also understand the unique developmental period of the preschool child (Fleer, Fragkiadaki, & Rai, 2021). Young children's leading activity is play (Vygotsky, 1966), and it is through play that teaching programs for learning are usually organized by teachers (Siry & Kremer, 2011). Third, teacher motivation in intentionally teaching science also matters (Fleer, Fragkiadaki, & Rai, 2021). In the literature on early childhood teachers' professional development, it has been noted that teachers' motivation for practice change (Nuttall et al., 2015) is oriented towards designing and implementing effective play-based programs (Hadley, Waniganayake, & Shepherd, 2015).

There are many playing models in the literature, playing conceptions in different cultures, and definitions of what play is and what it is not. Many play theories focus on the playing stages, where children progress from manipulative finger play, and later material and solitary playing, through parallel to role play or fantasy playing. A cultural-historical playing view does not focus on age-related stages of play development. Play arises as a result of the dialectic between children's psychological functioning and the social and material conditions available in the environment (Fleer, Fragkiadaki & Rai, 2020). Vygotsky (1966) identifies two key elements for playing understanding that distinguish this perspective from the developmental perspective. First, playing emphasizes the creation of imaginary situations that are related to the games' roles and rules. Second, changing meanings of actions and objects are needed in a play (Vygotsky, 1966). Children manage objects and create meanings while they play, where objects and actions are given a new meaning (Vygotsky, 1966) through imaginary situations as the "basic unit of play" (Elkonin, 2005:13). Vygotsky said that "play contains all the developmental tendencies in a condensed form; in play it is as though the child were trying to jump above the level of his [sic] normal behaviour" (Vygotsky, 1966: 16).

The first step in creating the CPW was the cultural-historical synthesis of two binary values – play and learning into a conceptual play (Fleer, 2011). A cultural-historical understanding of imagination theorizes the bridge between play and learning in programs that seek to support concept formation. A dialectical view of imagination and cognition is placed in the foreground, and through this, the theory of play, called conceptual play, is introduced. It is argued that conceptual play will help preschool teachers to develop concepts with children in play-based programs. The second step was to study and incorporate the play world. The foundations of the play world began with the research of Gunilla Lindqvist (Lindqvist, 1995) in Sweden. The world of play is an approach that involves preschool teachers in children's play and foregrounds the problem scenario as part of the construction of the earliest play. The central assumption that underpins the world of play is that a preschool teacher has an active role in changing the conditions of children's play. A preschool teacher creates a dramatic situation with the children through the collective acting out of the plot found in stories, fairy tales or children's books. Children live the characters' experiences and relive their emotions together through the narrative while dramatizing the story. "The interplay between emotion and intellect gives rise to the development of imagination while they play" (Lindqvist, 1995:49). Further research into the STEM learning and playing has led to the Conceptual PlayWorld (Fleer, Fragkiadaki & Rai, 2020) as a model for the application of the STEM approach (Fleer, 2018; 2019) which has been studied in various segments of the STEM, Scientific PlayWorld (Fleer, 2017a), Digital PlayWorld (Fleer, 2017b) and Engineering PlayWorld (Fleer, 2020).

THE CPW IN A TEACHING PROCESS

The CPW was introduced through the teaching of two subjects, the compulsory subject Methodical Practicum of Getting to Know the Environment and the optional subject Children's Play and Creativity. Students were introduced to the theoretical assumptions of the model and were gradually guided, based on the literature (Fleer et al., 2023; Fleer, Fragkiadaki, & Rai, 2020; Fleer, 2018), through the CPW designing. They were tasked with designing the CPW based on a story of their choice and a plan given in the literature. Five characteristics of a CPW to support imaginary play and STEM thinking and learning (Fleer, 2018): 1. Selecting a story for the CPW; 2. Designing a CPW space; 3. Entering and exiting the CPW space; 4. Planning the play inquiry or problem scenario, and 5. Planning adult interactions to build conceptual learning in the role.

RESEARCH METHODOLOGY

The aim of the research was to assess the students'/ future preschool teachers' attitudes towards the integration of the STEM learning approach in early childhood practice before and after the CPW model introduction.

The research sample comprised students/future pre-school teachers (N=46) who attended the compulsory course Methodical Practicum of Getting to Know the Environment and the optional subject Children's Play and Creativity.

The descriptive method and scaling technique were applied. The research instrument was a five-point Likert-type scale containing 12 items (DeJarnette, 2018) that was adapted for research purposes. The scale measured three dimensions of attitudes (the importance of applying the STEM learning approach in preschool age, the STEM learning approach knowledge and ways of its reception in early childhood practice, and confidence in applying the STEM learning approach in practice). A higher average value indicated greater acceptance of a particular dimension.

The students'/future preschool teachers' attitude towards the integration of the STEM learning approach in early childhood practice was measured before and after the CPW model introduction. The reliability of the scale was defined by the Krombach alpha coefficient (0.859 before, 0.915 after). Arithmetic mean with a corresponding standard deviation was used for the description. The differences in the attitude between the two time intervals were examined with paired samples of a T-test (Paired T-Test).

RESEARCH RESULTS WITH DISCUSSION

The questionnaire items were grouped into three dimensions: the importance of applying the STEM learning approach in preschool age, the STEM learning approach knowledge and how to adopt it in early childhood practice, and preschool teachers' self-confidence regarding the application of the STEM learning approach into practice. *Table 1* presents the differences in students' attitudes on the dimensions before and after the introduction of the STEM learning approach.

Table 1. Differences in students' attitudes on the dimensions before and after the introduction of the STEM learning approach

Scale dimensions	**Before**		**After**		**t**	**df**	**p**
	M	**SD**	**M**	**SD**			
Application importance	4.04	0.63	4.40	0.43	-3.069	45	0.004
Knowledge	3.28	0.61	4.19	0.50	-7.861	45	0.000
Self-confidence	3.93	0.63	4,35	0.45	-3.622	45	0,001

M = arithmetic mean, SD = standard deviation, t = paired samples, T-test, df = degrees of freedom, p = statistical significance. Theoretical range: 1 = strongly disagree, 5 = strongly agree.

The respondents were more aware of the importance of the STEM learning approach being applied in preschool after the model introduction compared to the measurement before (M = 4.40, SD = 0.43 vs. M = 4.04, SD = 0.63), t = -3.069, df = 45, p = 0.004. The STEM learning approach knowledge and its application in early childhood practice was also better after the model introduction (M = 4.19, SD = 0.50 vs. M = 3.28, SD = 0.61), t = -7.861, df = 45, $p < 0.001$. A statistically significant difference also existed when it came to the dimension: self-confidence regarding the STEM learning approach application in early childhood practice (t =-3.622, df = 45, p = 0.001). Self-confidence was higher in the second measurement (M = 4.35, SD = 0.45) compared to the first (M = 3.93, SD = 0.63).

In the following text, we will refer to individual items within each dimension. The future preschool teachers' attitudes regarding the importance of the STEM learning approach application (*Table 2*) in preschool age were both high and equal before and after the model introduction. Within this dimension, a statistically significant difference was established on all three items. Therefore, preschool teachers believed in the importance of the STEM learning approach being applied in preschool age, both before and after the model introduction, and we could say that the model influenced the strengthening of that belief.

Table 2. The importance of the STEM learning approach being applied in pre-school age.

The item No.	**The importance of STEM learning approach being applied in pre-school age**	Before		After		**t**	**df**	**p**
		M	**SD**	**M**	**SD**			
p1	I will regularly use the STEM learning approach in working with children.	4.17	0.71	4.46	0.50	-2.227	45	0.031
p11	I believe that the STEM learning approach application in a real program is important for the holistic development of preschool children.	3.98	0.88	4.28	0.54	-2.004	45	0.051
p12	I believe that science, technology, engineering, and math concepts and activities are appropriate in working with preschoolers.	3.96	0.92	4.46	0.50	-2.901	45	0.006

M = arithmetic mean, SD = standard deviation, t = paired samples, t = test, df = degrees of freedom, p = statistical significance. Theoretical range: 1 = strongly disagree, 5 = strongly agree.

When it comes to the STEM learning approach knowledge and the way of its reception in early childhood practice (*Table 3*), it was evident that the future preschool teachers, observing individual items, before the model introduction, expressed a heterogeneous attitude, while after the model introduction, their attitudes were quite high and equal on all items. Before the model introduction, the future preschool teachers expressed a moderately high attitude towards their ability to plan and apply the STEM learning approach in the real kindergarten program and also towards the ability to design, monitor, and document strategies for children's learning and development process in connection with the STEM learning approach application. The preschool teachers perceive as moderate (average around 3.00 before the model introduction, average above 4.00 after the model introduction) their STEM learning approach knowledge, familiarity with strategies and resources for the STEM learning approach implementation in the real kindergarten program and their understanding of how the STEM learning approach could be integrated into the development of the real kindergarten program. We may conclude that the model had an impact on a positive change in the pre-school teachers' attitude towards the STEM learning approach knowledge and ways of its reception in practice, but also that there was room for further work in this domain.

A statistically significant difference was not observed on the item: "*When I start working, I will need professional training to include the STEM learning approach in the real kindergarten program more effectively and more often*."

The score on the item is equal and moderately high both before and after the model introduction. This showed us that future preschool teachers were aware of the need for continuous professional development in this domain.

Table 3. The STEM learning approach knowledge and ways of its reception in practice.

The item No.	STEM learning approach knowledge and how it is adopted in practice	Before		After		t	df	p
		M	SD	M	SD			
p5	I understand how the STEM learning approach can be integrated into the development of a real kindergarten program.	3.17	0.93	4.22	0.66	-6.349	45	0.000
p6	I am familiar with the strategies and resources for the STEM learning approach implementation in a real kindergarten program.	2.85	0.94	4.24	0.52	-8.244	45	0.000
p7	I can plan and apply the STEM learning approach in a real kindergarten program.	3.80	0.75	4.41	0.50	-4.556	45	0.000
p8	I am able to come up with strategies for monitoring and documenting children's learning and development processes related to the application of the STEM learning approach.	3.57	0.83	4.26	0.61	-4.317	45	0.000
p9	When I start working, I will need professional training to include the STEM learning approach in the real kindergarten program more effectively and more often.	3.96	0.82	4.15	0.84	-1.086	45	0.283
p10	I am well-versed in the STEM learning approach.	2.85	1.03	4.07	0.71	-6.725	45	0.000

M = arithmetic mean, SD = standard deviation, t = paired samples, t = test, df = degrees of freedom, p = statistical significance. Theoretical range: 1 = strongly disagree, 5 = strongly agree.

When we considered individual items within the Self-Confidence dimension regarding the STEM learning approach application in practice (*Table 4*), the preschool teachers showed a high degree of self-confidence after applying the model on all items and after introducing the model. There was no change in the preschool teachers' attitudes regarding the enjoyment of the STEM topics development with children. It was high both before and after the model introduction, which showed us that future preschool teachers would be happy to develop STEM topics with children, in general. After the model introduction, the future preschool teachers were more positive about their comfort in the STEM learning approach planning and implementation with children. They were particularly more positive regarding the statement that the STEM learning approach inclusion in their future work was within reach. These findings indicated that after the model introduction, there was an increase in future preschool teachers' self-confidence regarding the STEM learning approach application in practice, particularly in the domain of preschool teachers' familiarity with this approach.

Table 4. Self-confidence regarding the STEM learning approach application in practice.

The item No.	Confidence in STEM learning approach application in practice	Before		After		t	df	p
		M	SD	M	SD			
p2	I feel that I will feel comfortable in the STEM learning approach planning and application with children.	4.11	0.60	4.37	0.49	-2.136	45	0.038
p3	I think I will enjoy the STEM topics development with children.	4.24	0.79	4.46	0.50	-1.529	45	0.133
p4	I believe that the STEM learning approach incorporation into my future work is within reach.	3.57	1.11	4.17	0.68	-3.199	45	0.003

M = arithmetic mean, SD = standard deviation, t = paired samples, t = test, df = degrees of freedom, p = statistical significance. Theoretical range: 1 = strongly disagree, 5 = strongly agree.

Our research findings were in agreement with the research results (Stephenson, Fleer, Fragkiadaki, & Rai, 2021). They indicated that thanks to the CPW model, future preschool teachers had gained a positive experience and a new tool for the STEM learning approach integration; they improved their competence and self-confidence in the STEM learning approach application and were encouraged to build their professional identity as STEM preschool teachers.

CONCLUSION

The findings indicated that the CPW model could create conditions for preschool teachers' positive attitude shift toward the STEM learning approach application. The future preschool teachers' change of attitude occurred in all three domains: the STEM learning approach knowledge and the way of its reception into practice; the importance of the STEM learning approach application in preschool age and self-confidence regarding the STEM learning approach application in practice. The CPW model can be one of the models of the STEM learning approach application in early childhood practice aligned with the preschool children's learning understanding and their development, but it should be further studied and developed in accordance with our practice/context.

Special attention should be paid to the initial future pre-school teachers' education and they should be trained to practice this or other adequate models for the STEM learning approach application in educational work during their studies. Among other things, future preschool teachers should be encouraged to apply this approach to gain working experience with children through their participation.

The limitations of our research referred to the number of respondents, which was determined by the number of students who attended the subjects. A suggestion for future research refers to the model application with students in practice and the techniques and instruments' designing which will enable us to look at different aspects of their application.

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PARENTS' PERCEPTIONS OF THE STEM CONCEPT OF LEARNING WITH STUDENTS OF THE FIRST CYCLE OF PRIMARY EDUCATION

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Abstract: This empirical research aims to examine parents' opinions on the STEM concept of learning. The sample included 125 parents of students in the first cycle of primary education. A descriptive method and surveying and scaling techniques were applied. A survey questionnaire with a five-point Likert-type rating scale was used. According to the majority of the parents surveyed, they do not use STEM activities with children and they have never attended any activity or workshop on that topic, because the school has not organized this type of activity; however, they will be happy to participate in these activities if the school organizes them. A large number of surveyed parents believe that it is necessary to take children to science museums, aquariums, workshops on the use of digital tools, or other events related to mathematics, the World Around Us/Nature and Society, and the Digital World since this would be one of the effective ways of encouraging children to develop a positive attitude toward the subjects encompassed by the STEM concept. The results indicate the need to support parents in understanding and applying the STEM learning concept with children, with a focus on the benefits that the application of this learning concept has on children's development, as well as the fact that schools and teachers do not deal, to a sufficient extent, with STEM activities by cooperating with parents. This opens up opportunities for future research on this problem within the first cycle of compulsory education.

Keywords: parents, children, STEM, integrative approach.

INTRODUCTION

STEM (Science, Technology, Engineering, Mathematics) learning concept has become a subject of numerous studies on all levels of education (from preschool to higher education), which indicates manifold advantages and opportunities for implementation, in both curricular and extracurricular activities.

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Ocal and Tuğluk (2023: 550) consider the STEM approach to "go beyond mere memorization of information to create solutions for everyday problems using the obtained information."

The aim of STEM concept is "to find solutions to problems by using scientific methods and giving importance to individual and collaborative studies" (Ceylan, & Akçay Malçok, 2020: 718), and such an approach to science, technology, engineering, and mathematics has an important role in developing skills for the 21st century. İdin & Dönmez (2020) state that STEM education inspires critical thinking, creativity, innovation, and communication. This aligns with the objectives of primary education and cross-curricular competencies in the Republic of Serbia. These include "the development of key competencies for lifelong learning and cross-curricular competencies in accordance with the development of contemporary science and technology; development of creative abilities, critical thinking, motivation for learning, the capability of teamwork, the capability of self-assessment, initiative and expressing one's own opinion" (Law on Primary Education*,* 2023: 5).

As children from an early age explore, observe, seek solutions and gain their first experience and knowledge about the world surrounding them within the family, "for the success of science education in classroom and out-of-school settings, parents' behaviors related to STEM are of substantial importance" (Šimunović, Reić Ercegovac, & Burušić, 2018:977). "Although parental involvement has been systematically forgotten as a critical factor" (Salvatierra & Cabello, 2022: 218), the results show that STEM activities can promote parental engagement, improve the value parents attribute to STEM, and positively affect STEM learning in preschoolers.

On the importance of including parents in schools, authors Matejević and Jovanović (2017: 14) state that "when the parents are involved, they learn about school programs and educational objectives at school, support their children's learning at home more effectively, and influence future education of their children more adequately." The strategic documents of the Republic of Serbia emphasize the need for and opportunities for parents to be involved in the operation of schools. According to the Law on Primary Education, schools are obligated to include the plan of involving parents or other legal guardians in their Development Plan. The same law states that with the aim of strengthening "educational activities of schools and encouraging individual preferences and interests" (Law on Primary Education*,* 2023:13), schools are obligated to implement extracurricular activities of the students, including those in the field of science. Through the program of cooperation with the family, the school defines areas, contents, and form of cooperation with parents, which, among other activities, include involvement in both educational and other school activities. In line with the aforementioned, the school also has the legal capability to implement STEM activities and realize cooperation with the parents. Therefore, it is important for the school to "take initiative for the inclusion of parents into school activities through cherishing different partnership forms of a school and a family" (Matejević & Jovanović, 2017:18) to achieve well-being and support for the holistic development of a student, which is one of the primary objectives of primary education. We are witnessing that there is not enough research "on parent involvement in STEM as an integrated focus" (Thomas et al., 2020: 1). However, in a research conducted by Gülhan by analyzing 24 studies, the results show that there was a certain increase in 2021 and reportedly, "the subject of family participation in the STEM program (parent-child activities) is frequently studied" (2023:7). The researchers believe that "parents have a positive impact on their children's engagement with STEM and consequently on their achievement" (Milner-Bolotin & Marotto, 2018:53) and that "STEM education studies involving family participation is important in terms of bringing a different perspective to STEM education" (Gülhan, 2023:9), but despite the importance of parental involvement in STEM activities, there is still insufficient research in this area. In order for teachers and schools to engage parents in a meaningful way, they need to understand how parents perceive their role in their child's education regarding STEM. This is the subject of our research.

RESEARCH METHODOLOGY

The objective of the research is to examine the opinions of parents whose children attend the first cycle of education about the STEM approach. The following research tasks have been formulated: investigate if the professions/hobbies of parents are related to the STEM field and their awareness of STEM; investigate to what extent parents are engaged in STEM activities at home; determine if the parents need support in preparing and implementing STEM activities and the type of support they need; investigate if the parents have attended the activities, workshops at school and teacher's classes where STEM concept was applied; inquire if children have attended STEM-base activities and workshops outside of school; investigate which methods are efficient for parents to inspire their children to develop a positive attitude toward subjects within the STEM field.

A descriptive method and techniques of surveying and scaling were applied. A questionnaire with a five-point Likert-type evaluation scale was used. The instrument used was developed by combining adopted and modified questions from the instrument (Marotto & Milner-Bolotin, 2018) and questions formulated based on relevant and tangent literature. In the introductory section of the instrument, besides clear instructions, we also included the link to the STEM education center https://www.stemeksperimenti.com/. Here, the participants could get familiar with the STEM approach to learning. In the first part of the questionnaire, the participants were required to provide basic information (gender of the parent, level of education, age, gender of the child, and grades they attended), while the second part of the instrument contained questions related to the objective of our research. The survey was conducted online, using an electronic questionnaire. The survey was conducted in January 2024. The acquired data were processed using the SPSS program.

The sample of the survey included 125 parents of students in the first cycle of education from different parts of Serbia.

Table 1. Structure of the sample of participants

	f	%
Gender of the parent		
Male	21	16.8
Female	104	83.2
Level of education of the parent		
Primary school	1	0.8
High school	39	31.2
College/University	54	43.2
Master	27	21.6
PHD	4	3.2
Age of the parent		
Younger than 34	16	12.8
From 34 to 37	38	30.4
From 38 to 41	40	32
Older than 41	31	24.8
Gender of the child		
Male	64	51.2
Female	61	48.8
Grade the child attends		
First grade	20	16
Second grade	31	24.8
Third grade	29	23.2
Fourth grade	45	36

RESULTS AND DISCUSSION

The first task to deal with was to determine whether the professions or hobbies of parents were related to any STEM discipline. 33 (26.4%) parents responded that their profession/hobbies were related to a STEM discipline, 28 (22.4%) partially related, and 64 (51.2%) parents responded negatively. Parents who answered with *yes* or *partially* were asked whether they would like their child to follow in their footsteps. 42.4% of the parents stated that they would like their children to continue on their path and get involved in some of the STEM disciplines.

Having in mind that within the group of surveyed parents, there were some who were involved in some of the STEM disciplines and the majority of those who weren't, it was important to examine whether the parents were aware of the STEM concept. The results of our research show that parents responded that they had not heard anything about STEM before to a low extent (M=2.52; SD=1.753) while the results show that "64.51% responded that it was not entirely clear to them what STEM education was about" (Milošević, 2022: 204). Milner-Bolotin & Marotto also state (2018) that the problem with involving parents and their support to the children in STEM activities was that some parents did not have enough information about the STEM concept, while the other problem was a language barrier.

In the following task, we have examined the extent to which parents were dedicated to STEM activities at home. Cronbach's α coefficient for the scale measuring parents' dedication to STEM activities is 0.926, which indicates the reliability of the scale.

Table 2. Responses on the extent of dedication to STEM activities at home

	M	SD
I invent various games in which I apply STEM.	2.66	1.350
I buy various board games which support STEM.	2.92	1.462
I buy various toys which support STEM.	2.83	1.430
While buying board games and toys, I choose those that support STEM.	2.82	1.362
I create toys with my child through STEM.	2.62	1.435
I exchange experiences and ideas about STEM with other parents.	2.10	1.201

The role of families is exceptionally important in different areas and spheres of a child's development, i.e. "parents shape children's interests and self-efficacy about STEM and content application that can favor their children's approach to STEM" (Salvatierra & Cabello, 2022: 218). The findings presented in *Table 2* testify that the parents are not dedicated to a sufficient extent to STEM activities with children at home. The parents do not buy STEM-oriented games and toys, perhaps, because they require additional financial expenses. However, the findings also indicate that the parents very rarely invent different games and create toys with their children relying on the STEM concept. The lowest rating is recorded for the item stating, "*I exchange experiences and ideas about the STEM concept with other parents*." The results indicate the need to guide and empower parents to implement and use STEM activities and content with children. Although the parents have a positive attitude towards STEM education, they "also needed more training on how to work with their children in STEM activities and scaffold their children' learning" (Wan, Jiang & Zhan, 2021:940). Regarding the question of whether the parents needed support in preparing and implementing STEM activities, the following results were obtained: 79 (63.2%) parents feel that they need support in preparing and implementing STEM activities, 40 (32%) are not sure whether they need support and 6 (4.8%) responded negatively. Since the parents stated they needed support, one of the ways to address the problem is also one of the objectives of the Education Strategy until 2030, i.e. availability and openness of pre-university education which involves "a number of established functional resource centers for additional support to children, students, parents and employees in educational institutions" (*Strategija razvoja obrazovanja i vaspitanja u Republici Srbiji*, 2021:39). Thus schools will have the possibility to provide support for parents in implementing the STEM concept of learning through different forms of cooperation.

The parents who responded that they needed support were asked via an open-ended question to specify what kind of support parents needed. *Table 3* shows some of the parents' answers.

Table 3. Responses and suggestions of parents about the kind of support

"Workshops with children and parents, STEM educational sets and models to follow in working with their children."
"Workshops to demonstrate to parents how to implement STEM activities in everyday play with their children using materials accessible to everyone."
"Parents should get familiar with STEM concept itself and be provided with examples of activities they can use with their children."
"More information from schools and professional teams."
"More education about what STEM represents and what it entails."

"Textbooks could include sections for parents related to preparation and implementation of STEM activities."
"First of all, we need to have an educational workshop at school to get more familiar with the system and be provided with explanations and examples on how to work with children within this framework."
"I don't think that preparation and implementation of STEM activities should be parents' responsibilities. It would demand a certain level and breadth of their education which cannot be expected in a large percentage of our population. Those who already have a certain education and willingness to work with their own children could use educational workshops as the most convenient manner of engagement and learning of busy parents. My opinion is that STEM is primarily an approach that should be implemented at schools."

Types of support that the parents listed and described (*Table 3*) indicate that parents believe it is necessary to explain and present the STEM concept in more concrete terms, conduct workshops for parents and children, present models and examples that could be applied with children at home, provide support from schools and school staff and propose that the textbooks should include sections dedicated to parents with guidelines for STEM activities. The last response in the table represents the opinion that STEM should be nurtured only at schools since its implementation requires a certain education level of the parents. By all means, through education, preparation, and providing guidelines to all interested parents, these barriers in the context of the implementation of STEM activities could be overcome. The family environment is the relevant and the primary environment for a child (Vilotijević, 2002). Therefore, learning based on the popular STEM concept of learning should be nurtured in this crucial environment for a child. *Table 4* shows the responses of the parents on participation in activities and workshops organized by schools on STEM.

Table 4. Parents' responses on participation in STEM activities and workshops at schools

	f	%
Yes	6	4.8
No, because I couldn't attend	16	12.8
No, because the school hasn't organized this kind of activities and workshops	103	82.4
Total	125	100.0

The findings show that 82.4% of the parents state that they haven't attended these kinds of activities and workshops because they haven't been organized at schools. Reportedly, 74 (59.2%) parents would attend if the school implemented and organized these kind of activities. Statistically significant differences exist between the level of parents' education and their potential attendance of activities and workshops that a school would organize (χ^2=24.969; df=12; $p<0.05$). There are no statistically significant differences between other sociodemographic variables and parent's responses regarding the attendance of STEM activities and workshops whether they should be organized at schools.

Table 5 shows parents' responses about attending classes where a teacher used STEM.

Table 5. Parents' responses about attending STEM classes.

	f	%
Yes	4	3.2
No, because I couldn't attend	15	12.0
No, because a teacher hasn't organized this kind of work	106	84.8
Total	125	100.0

84.8% of the parents state that they haven't attended this kind of activity because it hasn't been organized by the teacher. However, 62.4% of the parents responded that they would attend an event if organized by the teacher. By all means, the results obtained through our research sample show that schools and teachers are not sufficiently dedicated to collaborating with parents and involving them in STEM activities. However, "students need to be introduced to STEM areas as early as possible in the learning process so they would better accept them" (Puška & Puška, 2022: 123). The application of STEM models and concepts of learning and working with children features numerous benefits such as cooperation, exchange of ideas, work in groups, interaction, and research (Hanh, 2021). In line with the benefits, "STEM follows the principles of universal design for learning according to all three criteria – representation, engagement, and action and expression. Thus, it respects the diversity of all participants in the learning process and leads to better acquisition of knowledge, skills, and attitudes" (Stantić Miljački, 2020: 104). Therefore, we can agree that the school represents a favorable environment for the promotion of STEM activities and that the school practice should more frequently include this kind of work with students but also with their parents. The researchers state that "school-related projects, homework assignments, and visits to science centers open additional opportunities for positive STEM-related interactions between children and family members" (Rodari, 2009; Vartiainen & Aksela, 2013, according to Milner-Bolotin & Marotto, 2018).

31 (24.8%) parents responded positively, while 94 (75.2%) parents stated that their child had not attended STEM-based activities and workshops outside of school. Compared to older parents, younger parents more often indicated that their child had attended STEM activities and workshops outside of school (χ^2=9.389; df=3; p<0.05). Other sociodemographic variables proved not be relevant when it comes to children's prior experiences with STEM activities and workshops outside of school.

Table 6. Correlations between attending STEM activities outside of school and STEM-related professions/hobbies of the parents

		My child has attended STEM activities and workshops outside of school.	My profession/hobby is related to STEM disciplines.
My child has attended STEM activities and workshops outside of school.	r	1	.322
	p		.000
	N	125	125
My profession/hobby is related to STEM disciplines.	r	.322	1
	p	.000	
	N	125	125

Based on the calculated Pearson correlation coefficient, there is a positive and statistically significant correlation (r=0.322; p=0.000). The findings indicate a connection between a profession/hobby of a parent and child's participation in STEM activities and workshops.

The question is: What are the efficient ways for parents to motivate their children to create a positive attitude toward school subjects included in STEM (i.e. mathematics, world around us/science and social studies and digital world)? The parents ranked the suggested means of motivating children to develop a positive attitude towards curricular subjects from STEM field. Among the combination of multiple offered response modalities, the majority of parents primarily choose the modality that describes that it is necessary to *take children to science museums, aquariums, workshops on using digital tools, or other events related to mathematics, World Around Us / Science and Social Studies and Digital World.* The next most frequent choice was the modality which emphasizes that it is necessary *to help children with homework in Mathematics, World Around Us/Science and Social Studies; enroll children in extracurricular activities related to Mathematics, World Around Us/Science and Social Studies and Digital World* and the fewest number of parents choose modality which describes that it is necessary *to point out the role that Mathematics, World Around*

Us/Science and Social Studies and Digital World have in everyday life. "Numerous informal educational contexts such as museums, science centers and camps, botanical gardens, technology parks and facilities, in general spaces that contain and can offer information and insights related to science, technology, and engineering, are becoming important and essential places of learning" (Burušić et al., 2018: 27). The authors state that "out-of-school science clubs and visits to science centers open additional opportunities for positive STEM-related interactions between children and family members" (Milner-Bolotin & Marotto, 2018:53), which implies that these kind of visits should be more prevalent in family activities.

CONCLUSION

It is a fact that "most of the children start losing their interest in science and mathematics during school days" (Qureshi & Qureshi, 2021: 146) which implies the need to change and modernize school practice, educate and prepare parents, and implement STEM activities and workshops with children, focusing on bringing this kind of interactive and interdisciplinary method of work closer to children. Inclusion of parents in educational activities with children is very important for "the development of their competencies and their later achievements" (Đević, Stanišić & Vujačić, 2021:89) and this is why cooperation of a family and a school is essential for student success (Thomas et al., 2020). There are many possibilities for how teachers can include parents in STEM activities and events (Milanović, Miletić & Mijajlović, 2024). According to this survey, we can conclude that parents are not significantly dedicated to STEM activities and that they need support and training on how to implement STEM in family upbringing and free time. As expected, the findings show that there is a positive and statistically significant connection between STEM-related professions/hobbies and child participation in STEM activities and workshops. Based on the obtained results, it is necessary to support parents in the implementation of STEM activities with children and introduce parents whose profession/hobbies are not related to STEM disciplines with this innovative type of learning more thoroughly. Further research could focus more on this topic.

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STEM APPROACH FOR 21st CENTURY SKILLS AND INTERDISCIPLINARY DEVELOPMENT – EFL TEACHERS' ATTITUDES

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Abstract: STEM education is an approach that has affected all countries of the world in recent years. The study aims to explore English as a foreign language (EFL) teachers' beliefs about the potential of the STEM approach to contribute to interdisciplinary and 21st-century skills development in teaching EFL in primary and secondary school education. It deals with EFL teachers' attitudes towards the relevance of the STEM approach for moving from de-contextualized use of technology in learning towards a learning flow that fosters engagement with digital experiences in a way that can develop students' cooperation, critical thinking, autonomous learning, and their mindset growth. The participants of the study were 45 EFL teachers working both in primary and secondary schools situated in various regions in Serbia. This paper describes their attitudes towards the relevance of the STEM approach in primary and secondary education on the basis of quantitative and qualitative data obtained through teachers' questionnaires. The results show how positive attitudes of EFL teachers toward the STEM approach can effectively support students' development of interdisciplinary connections and 21st-century skills. Findings are discussed with regard to teachers' level of education, place of work, and years of experience intending to reveal their awareness and knowledge of professional skills required for possible application of this approach and to indicate relevance for using the STEM approach in primary and secondary school education. This study concludes by listing the benefits of the STEM approach summarized by primary and secondary EFL teachers in Serbia on the basis of their experience in implementing the STEM approach in the primary and secondary school curriculum.

Keywords: STEM approach, interdisciplinary connections, 21st-century skills, primary and secondary school education

INTRODUCTION

Contemporary knowledge-driven society prospers on scientific and technological revolutions in new technologies, entailing people to constantly engage

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in its flow (National Academies of Science, 2007). Intending to make it available to everybody and provide them with the required skills for thriving in this new information-oriented and digital society, education in the fields of science, technology, engineering, and mathematics (STEM) is becoming progressively more significant (National Society of Professional Engineers (NSPE), 2013). Mathematics is a part of the cultural inheritance that computes mathematical ideas, demanding work competencies to keep pace with time development (Hedlin& Gunnarsson, 2014). Additionally, people cannot be able to differentiate between mathematical and other knowledge when solving ordinary problems, thus problems cannot be solved without a set of knowledge. It involves a combination of different aspects of knowledge highlighting the need for STEM education.

In the digital area of the 21st century, the STEM concept has gradually taken its place in the educational system encouraging teachers to implement it in their teaching practice. The concept of STEM involves the integration of the four disciplines, i.e. science, technology, engineering, and mathematics into one component (Abdullah et.al., 2017). Moreover, the STEM concept is supported by the integration of 21st-century skills, focusing on a student-centered teaching approach where students work on solving problems through various projects and analytical assignments that require the involvement of critical thinking, collaboration, and cooperation (Breiner et.al., 2012). Practical application in daily life activities is the crucial outcome of the STEM concept in education. Similarly, the learning process involves the activation of social elements and cultural factors just like the physical interaction of students in creating skillful and competitive students ready to become a part of the global world. Gradually, the STEM concept has overtaken educational systems worldwide due to its relevance and dynamics of development raising the awareness of the need for integrating it in teaching practice. Nevertheless, it is mainly in the developed countries that students feel reluctant to take part in STEM activities (Schreiner & Sjøberg, 2007). For that reason, a teacher's role is predominantly relevant in changing students' attitudes towards STEM concepts in education. Moreover, teachers are expected to motivate their students by facilitating the very process of learning with STEM activities and engaging students in STEM. Subsequently, teachers need to be well educated and prepared on how to use the STEM concept in their teaching.

The purpose of this research is to study the teachers' attitudes towards STEM aiming to contribute to the current research by employing a comprehensive method to observe teachers' attitudes towards STEM. Therefore, a questionnaire was used that specifically emphasizes defining features (or key principles) of STEM to measure the attitudes.

The defining features were obtained by systematically reviewing present literature focusing on teachers' attitudes to (1) STEM impact on teachers' role in 21st century skills development, (2) pedagogical aspects in STEM teaching, (3) integrated contextual learning impact on interdisciplinary development, and (4) STEM impact on students' learning. Examining teachers' attitudes about each of these features separately may help focuse exclusively on the factors related to teachers' attitudes toward teaching with STEM. Previous studies were focused on examining aspects linked to teachers' attitudes toward introducing STEM in their teaching practice, emphasizing the connections between the attitudes and professional development (e.g. Han et al., 2015; Nadelson et al., 2013). Nevertheless, there might be other factors like those of individual and contextual nature, affecting the teachers' attitudes toward STEM concepts (Clark et al., 2014). This study aims to discover how teachers of English perceive the role of the STEM approach in contributing to interdisciplinary connections and 21st-century skills development in teaching EFL. Furthermore, it seeks to explore whether there are differences in EFL teachers' attitudes regarding the relevance of the STEM approach for developing cross-curricular connections and 21st-century skills, based on teachers' experience, level and type of education, and type of school they work at.

THE THEORETICAL FRAMEWORK OF THE STEM APPROACH

The necessity for STEM implementation in primary education is now a common acknowledgement of the majority of teachers, even of those who express their concerns, due to a deficiency of acceptable relevant trainings or due to a lack of experience. As stated by Wagner (2008), 21st-century students need the ability to generate new knowledge and apply this knowledge to new situations and problems rather than memorizing existing knowledge. Moreover, based on interviewed business leaders, Wagner identified seven central skills in which students need to develop proficiency: 1. Critical thinking and problem-solving; 2. Collaboration across networks and leading by influence; 3. Agility and adaptability; 4. Initiativeand entrepreneurialism; 5. Effective oral and written communication; 6. Accessing and analyzing information; and 7. Curiosity and imagination (Wagner, 2008). These skills, called "21st-century skills," are a blend of knowledge, skills, literacy, and expertise that students require to achieve success at work and in life (P21, 2015). Considering the popularization of the STEM concept in the 2000s, several STEM educators have performed researchassociated to integrated STEM education (Cervetti et al., 2012; Guzey et al., 2016; Harwell et al., 2015; Lam et al., 2013; Lederman & Lederman, 2013; Roehrig, Moore, Wang & Park, 2012). In spite of many benefits of STEM integration that have been supported, teachers struggle to indulge in the idea of teaching through an integrated technique.

Studies focused on learning outcomes, sustain that learning science in an integrated way develops students' problem-solving skills, their critical thinking skills, collaboration skills and results in better theoretical understanding. Nevertheless, there are no studies proving that these reported benefits are significantly different from learning science through a single-subject approach or not, so additional empirical support is needed. Furthermore, even when teachers are persuaded of the value of integration, they have restricted knowledge of learning through STEM integration or lack academic knowledge to teach through integration (Ring et al., 2017). The crucial challenges linked with teaching through an integrated manner include: a) teachers' unwillingness to teach through an integrated method (attitudinal) because of absence or limited experiences (Frykholm & Glasson, 2005; Gresnigt, Taconis, van Keulen, Gravemeijer & Baartman, 2014), b) teachers' beliefs that teaching through integrated method demands students' theoretical understanding of central subject content (Estapa &Tan, 2017), c) absence of resources to teach through an integrated method, d) teachers' absence of knowledge and experiences in engineering and technology, and e) lack of time for shared planning (Lederman & Lederman, 2013; Yeung & Lam, 2007). Nevertheless, the mutual suggestion of all these studies leads to the lack of teachers' perceptions of STEM integration supported by inadequate theoretical knowledge and skills for STEM integration. Consequently, EFL teachers feel reluctant to implement STEM in their teaching practice.

On the other hand, Moore (2008) assumes that STEM integration fosters students' motivation, engagement, and interest in STEM careers. Supporters of STEM integration argue that these outcomes are achievable due to the fact STEM integration focuses on students' engagement with real-world problems, enabling students to acquire content knowledge and practices from various disciplines (Moore, 2008). Subsequently, teachers are supposed to develop responsibility towards promoting theoretical knowledge of STEM and to allow their students opportunities for meeting STEM conceptions. To accomplish this, Moore (2008) advocates measuring pre-service teachers' conceptions of STEM together with theoretical knowledge of STEM. Furthermore, such an approach will withstand recognizing possible challenges of pre-service teachers' conceptions of STEM and support their theoretical knowledge related to STEM integration.

PURPOSE AND RESEARCH QUESTION

The present study draws upon prior research on teachers' readiness toward STEM-based contextual learning. The results of the previous research indicate that in some teaching contexts, 97% of elementary school teachers have readiness to implement STEM-based contextual learning and that 97% of them have implemented it in their teaching context (Shidiq & Nasrudin, 2021). The participants involved in the described study were 32 elementary school teachers in Bandung, West Java, Indonesia, coming from 23 different elementary schools. Contextual learning has a focus on the delivery of knowledge relevant to the concept and the student life. STEM-based contextual learning contributes to learning making it more meaningful. STEM learning has been applied at various levels of school, but there are still not many who conducted it in elementary schools (Akaygun & Aslan-Tutak, 2016; Fassa, Tytler, Freeman, & Roberts, 2013; Jho,2016; Madden et al., 2013).

Subsequently, the present study focuses on providing insight into EFL teachers' readiness toward STEM implementation, with a particular emphasis on teachers' beliefs. The total of 45 participants was a mixture of both primary and secondary school teachers coming from various regions in Serbia. In addition, the study examines the relationship between background characteristics, school context, and teachers' attitudes separately for each of the defining features of STEM: a) STEM approach contribution to teacher's role in developing 21st-century skills, b) STEM techniques (project/problem-based learning, inquiry-based learning, collaborative learning, personalized learning, integrated learning, peer teaching, flipped classroom, differentiated instruction, and formative assessment), c) integrated contextual learning impact on interdisciplinary development and d) STEM teaching impact on the students. By examining teachers' attitudes toward each of these characteristics separately, a more detailed analysis of teachers' beliefs toward teaching STEM can be obtained. The specific research question of this study is: How do teachers of English see the role of the STEM approach to contribute to interdisciplinary connections and 21st-century skills development in teaching EFL in primary school education?

RESEARCH METHOD

Sample and Procedure

The aim of this study was to highlight EFL teachers' beliefs about the potential of the STEM approach to contribute to interdisciplinary and 21st-century skills development in the educational school system. The data were collected by means of a questionnaire and presented in the form of descriptive statistics. An online questionnaire was administered to 45 EFL teachers working both in primary and secondary schools situated in various regions in Serbia between January and March 2024. All the teachers participating in the research formed an accidental convenience sample being members of the online group of EFL teachers – *Reaching English*. Having expressed their willingness to participate in the study, the respondents received the questionnaire by email. The participants were predominantly female teachers (95.6 %) with a mean age between 40 and 50 (66.7%) and an average MA level of education (60.0 %). The largest is the percentage of teachers whose work experience was between 10 and 20 years as EFL teachers (48.9%). With regards to STEM pre-knowledge, 51.1% of participants declared to be acquainted with STEM. On the other hand, in terms of the STEM vision of their colleagues at school, 75.6% of the participants stated they did not know whether they had positive attitudes. The descriptive variables of the participants are shown in *Table 1*.

Table 1: Descriptive statistics of the sample of participants

Variable	Description	Percent
Female	Gender	95.6
Between 40 and 50	Age	66.7
10-20	Years of experience as EFL teacher	48.9
MA	Level of education	60.0
I'm acquainted with STEM	STEM pre-knowledge	51.1
I don't know	STEM vision	75.6
Elementary school	Place of work	82.2

RESULTS AND DISCUSSION

Measures of Attitudes towards the Relevance of STEM

To determine EFL teachers' attitudes toward the relevance of STEM, a questionnaire in alignment with the theoretical framework was developed.[1] Items were created for each of the four distinguished STEM principles: a) STEM approach contribution to the teacher's role in developing 21st-century skills, b) STEM techniques (project/problem-based learning, inquiry-based learning, collaborative learning, personalized learning, integrated learning, peer

[1] The questionnaire for the purpose of this research paper was adapted from: https://www.surveymonkey.com/r/TI-STEM-EN.

teaching, flipped classroom, differentiated instruction, formative assessment), c) integrated contextual learning impact on interdisciplinary development and d) STEM teaching impact on the students. In line with the theoretical framework for teachers' attitudes of STEM, respondents were asked to indicate their level of agreement with these items on a five-point Likert scale (1 = strongly disagree, 2 disagree, 3 = neutral, 4 = agree, 5 = strongly agree).

All items about STEM relevance were formulated as "In your opinion, how could the STEM approach contribute to teacher's role in developing 21st-century skills?", and the items about STEM techniques as "In your opinion, could the following pedagogical approaches be part of STEM teaching?", the items about integrated contextual learning "In your opinion, how could integrated contextual learning have impact on developing interdisciplinary connections?", and the items about STEM impact on students "In your opinion, how does innovative STEM teaching have a positive impact on the following?" The sample items for all STEM principles are shown in the questionnaire.[2] In favor of confirming the validity of the questionnaire, a factor analysis (FA) was performed. All the items for all four scales had values above 0.4 and no items were excluded after the Confirmatory Factor Analysis (CFA). Each of four scales saved the same items which were grouped into new named factors. Moreover, mean values and standard deviations for the four scales had high values (21st Century-Teacher, STEM-Techniques, Learning-Development and Students'-Benefits).

According to the suggested value of Pearson correlation coefficient, scales covary linearly in the following way: the highest linear correlations are between the scales Learning Development and 21 Teachers (r=0.805) and scales Students Benefits and STEM Techniques (r=0.801). The variance of the named scales changes in a linear manner as the variance of the others change. Subsequently, the values of Pearson coefficients are nearest to the suggested value 1, which signifies the positive correlation (*Table 2*).

Table 2: Bivariate correlation with Pearson correlation coefficient

Scales	21 Teacher	STEM Techniques	Learning Development	Students Benefits
21 Teacher	1	0.730	0.731	0.648
STEM Techniques	0.730	1	0.735	0.005
Learning Development	0.805	0.755	1	0.628
Students Benefits	0.648	0.801	0.628	1

[2] The questionnaire: https://docs.google.com/forms/d/1E1aY_-TGj8SJt5Msp2Ve91jIktBDQyk-kxQNSYMDDfcY/edit

In addition to Levene's T-test of equality and indicator of significance, a few items in each of all four scales reached statistical significance according to the gender variable. In the scale 21 Teacher, two items out of nine had F values less than 0.05 and the marked values from the original table are extracted and shown in the *Table 3*. Alternatively, the scale STEM Techniques had three items statistically different. Levene's T-test was proceeded according to gender variable *(Table 3)*.

Table 3: Levene's T-Test with equality of means (F-test statistics, t- and p-Significance)

Scales with items	**F**	**t**	**p**
Scale 21Teacher			
A teacher can provide constructive feedback to students and uses assessment data to adjust teaching strategies as needed	1.147	0.966	0.494
A teacher can establish and maintain a positive and inclusive classroom environment conducive to learning	1.117	0.792	0.562

Table 4 shows the standardized regression weights, p values and explained variances of the five different regression analyses. Data Analysis SPSS software (version 17.0) defined the predictor variables most suited to explain the variance in teachers' attitudes via regression analysis for all four STEM principles. Standardized regression proves the results based on the model with 71% of the variance explained according to the adjusted r^2(r^2=71). Furthermore, predictive variables *21 Teacher, place of work, gender, STEM vision, age, level of education, knowledge about STEM, Students Benefits, years of experience as EFL teacher, Learning Development* can predict EFL teachers' answers for the dependant variable *STEM Techniques*. The relationship between teachers' contextual characteristics and their beliefs differs depending on the STEM scale. While teachers' beliefs in *Learning development* reached statistical significance (p = 0.019, standardized coefficients beta= 0.34 and standardized error= 0.226) just like in *Students Beliefs* (p=0.000, standardized coefficients beta=0.504 and standardized error=0.104)other background characteristics had values far above the desired value toward the dependant variable STEM Techniques. In addition, three background characteristics had negative standardized beta coefficients: age, level of education and knowledge about STEM. However, these variables had positive values in terms of standard error (*Table 4)*.

Table 4: Standardized regression weights, p values, and explained variances of the five different regression analyses

Model	Unstandardized Coefficients B	Stand. Error	Standardized Coefficients Beta	t	Sig
Background characteristics Constant	4.006	6.508		.616	.542
TS_Learning_Development	.557	.226	.340	2.463	.019
TS_Students_Benefits	.463	.104	.504	4.448	.000
STEM vision	.908	1.166	.073	.779	.442
Gender	.531	2.328	.019	.228	.821
Age	-.904	1.175	-.092	-.769	.447
Years of experience as EFL teacher	.031	1.087	.003	.028	.978
Level of education	-.397	.721	-.053	-.550	.725
Place of work	.250	.706	.036	.354	.730
Knowledge about STEM	-.261	.751	-.034	-.348	.214
TS_21_Teacher	.180	.142	.175	1.265	.586

	Sum of Squares	df	Mean Square	F	Sig.
Regression	1113.023	10	111.302	11.828	.000[a]
Residual	319.955	34	9.410		
Total	1432.978	44			
Dependent variable: Stem_Techiques					

MAIN FINDINGS

The emphasis of this study was on exploring EFL teachers' attitudes on the role of the STEM approach in contributing to interdisciplinary and 21st-century skills development in primary school education. Prior research was focused on STEM-based contextual learning questioning teachers' readiness to implement STEM-based contextual learning, resulting in 97% of participants in other studies who have implemented it in their teaching context (Shidiq & Nasrudin, 2021). Therefore, this study specifically examined the relationship between the participants' background characteristics, level of education, place of work, and years of experience, and their attitudes toward teaching STEM.

Namely, the participants of the study were mainly female teachers. This does not diminish the relevance of the results. The EFL teachers working both in primary and secondary schools are predominantly females in the Serbian educational system. Speaking of experience, the participants working between 10–20 years prevail just like those holding MA degrees. The data is relevant for evaluating other results and discussing the participants' attitudes towards STEM relevance. Participants who are primary EFL teachers are predominant in this study and their attitudes towards STEM prove their awareness and knowledge of professional skills required for the possible application of this approach and to indicate relevance for using STEM approach in primary school education. One participant states:

> *I put a lot of work into the realization of my ideas that are student, reality, and time-driven, I do not put much effort into the writing procedures of plans or objectives, that can stand in the way of my creativity in the classroom. Programs can provide boundaries that keep teachers stuck and in stagnation. Education is progress, which depends on students' needs, interests, and goals. A teacher's inner desire to help the student maximize his/her potential is the most important effort to put in the process of teaching.*

The results of FA demonstrate that the participants consider all the items relevant for all four scales due to the values (all the items remained high values after CFA). Another participant clarified:

> *I put a lot of effort and my students enjoy innovations in the classroom. It takes a lot of planning and materials and it's time-consuming, but it's worth it because the effects of the STEM approach are far more practical and lasting than teaching with traditional methods."*

This statement correlates with the item *A teacher can establish and maintain a positive and inclusive classroom environment conducive to learning* which reached statistical significance (*Table 4*). The results of Pearson correlation coefficients prove the significance of teacher role (21 Teacher scale) on students' progress (Learning Development scale) as well as the dependence of the two (*Table 2*). In addition, students may highly benefit from the STEM approach in teaching (the positive correlation of Students Benefits and STEM Techniques). The majority of participants stated they put a lot of effort into the process of implementing STEM teaching in primary school curriculum which proves their awareness that the STEM concept should be supported by the integration of 21st century skills, focusing on a student-centered teaching approach where students work on solving problems through various projects and analytical assignments that require the involvement of critical thinking, collaboration, and cooperation (Breiner et.al., 2012). On the other hand, a minority of participants working in secondary schools believe that their students have low potential for the STEM concept, as stated by one EFL teacher:

> *I have students who have zero STEM affinities, let alone abilities, and who still cannot grasp basic mathematical operations. I try to include problem-solving and critical thinking as much as possible and to enhance their IT skills asking them to use certain applications for project group and individual assignments.*

Standardized regression results prove that predictive variables *21 Teacher*, *place of work*, *gender*, *STEM vision*, *age*, *level of education*, *knowledge about STEM*, *Students Benefits*, *years of experience as EFL teacher*, and *Learning Development* can predict EFL teachers' answers for the dependant variable *STEM Techniques*. Furthermore, EFL teachers' attitudes about *STEM Techniques* can be valued primarily according to the attitudes about Learning Development and Students Benefits and less based on other variables. However, due to the small sample, the possibility of drawing generalized conclusions is low. In order to generalize the results, a bigger sample is needed.

CONCLUSION

Significance

As previously mentioned, this study aimed to explore EFL teachers' beliefs about the possibilities of the STEM approach in regard to interdisciplinary and 21st-century skills development in teaching EFL in primary and secondary school education. The results confirm that their beliefs about professional development are positively linked to teachers' attitudes toward all key principles, whereas several other variables are positively correlated with attitudes toward one or two key principles. The findings of this study are significant since they provide insight into the possible obstacles to the successful implementation of STEM education. The prior research results indicate that in some teaching contexts, 97% of elementary school teachers are ready to implement STEM-based contextual learning and 97% of them have implemented it in their teaching context (Shidiq & Nasrudin, 2021). However, this study was focused on contextual learning with an emphasis on the delivery of knowledge relevant to the concept as well as the student life.

The results of the present study further refine the previous findings. Experienced teachers especially struggle with inquiry-based learning and personalized learning. Therefore, these results indicate that professional development targeted at improving (attitudes toward) specific key principles and adapted to a person's background experience could be more useful than general professional development for improving teachers' attitudes and ultimately the implementation of STEM. In addition, by using a differential approach to examine teachers' attitudes, the research results also suggest possibilities for improving specific aspects of teachers' attitudes toward STEM. Professional development and access to technical resources are particularly important for improving teachers' attitudes toward the STEM concept. These findings are valuable, as they allow school administrators to pinpoint specific shortcomings in their school's current implementation of STEM and explicitly target these aspects.

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DEVELOPING CREATIVE AND CRITICAL THINKING THROUGH STEAM PROJECTS IN EARLY ENGLISH LANGUAGE LEARNING: A CASE STUDY

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Abstract: This case study explores how project-based STEAM activities in English foster creative and critical thinking in young children. The participants were two boys, aged 3 and 5, native Serbian speakers exposed to English as a foreign language daily. A pressure-free, whole-child learning environment based on Montessori principles and Bloom's taxonomy incorporated in STEAM activities supported their authentic learning experiences within the CLIL framework. Home-based projects addressed the boys' developmental needs and interests while encouraging exploration, creativity, and critical thinking. Over three years, the researcher documented their progress through audio and video recordings, photographs, drawings, and written observations. The findings suggest that STEAM projects, combined with Montessori principles and CLIL lesson plans, enhance creative and critical thinking in problem-solving situations in English. The study highlights the benefits of conducting complex STEAM activities in early English language learning for deeper engagement in the learning and thinking processes.

Keywords: Montessori, STEAM, CLIL, early English language learning, creative and critical thinking

INTRODUCTION

The 4Cs framework—content, cognition, communication, and culture— is a prerequisite for thriving in a global society (Coyle et al., 2010). The Montessori Method and STEAM (Science, Technology, Engineering, Arts, and Mathematics) educational concepts aim to prepare individuals to tackle personal and professional challenges (Slipukhina, 2022). Introducing Bloom's Taxonomy early enhances higher-order thinking skills (Benjelloun et al., 2019). STEAM projects grounded in Montessori principles and the CLIL (Content and Language Integrated Learning) approach can foster confident and creative learners.

This study aims to investigate how the combination of these educational concepts fosters critical and creative problem-solving. The theoretical background covers valuable insights, and the methodology describes the evolution

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of two significant projects over three years of research. The findings connect theory to practice and offer solutions, recommendations, and considerations for future research.

THEORETICAL BACKGROUND

Bloom's taxonomy

Bloom's taxonomy (Bloom, 1956; Anderson, 2001) categorizes cognitive skills into six levels, emphasizing higher-order thinking, including critical and creative thinking skills.

Benjelloun et al. (2019) demonstrated this framework's impact on improving vocabulary and cognitive skills in young English learners. After 12 weeks, struggling students advanced in analysis, and high-performing students expanded their vocabulary and communicated their ideas more effectively.

Creative and critical thinking skills

Creative thinking involves synthesizing disparate ideas to form innovative solutions, with individuals drawing from personal viewpoints to address societal challenges (Birgili, 2015; National Research Council, 2011). Critical thinking complements this by encouraging the analysis of problems from multiple perspectives (Dewey, 1933; Paul & Elder, 2014). Attitudes such as risk-taking and openness enhance creative abilities (Piirto, 2011; Robinson, 2011; Sternberg & Lubart, 1991). The shift from rote memorization to critical thinking in language learning enriches communication, idea generation, and confidence in language use (Li, 2016). The CLIL approach promotes cognitive and language development through scaffolding strategies (Lockley, 2013; Wilson, 2016).

CLIL

CLIL supports language acquisition and critical thinking through engaging activities, like storytelling and playtime, contributing to vocabulary enrichment and cognitive development (Coyle et al., 2010; Prošić-Santovac & Savić, 2022). Interactive creative methods (Benjelloun et al., 2019; Widiastutu et al., 2017) enhance critical thinking, while complex topics in early English language teaching (Cameron, 2001) foster the development of language skills.

STEM-STEAM

STEM education, particularly at home, utilizes tools such as construction toys, board games, everyday materials, and online resources to foster creativity and problem-solving (Mei, 2017; Vartiainen & Aksela, 2019). The integration of the Arts in STEM—transforming it into STEAM—further nurtures higher-order thinking, problem-solving, and collaborative skills (Wai Leng, 2023; Krüger, 2021).

Montessori Method

The Montessori Method also promotes creativity through independent learning and imaginative play. This philosophy of child development encourages convergent and divergent thinking, fostering essential skills for future innovation (Robson & Franco, 2023). According to Slipukhina (2022), it aligns with STREAM education, nurturing intellectual growth and societal responsibility. It is an educational approach that enhances communication, collaboration, and effective learning at all developmental stages.

METHODOLOGY

Research design

This case study examined the developmental trajectories of two young boys, Laki (aged three) and Kiki (aged five), as they acquired critical and creative thinking skills within the context of English language learning. The research incorporated CLIL-planned lessons and Bloom's taxonomy into two STEAM projects grounded in Montessori principles as part of a three-year retrospective ethnographic study. The involvement of the mother provided and supported the whole-child approach. It captured spontaneous and prompted speech moments in English at home and in other contexts.

The primary objective of this case study is to investigate how critical and creative thinking skills emerge and evolve in early English language learning over three years of STEAM-based projects in the CLIL framework.

Participants

The research spanned the period from when Kiki was 2 years and 4 months old (2; 4) and Laki was 10 months old (0; 10) to when they reached 5 years and 4 months (5; 4) and 3 years and 4 months (3; 4), respectively. English language learning started early with nursery rhymes, which naturally extended from the classroom practices of the researcher. Serbian was the primary language for family communication. Playtime, structured teaching sessions, and other interactions between the participants and the researcher occurred in English.

As Laki entered his second year, Kiki progressively started conversing with him in English. Code-mixing occurred but decreased.

The children's interests inspired the development of two STEAM projects: Laki's fascination with animals and dinosaurs (project "Animals") and Kiki's curiosity about nature, our planet, and the Solar System (project "The World").

Instruments

The researcher used various data collection methods, including audio and video recordings, photographs, participants' drawings, and written observational notes. Bloom's Taxonomy was applied to assess and enhance the participants' communication skills, ensuring systematic cognitive and linguistic development.

Procedure

English language learning started during playtime. As the children matured, it became evident that Montessori activities needed support for further cognitive development. The integration of STEAM-based interdisciplinary activities created additional opportunities to foster higher-order thinking. These project-based activities within the cognitive domain with CLIL lesson plans ensured the purposeful integration of content and language.

In the first year, the sessions were flexible and often included improvisation. The dynamics and complexity of projects evolved and shifted toward addressing real-life problems in meaningful contexts.

These activities promoted communication, cognitive engagement, and language development. The systematic application of Bloom's Taxonomy illustrated the progression of critical and creative thinking skills in English.

RESULTS

Table 1 presents the learning objectives for the "Animals" project. Each "C" section includes examples and explanations of critical and creative thinking in English.

Table 1. Project's objectives within 4C's framework (theme "Animals") (based on Coyle et al., 2010)

4C's Framework	Project's Objectives
Content	• to learn facts about animals and dinosaurs • to encourage respect for animals • to develop practices leading to the admiration of animals' differences • to empower critical and creative thinking

Critical thinking - analyzing (questioning, distinguishing, categorizing, and correlating the similarities between animal and human features)
The boys are working on a fossils kit. Kiki is digging and Laki is standing nearby and watching, ***Kiki 5; 1, Laki 3; 1***
K: You will see when I finish it. You have to be patient. Play something or run around. Yes, dinosaur is inside, I'll smash it out. Move Laki, I'll hit you with the hammer. (*I might hit you with the hammer*.)
Kiki found a fossil
R: Laki, what's that?
J: That's a baby dinosaur! T-Rex! I love T-Rex!
R: How do we call dinosaur bones? (*pause*) Fossils. And when we see the entire body made of bones?
J: Skeleton!
K: Do I have skeleton?
R: Yes.
K: Da li ti imaš skeleton?
R: Da, skelet. Svi imaju skelet.
K: Laki, you have skeleton!
L: Mummy, I got skeleton inside!

Critical thinking – evaluating (reflecting and commenting on the animal's appearance)
Visiting the village household and seeing some farm animals (sheep, pigs, hens) – ***Kiki 4; 1, Laki 2; 1***
L: It's a sheep!
R: It's a sheep! What does the sheep say?
L: Baaaaa.
R: Awww, look at the baby lamb, it's white and brown. It's sooo cute.
L: It's so sweet and shiny.
Laki associates the white color of the sheep's wool with the white color of the snow he experienced that same month.

Creative thinking – creating (adapting the stories to the context)
The researcher and the participants were testing the location of the light source and the changing size of shadows.
Inspired by the dark room and the flashlight, ***Laki 3; 1***
L: A scary story. (*puts the flashlight underneath his chin for a spooky effect*)
L: Once upon a time… It's a little spooooky story…a spooky…
R: A spooky…
L: Bear.
R: A bear?
L: Yes. Bear!
Laki likes children's books like "We're Going on a Bear Hunt" by Michael Rosen and "Brown Bear, Brown Bear, What Do You See?" by Bill Martin, Jr.

Cognition	• to develop participants' critical and creative thinking skills through lower and higher-order thinking questions • to develop participants' skills in asking questions that enable their critical and creative thinking skills development • to compare animals' features, footprints, food habits, sleeping habits, habitats • to compare dinosaurs, their size, features • to compare dinosaur herbivores and dinosaur carnivores

Critical thinking – analyzing (questioning and correlating the elements interacting in the experiment)
In the volcano experiment, Kiki realizes the relationship between baking soda and vinegar, ***Kiki 5; 4***
The scene for the volcano eruption was set outside, with volcano and dinosaur toys. The researcher gives Kiki vinegar to pour into the baking soda at the bottom of a volcano made from a plastic cup and aluminium foil.
R: Watch out, lava! That was the volcano eruption.
K: Can we put more vinegar? We want more eruptions. (*referring to his brother and himself*)

Critical thinking – evaluation (testing the size and shape of footprints)
Footprints in the snow (Guess whose footprint is it?)– ***Kiki, 5; 1, Laki 3; 1***
Kiki made footprints in the snow, then measured them and discovered all of his footprints. He also found Laki's and the researcher's footprints. The dogs' footprints were easy to identify, although Kiki initially pretended that they were bear footprints.

Creative thinking – creating (directing the imaginative role-play while incorporating knowledge about dinosaurs' distinctive features)
Laki wants to perform an act, starring Polar Bear (the researcher) and Triceratops (himself), ***Laki 3; 4***
L: I'm Triceratops, the herbivore. (inspired by the line in one *Sesame Street* episode about the dinosaurs)
R: But, you're a dinosaur. Dinosaurs are extinct!
L: Yes, we disappeared a looong time ago.
R: Is that a frill on your head?
L: Yes. And these are my horns, and my teeth. These are my arms.
R: How do you call your hands?
L: Manus. And these are my legs.
R: And, how do you call your feet?
L: Pes.
R: Nice to meet you my friend. I live at the North Pole. Do you like cold or warm weather?
L: Mmm…ergh…warm. Let's play "Guess Who"!
R: Ok. Me first. It likes fish, pears, and honey. And, it sleeps during winter.
L: It's a bear.
R: Yes, now it's your turn.
L: It's got a loong tail. It's got spikes. It's got small arms.
R: Is it T-Rex?
L: Yes!

Communication	• to acquire basic vocabulary, differentiate between regular and irregular nouns' pluralization rules, properly use the indefinite article "a/an" and pronouns, differentiate between Past, Present, and Future tenses, understand comparison of adjectives, and enhance the ability to describe (the language of learning) • to acquire new vocabulary and grammar through scaffolding (language for learning) • to acquire new content and language and to actively use the acquired knowledge to articulate meaning (language through learning)

Critical thinking – analyzing (explaining the difference through scaffolding)
*Laki mistakes the positive and comparative forms of the adjective 'big,' and Kiki corrects him, **Kiki 5; 4, Laki 3; 4***

K: No Laki, it's big, bigger and the biggest!

Critical thinking – evaluating (validating grammar rules in English language use)
*The boys were playing outside and making lots of fish in the plastic fish mold with mud, when the researcher initiated new lyrics to the tune of the song "Five Little Monkeys", in order to provide the context for learning irregular plural nouns; **Kiki 5; 4, Laki 3; 4***
R: Let's sing a song about fish, shall we?
Five little fish swimming in the sea,
One jumped high and hurt her fin.
Mummy called the doctor and the doctor said,
"No more fish jumping out of the sea".
The researcher removes one fish as they continue singing together until none are left. Kiki needed scaffolding a couple of times until he understood the rule. Laki required extra help, as he struggled with the irregular plural form and repeatedly said 'fishes,' although he regularly corrected himself after each instance of scaffolding.

Creative thinking – creating (adapting the imaginary scenario to the context while applying grammar properly)
*Imaginary rescue scenario, **Laki 3; 3***
Laki made a shelter using big sofa pillows to cover the gap between the sofa and the coffee table.
L: Mummy, let's hide.
R: Ugh, I'm too big.
L: It's too small. Imam ideju! I've got an idea.
R: What are we gonna do?
L: Look, volcano stopped erupting. We're safe now.
Not satisfied with his solution, he proposed another one shortly after so we could continue playing.
L: Let's make two shelters – one for you (*handing the pillow to the researcher*) and one for me.

Culture	• to develop the ability to empathize with animals • to develop an understanding of the relationships between people and animals

Critical thinking – analysis (correlating the facts and deducing a conclusion based on it)
*Laki spotted a caterpillar outside, **Laki 3; 4***
L: Look mummy, a big fat caterpillar. It's not hungry anymore. (*it's not moving because it's dead*)

Critical thinking – evaluating (validating the feelings in response to the outcome)
*Reaction to the scene in the animated movie "The Land Before Time", he realized that something had happened to Littlefoot's mum, **Laki 3; 2***
L: Mummy, I'm sad.
R: Why?
L: Dinosaur mummy.
Laki goes to sit on the floor in the corner of the room.
J: I'm so sad, mummy.
R: Why?
L: I'm so sad that dinosaur's mummy…
R: What happened to her?
J: It's not very well. It's hurt.
R: And where is she?
L: I don't know.
We hug.

Creative thinking – creating (collaboration and negotiating on the materials and colors of the bird-seed house)
*Inspired by bird-watching and based on their previous knowledge about resident birds (sparrows and great tits), we decided to make a bird-seed house – **Kiki 4; 11, Laki 2; 11***

Table 2 outlines the learning objectives for the "The World" project. Written examples illustrate the development of critical and creative thinking processes in early English language learning.

Table 2. Project's objectives within 4C's framework (theme "The World") (based on Coyle et al., 2010)

4C's Framework	Project's Objectives
Content	• to learn facts about countries and planets • to encourage respect for other nations and cultural heritage • to develop practices leading toward ecological awareness • to promote critical and creative thinking

Critical thinking – analyzing, **evaluating** (calculating, and testing the most effective transportation of water)
*Playing outside in the muddy puddles, self-initiated play, **Kiki 5; 4, Laki 3; 4***
The participants were transporting water with spades from one muddy puddle into another one with less water. Kiki found another more interesting way to transfer water. He was "making water slide" against the slightly inclined concrete plate and pouring water in the crease, whereas Laki decided to fill the bucket first and then pour the water in the other puddle.

Creative thinking – creating (building a famous bridge in London that we learned about)
*We are preparing wooden blocks to build a bridge, **Laki 3; 4***
L: Let's make a big one!
We are singing "London Bridge is Falling Down"

Cognition	• to develop participants' critical and creative thinking skills through lower and higher-order thinking questions • to develop participants' skills in asking questions that enable their critical and creative thinking skills development • to compare people, cultures, planets

Critical thinking – analyzing (deconstructing the story and correlating facts)

*The fairy tale "Snow White and the Seven Dwarfs", read and told many times, raises questions in Kiki, as does the cartoon series "Numberblocks", **Kiki 5; 2***
K: Why the king and queen live far away? Where?
R: I'm not sure. They didn't write which country, we only know that it's a country far away.
I continue telling the story.
K: Why the stepmother doesn't like Snow White?
R: Because she is jealous of her beauty.
Later on…
L: Mirror, Mirror on the wall,
Tell me,

Who's the Fairest of them all?
You are my Laki. (*we all laugh*)
The dwarfs are mentioned in the story for the first time.
K: Why is seven a lucky number? (*the number seven in the "Numberblocks" cartoon series is called "Lucky Seven"*)

Critical thinking – evaluating (predicting based on previous knowledge and arguing the given answers)

During part of a quiz, ***Kiki 5; 1***
R: Can you tell me, what is the color of the planet Mars?
K: Red.
R: Why?
K: Because it's hot and there are volcanoes. (*It is not hot, although it is red and it has volcanoes.*)
R: What about Uranus and Neptune? Are they hot planets?
K: Yes. They are hot. (*Smiling, because he likes occasionally giving the wrong answers on purpose.*)
R: Are they further from the Sun?
K: No, I see they are near.

Creative thinking – creating (solving the problem of sizes by negotiating the outcomes)

Laki was drawing family members, ***Laki3; 1***
Laki: Ovo je mama. (*Pointing at the drawing.*) Ovo je tata. (*Then draws another smaller head with features.*) Ovo je Laki. Ovo je Kiki. (*Draws a bit smaller head then the one he drew before, so he decides it is a baby.*) Hmmm… ovo je beba. (*Drawing another head for Kiki.*) Ovo je Kiki. Look, we're a family!

Communication	• to acquire basic vocabulary, differentiate between regular and irregular nouns' pluralization rules, use Past, Present, and Future tenses, learn how to ask questions, and enhance the ability to describe (language of learning) • to acquire new vocabulary and grammar through scaffolding (language for learning) • to acquire new content and language and to actively use the acquired knowledge to articulate meaning (language through learning)

Critical thinking – analyzing (questioning and structuring for a meaningful conversation)

Wishing a happy birthday to our cousin via viber video call, ***Kiki 5; 3***
R: Kiki, S. speaks English.
S: Hello, how are you?
K: I'm Kiki, I'm five. (*to excited to hear what she said*)
S: You're eating an apple?
K: Yes.
S: Is that your favorite fruit?
K: Yes. What's your favorite fruit?

Critical thinking – evaluating (experimenting on the previously made predictions)

Playing in the park, ***Kiki 5; 4, Laki 3; 4***
K: Come on Laki, don't be scared.
L: Come up, up, up! Wow, it's so fun! (after sliding down)
Kiki wants to clims backwards, in the opposite direction, going up the slide.
L: No Kiki, it's dangerous!

Kiki and Laki would communicate in English in the park with children attending school, whom are usually fascinated with their communicational skills and sometimes would ask if they had lived somewhere abroad
A twelve-year old boy B. (the boy and his dad agreed with the researcher to write down the first letter of the boy's name, but they also agreed on the boy's full name and age appearing in the research) *hears boys speaking in English while playing in the park, and addresses me*
B: Odakle su oni? Iz Amerike?
R: Ne, samo znaju da govore na engleskom.
B: Pa kako su naučili? Mali su.
The boy was then asking them to name objects in the park, translate words from Serbian to English. And every time he met them afterwards, he would great them in English and tell his friends about them.

Creative thinking – creating (collaborating while inventing a role-play)

Playing with the fire truck and the police car, ***Kiki 5; 4, Laki 3; 4***
K: I'm going to fix it.
L: I've got new ladder, I'm happy again. Weeeee! We've got new ladder. Yes, new ladder. He's fixed it. *(reffering to Kiki the mechanic)*
Changing roles, Kiki carries his traffic light in Laki's mechanic shop
K: Can you give me three new lights and one button. New.
L: The ladder is broken! (*focusing on the fire truck again*)
K: Huh… (*realizing Laki will not fix his traffic light; he switches it for the police car*) Laki, my tire is flat!
L: Yes.
K: Can you pump my tire?
L: Yes, c-c-c.

Culture	• to develop the ability to empathize with other people • to build an understanding of the relationships between people, nature, and food • to develop love for the family and the entire humanity

Critical thinking – analyzing (organizing and attributing according to size and shape)

While looking for pinecones – ***Kiki 4; 10, Laki 2; 10***
K: I found one!
L: Me too!
K: Another one!
After collecting them, we chose the ones we'd like to place on the kitchen table, arranging them to represent family members based on their shape and size

Critical thinking – evaluating (defending one's things, validating the rule of sharing, and experimenting with colors)

While painting – splashing color on a blacks sheet of paper, ***Kiki 4; 9, Laki 2; 9***
K: You don't have white. You need white.
L: I like white! (*Reaching for the watercolors.*)
K: No, those are mine!
R: Kiki, "Sharing is caring", remember?
K: Ok. (*sighs*) Here you are, Laki.
L: Thank you, Kiki!
R: Are we going to color the space?
K: Yes.
L: Like this, mummy. (*Puts the painting brush in the water and then chooses the color.*)
R: Yes, like that. So, what colors are we going to mix? When we mix yellow and…

K: Red.
R: What color do we get?
K: Orange.
R: Yellow and blue?
K: Green.
R: Blue and red?
K: Purple.

Creative thinking – creating (facilitating the existing notions of space and distance and composing them into inventive phrases)

*Kiki addressed the researcher, **Kiki 5; 4***
K: I love you to the planet Earth and back.
R: Do planete Zemlje? Ali mi živimo na planeti Zemlji.
K: Znam. To znači volim te malo. (*smiling*) I love you to the Neptune and back – znači volim te mnogo, zato što je to daleko. (*We hug and kiss.*)

DISCUSSION

The CLIL framework Coyle et al. (2010) suggested was particularly effective in promoting critical thinking in home-based learning. It allowed for the application of the English language in authentic, problem-solving contexts, consistent with Lockley (2013) and Wilson's findings (2016). The flexible nature of the lessons—especially during the first year—enabled an adaptive, responsive teaching approach that nurtured the children's natural curiosity and creativity.

Benjelloun et al. (2019) highlighted that interactive and creative teaching enhances critical thinking. This study illustrates how learning extends beyond traditional educational settings. The children's informal interactions with their mother in English played a significant role in language acquisition.

The boys' engagement with tasks such as analyzing animal fossils and features, conducting volcano experiments, constructing models, and creating imaginative stories in English exemplify the integration of Bloom's taxonomy and higher-order thinking skills' promotion—analysis, evaluation, and creation—through STEAM activities provided at home, as ones described by Mei (2017) and Vartiainen and Aksela (2019).

The analysis and synthesis of new knowledge were particularly evident in the children's ability to make connections across different areas of learning. For instance, Kiki's experiment with water transfer and the construction of a "water slide" involved critical thinking as he evaluated methods of solving a problem and came up with a creative solution. Similarly, Laki's imaginative play with dinosaur models demonstrated his ability to apply new concepts (e.g., herbivores vs. carnivores) in a role-playing context, fostering creativity and cognitive development.

The study also emphasizes the importance of scaffolding in supporting critical thinking development, particularly in language learning, as Lockley (2013) and Wilson (2016) proposed. Structured play, prompting questions, and direct language support enabled the children to refine their thinking, correct misconceptions, and engage in deeper learning, as outlined by Widiastutu et al. (2017). Cameron (2011) argued that complex concepts introduced in English language teaching can improve language skills in young learners. According to this study, these topics (e.g., dinosaurs, space, feelings) offered increased opportunities for the progression of language skills. They also encouraged thinking processes in problem-solving situations.

CONCLUSION

The findings of the "Animals" and "The World" projects underscore the critical role of thematic and content-driven activities in promoting higher-order thinking and language development. The children demonstrated significant progress in critical and creative thinking in English language learning, empowered by questioning, reflection, and imaginative play. Additionally, their ability to engage with complex topics such as animal behavior, geography, and empathy shows how early learning experiences can build a foundation for cognitive and emotional growth. These results affirm the importance of fostering inquiry-based learning in early childhood education. They also suggest that by linking content to real-world experiences, children can cultivate the cognitive and emotional tools necessary for understanding their world and engaging with others, even in a foreign language.

IMPLICATIONS AND FUTURE RESEARCH

This study has several practical implications for educators and researchers interested in early language acquisition and critical and creative thinking skills. Montessori principles, STEAM activities, and CLIL lessons offer a strategic paradigm for nurturing well-rounded learners. The findings suggest that combining these approaches can foster a deeper understanding of content while simultaneously developing critical thinking, creativity, and language skills.

Future research could explore the long-term impact of such interdisciplinary approaches on academic achievement and social-emotional development. Additionally, research could investigate how the 4Cs framework and Montessori-based methods influence problem-solving abilities in diverse cultural and educational contexts. Further studies could also examine the impact of parental involvement in the learning process and its role in supporting cognitive and language development.

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INTEGRATING STEM INTO EFL CURRICULUM THROUGH STEM DAY ACTIVITIES: LEARNERS' AND TEACHERS' PERCEPTIONS

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Abstract: Primary English Language curriculum is increasingly focusing on developing competencies beyond language skills and knowledge. Studies show that integrating English as a foreign language with STEM has been found beneficial for developing learners' cognitive academic L2 proficiency and interest in STEM disciplines. The paper aimed to study how STEM Day activities affected learners' perceptions of integrated English and STEM disciplines, and how the experience of planning and organizing STEM activities shaped teachers' perceptions of the approach. The study applied a phenomenographic approach, and a purposive sample involving a total of 40 fifth- and seventh-grade primary learners (aged 11 and 13 respectively) and seven teachers was selected from a state school in southern Serbia on the basis of their experiences in STEM Days. The data were collected using two online questionnaires with both closed- and open-ended questions. The data of *Learner STEM Survey* reported in this chapter aimed to measure interest in integrated English and STEM as a key component of learners' STEM attitudes. The results indicate that a majority of learners developed a positive interest in English and STEM disciplines, but the STEM Day experience was perceived differently by two sample age groups: younger learners expressed significantly higher interest in all STEM areas and for integrated English and STEM, being statistically significant for the area of technology. Moreover, there were statistically significant differences in perceptions resulting from gender differences, boys expressing higher interest in technology and mathematics. The teachers highlighted STEM benefits for learners and pointed to some organizational challenges. The findings support the integration of STEM into the primary EFL curriculum and indicate an advantage of an early start for developing learners' positive interest in key aspects of STEM.

Keywords: English and STEM integrated curriculum, primary learners' interest in STEM, primary teachers' perceptions of STEM, STEM Day activities.

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INTRODUCTION

STEM is an innovative approach that has become one of the main foci of educational reforms today (Chesky & Wolfmeyer, 2015). It focuses on the integration of the content areas of science, technology, engineering, and mathematics, and it can be applied at all levels of formal education, from pre-primary to secondary education**.** In primary education, STEM's educational value is primarily seen in deeper content learning and in the development of 21st century skills of primary learners, well-documented by a vast body of research (Bertrand & Namukasa, 2022; Erkut & Marx, 2005; Guzey et al., 2016; Honey et al., 2014; Hudson et al., 2015; Mahoney, 2010; Puška et al., 2023; Rosicka, 2016; Sultana et al., 2021). Relevant learning theories that support STEM are constructivism, experiential learning, and learning by doing in social interaction, while being supported by a more able peer or a more knowledgeable adult (Vygotsky, 1986). Some studies show that STEM can be very beneficial for enhancing interest of low-income students in STEM disciplines and for encouraging their future careers in STEM fields (Hansen et al., 2023). Moreover, studies indicate that early exposure to STEM activities can enhance marginalized children's learning and literacy development (Bermudez et al., 2023). Applied in developing countries, STEM education can contribute to the economic advancement of these countries by providing learners with quality education in science, maths, technology, and engineering, by popularising STEM disciplines in education, and by narrowing the gender gap in STEM fields and careers (Chesky & Wolfmeyer, 2015; Nawaz et al., 2023; Trott & Weinberg, 2020).

Although STEM has been spreading worldwide to ever younger learners, its application is still limited globally. The approach is generally considered to be challenging to apply due to a number of requirements, some of which relate to teachers' competencies, professional support, and teaching resources, while the others may result from the learning environment and learners' cognitive abilities (Boice et al., 2021; Honey et al., 2014; Tang et al., 2021). Furthermore, in teaching contexts where English as a foreign language (EFL) is integrated with STEM, the requirements also involve EFL proficiency of both learners and STEM teachers, STEM content knowledge of English teachers, and learners' readiness to engage in STEM activities in English. Teachers' perceptions have been found to play a crucial role in accepting and applying innovation in education, and also in determining its success (Savić et al., 2020). To determine how integrated English and STEM experience may shape learners' perceptions, the chapter studies primary learners' interest for English and STEM disciplines upon their participation in STEM Day activities, while teachers' perceptions are examined through levels of their engagement in preparing and teaching the STEM Day activities.

LITERATURE REVIEW

Integration of English and STEM

Supported by research, traditional views on teaching EFL that focused mainly on mastering the linguistic forms are being replaced by approaches striving to develop the necessary skills for understanding STEM disciplines and finding solutions to real-life problems (Sultana et al., 2021). STEM education combines teachers' discipline knowledge and pedagogical content knowledge when creating integrated English and STEM tasks that require learners to utilize inquiry-based learning and scientific language in classroom interaction, thus simultaneously acquiring STEM multi-disciplinary content knowledge and English. As Banerjee (2016: 16) argues, "although focus of language learning is not on the content, language learning experience for learners may be made more effective and interesting by making connections to other disciplines" as a real-world experience.

As a result, STEM education lesson plans usually differ from traditional EFL lesson plans in a number of aspects: first, they may adopt engineering design process with six stages, i.e. ask, imagine, plan, create, test, improve (Nawaz et al., 2023), or 5E lesson design, i.e. engage, explore, explain, elaborate, and evaluate (Moran et al., 2021); second, to guide learners in the process of solving problems, STEM lesson plans often combine concepts from different disciplines that learners need in order to better understand the problems; third, they usually require learners to collaborate in small groups, and to communicate and make decisions together; fourth, ideally they provide authenticity by linking the problems to real-world issues and making them more interesting and relevant to learners' lives; fifth, they require the use of technology in problem solution; sixth, they involve hands-on experiential activities which are learner-centered and provide fun for learners; finally, rather than expecting the solution of the problem, this approach to language teaching sees failures as learning opportunities (Nawaz et al., 2023). The younger the learners are, the more scaffolding with scientific language, engineering design, and statistical representations they will need from teachers.

Learners' Perceptions of STEM

Learners' perceptions have been considered reliable measures of STEM program success because they have been found to affect learner engagement and participation in STEM activities (DeJarnette, 2012; Erkut & Marx, 2005; Friday Institute for Educational Innovation, 2012; Mahoney, 2010; Puška et al., 2023; Tang et al., 2021; Trott & Weinberg, 2020; Zhang et al., 2021). Tang et al. (2021)

have found five factors affecting primary learners' engagement in STEM activities and their success in learning: proficiency in English, teacher's pedagogical approach, learners' learning interest, classroom climate, and learners' cultural diversity. The more proficient in English the learners are, i.e. the more comprehensible input and output, the more positive effects are seen in STEM academic outcomes. Some studies further indicated that age may have an effect on attitudes (Mahoney, 2010; Puška et al., 2023).

Students' STEM attitudes have so far been measured with several instruments (Erkut & Marx, 2005; Friday Institute for Educational Innovation, 2012; Mahoney, 2010). Aiming to increase the number of girls in science in the United States, a group of experts developed a project involving science units for 8th-grade students and questionnaires for measuring and comparing students' attitudes toward science, mathematics, and engineering before and after teaching the new science units (Erkut & Marx, 2005). Pre- and post-intervention scores indicated that all students' attitudes toward science improved, but not toward mathematics and engineering. The study also found statistically significant differences in attitudes between male and female students, with male students having more positive attitudes for the content areas of technology and engineering, but there was no statistically significant difference based on gender for the content areas of science and mathematics (Erkut & Marx, 2005). Mahoney (2010) describes a complex process of designing and validating a student attitudinal instrument through the collaborative efforts of a number of experts. Interest, perceived ability, and value were thus found to be the main elements of the cognitive and affective response of learners to STEM. The application of the instrument with secondary school students showed some statistically significant differences between groups of older and younger students, the latter group expressing statistically significant higher levels of attitudes for mathematics, while there was no statistically significant difference in age groups' attitudes towards content areas of science, technology and engineering (Mahoney, 2010). Learners' age seems to play a significant role in how learners perceive STEM disciplines, documented by some more recent studies with primary learners, while gender does not consistently cause such differences (Leonidas de Oliveira et al., 2022; Puška et al., 2023).

Teachers' Perceptions of STEM

Teachers' beliefs about STEM and their teaching strategies play a crucial role in the success of STEM education (van Driel et al., 2018), especially with English language learners (ELLs) who may struggle to master mathematics and science concepts (Min et al., 2023). To make STEM content accessible to all learners, teachers need to acquire STEM discipline knowledge and develop and apply effective STEM education pedagogy (Collier et al., 2016). Interviews with pre-service primary school teachers revealed their anxiety related to teaching ELLs in linguistically and culturally responsive ways and put forward the need for developing effective scaffolding strategies, such as multimodal extralinguistic support through visual and auditory aids, body movements, and hands-on activities that rely on learners' senses and aid comprehension through different channels (Min et al., 2023). Additionally, García-Carrillo et al. (2021) found out that pre-service primary teachers had positive attitudes toward STEM education in spite of the number of challenges experienced when teaching coding and robotics in the classroom, viewing STEM as a beneficial approach both for the learners and the teachers.

Teachers' perceptions of STEM are shaped by the challenges related to its application, the biggest being crowded classes, lack of infrastructure, inadequate teacher qualification and training, low teacher motivation to introduce change and STEM innovation, outdated curriculum, obsolete standards, and textbooks that lack interesting content (Nawaz et al., 2023). To teach the STEM integrated curriculum effectively teachers need to develop pedagogical strategies for the successful incorporation of hands-on and inquiry-based activities that can help children understand abstract concepts in STEM disciplines, the key skill being "pedagogical expertise in scientific inquiry and technological design" (DeJarnette, 2012: 80). Besides developing the skills for successful collaboration with colleagues, STEM teachers need professional skills that support deep learning (Fullan & Langworthy, 2013). Teachers' engagement in STEM, from collaborative planning of STEM events to reflecting on their teaching effectiveness, provides opportunities for them to enhance their own scaffolding strategies and confidence to apply STEM regularly and thus nurture positive learners' perceptions of STEM.

Best Practices in STEM Teaching in Serbia

Although the Serbian Primary Curriculum does not explicitly give instructions about STEM teaching, a document titled Framework for Elective Activities (Eurydice Unit Serbia, 2022; MoESTD, 2021) instructs primary teachers to provide a variety of opportunities for upper-primary grades learners (ages 11 – 14) to develop lifelong learning skills and autonomy needed for thriving in life and career. Considering the suggested themes and types of learner and teacher involvement described in the Framework, many of the STEM principles are applied. Planning and realizing the program according to the Framework is determined as the responsibility of schools and teachers. This means that teachers' cross-curricular pedagogical skills and their positive perceptions of STEM innovation are keys to successful application of the Framework.

One of the researchers in the present study has designed and implemented a number of STEM activities aligned with the Framework, designed with a specific thematic focus, integrating English with STEM subjects in STEM Days for upper-primary grades. The activities aimed to contribute to learners' linguistic development while simultaneously providing opportunities for content knowledge acquisition. Two STEM Days will be briefly described (see also Savić & Živković, 2024).

1*. Maths Pirates and the Lost Treasure.* This STEM Day scenario integrated English with the school subjects of Mathematics, Computer Science, and Home Economics, and comprised four consecutive STEM Day sessions lasting 225 minutes. The scenario, designed by one of the authors of this chapter, is available online in European Schoolnet Academy MOOC *STEM Out-of-the-box* as an example of the best practice in teaching STEM in Europe (European Schoolnet Academy, 2023). This STEM Day theme was a treasure hunt in which English was used as the language of all activities, aiming to develop learners' literacy in English (writing a description), their financial literacy (counting money, converting different currencies, saving, spending and donating money, and understanding new economic concepts), and digital literacy (coding and computational thinking for navigating a map). The activities involved real-life situations that required solving maths problems and navigating a map, making decisions, negotiating opinions, asking and answering questions, and thinking critically and creatively. STEM Day ended with a visit by a guest speaker, an economics expert, who answered learners' questions about earning, spending, and saving money. To create the materials and activities the teachers used a number of online applications, such as Ginzy for teachers, Wordwall, Wakelet, Mentimeter, Bookcreator, QR code generator, and currency converter. Teacher-designed materials comprised a glossary of new words, a pirate word search, a pirate vocabulary quiz, a financial literacy quiz, interactive game-like maths activities, and money notes maths problems. Learners worked in groups, collaborated and supported each other, created maths problems for each other, gave feedback to each other, investigated the problem of finding a hidden treasure, proposed solutions, and asked and answered questions. Teachers applied the formative assessment procedure to monitor learners' progress, while learners participated in an anonymous poll on Mentimeter to evaluate the difficulty of specific activities and their own STEM Day experience.

2. *Aerospace in Class*. This STEM Day activity implemented a flipped classroom method. The theme was space and the design of a moonbase/house on the Moon within the Airbus Foundation Discovery Space project. Learners were given materials and tasks online dealing with concepts and vocabulary in English related to life on the Moon characterized by low gravity and the absence of atmosphere. STEM content areas explored were the subjects of

Science, Mathematics, and Engineering. The main task was to design a house on the Moon, to make a 3D model of it, and to describe it in English. The English teacher collaborated with class teachers to design tasks and select teaching materials by using applications such as Quizlet for reviewing vocabulary, and videos created by Airbus Foundation Discovery Space for explaining the conditions on the Moon and the qualities of materials needed to build a house there. The science content included types of building materials and their qualities, while the math content dealt with different shapes and calculations of angles in them, and engineering content involved both creative design and 3D model building. Working individually, learners designed and created 3D models of their houses on the Moon, took photos of them and shared photos with the teachers together with detailed descriptions of the house. The 3D models were created from cardboard, paper, LEGO blocks, plastic boxes, plastic bottles, plastic glasses, paper plates, paper rolls, and aluminum foil, in a number of shapes, from a ball, rectangular box, and sphere, to rather unique shapes and designs.

The present study of sample learners' and teachers' perspectives of STEM is mainly based on their experience in the above two STEM Days.

Aim of the Study and Research Questions

The aim of the study was to determine sample primary school learners' and teachers' perceptions about the integration of English with STEM disciplines in STEM Day activities, based on their participation in STEM Days described in the above sub-section. Being an innovative approach in Serbia, STEM is gaining the attention of enthusiastic teachers, but has so far not been researched in the Serbian primary teaching context. This gap asks for studies of all aspects of introducing the innovation, even on a small scale. In line with international studies dealing with learners' and teachers' attitudes to STEM, we focused on the construct of interest of STEM disciplines and English integration, on how it is shaped by learners' age and gender, and on teachers' perceptions of their STEM experience. Together with perceived ability and value, interest is a component of STEM attitudes which refers to learners' awareness, i.e. their initial interest in STEM disciplines, their internal motivation in STEM disciplines, and their long-term commitment to participating in activities that involve STEM disciplines (Mahoney, 2010). We posed the following four research questions:

RQ1: What is the sample learners' interest in integrated English and STEM?

RQ2: How does age affect sample learners' interest in integrated English and STEM?

RQ3: How does gender affect sample learners' interest in integrated English and STEM?

RQ4: What are sample teachers' perceptions of integrating English and STEM disciplines?

Considering the results of the previous studies of learners' and teachers' perceptions of STEM (Erkut & Marx, 2005; García-Carrillo et al, 2021; Mahoney, 2010; Nawaz et al., 2023; Puška et al., 2023), we expected generally positive attitudes of both groups.

METHODOLOGY

Research Design

This cross-sectional survey applied a phenomenographic approach with purposive samples of learners and teachers who responded to the survey issues. We performed a phenomenographic examination of the participants' experiences in STEM Day activities (Velasco & Hite, 2023). The aim of the study was twofold, i.e. to reveal sample learners' perceptions of STEM disciplines and English, in terms of interest, and how they are affected by learners' age and gender, and to analyze teachers' experiences of STEM Day activities and their conceptions of STEM. The study was extensive and a part of the results dealing with learners' perceived ability and value of STEM has already been published (see Savić & Živković, 2024), while the present chapter aimed to investigate learners' interest in English and STEM disciplines, interest regarded as an attitudinal component (Mahoney, 2010). We applied a mixed-method design and performed the analysis of quantitative and qualitative data to measure learners' and teachers' perceptions.

Sample

Participants were 40 primary school learners (*learner sample*) and seven primary school teachers (*teacher sample*) from a state primary school located in a city in southern Serbia. The sampling was purposive and only the learners and teachers who had participated in at least one STEM Day held in the school within the regular curriculum were invited to take part in the study. A total number of 40 primary learners participated in the study, representing the learner sample, distributed into two age/grade groups (AG, see *Table 1*).

Table 1: Demographic characteristics of the learner sample.

Learner Sample AGs	N	Girls N (%)	Boys N (%)	Age	Grade	Started EFL at preprimary N (%)	Started EFL in Grade 1 N (%)
AG1	23	13 (56.5)	10 (43.5)	11	5	11 (47.8)	12 (52.2)
AG2	17	8 (47.1)	9 (52.9)	13	7	9 (52.9)	8 (47.1)
Total	40	21 (52.5)	19 (47.50)	-	-	20 (50.0)	20 (50.0)

The teacher sample (see *Table 2*) comprised two class teachers (T2 and T3) and five subject teachers (one of them being a researcher in this study), with mean age of 49 years and teaching experience ranging from 10 years to more than 25 years. Their experience with STEM Day organization and teaching was diverse, from one STEM Day to more than 10 STEM Days.

Table 2: Demographic characteristics of the teacher sample.

Teacher Sample	Gender	Qualification	School Subject	Years of Teaching Experience	STEM Day Experience
T1	female	BA English Language and Literature	English Language	19	10+ STEM Days
T2	female	BA Class Teaching	Class Teacher	22	Several STEM Days
T3	female	BA Class Teaching	Class Teacher	24	Several STEM Days
T4	female	BA Physics	Physics	25	One STEM Day
T5	female	MA English Language and Literature	English Language	25 +	Two STEM Days
T6	male	MA ICT	ICT	10	Several STEM Days
T7	female	MA Geography	Geography	10	Several STEM Days

Instruments

Two instruments were applied in the study: the *Learner STEM Survey* and the *Teacher STEM Survey.* They were designed by the researchers drawing on several sources (Erkut & Marx, 2005; Friday Institute for Educational Innovation, 2012; Guzey et al., 2016; Mahoney, 2010). *Learner STEM Survey* was a comprehensive questionnaire with five perception scales, from which we are hereby reporting the results collected with 15 items (three statements for each of the five subject areas) of the scale for measuring sample learners' interest in integrated English and STEM disciplines: a) [*subject*] *is fun;* b) *I love* [*subject*]; c) *I like it when on STEM Day we do* [*subject*] *in English.* For clarity and understanding the statements were given in Serbian, sample learners' native language, and phrased positively. *Teacher STEM Survey* was a questionnaire with two perception scales, comprising a total number of 19 items about the cross-curricular approach on STEM Days and four open-ended questions about the benefits and challenges of planning and realizing STEM Days. All statements in both instruments were ranked on a five-point scale: 1 = *strongly disagree*, 2 = *disagree*, 3 = *neither agree nor disagree*, 4 = *agree*, 5 = *strongly agree*.

Procedure and Data Generation and Analysis

The attitudinal instruments were designed as Google Forms: The links were distributed as QR codes, filled out in regular classes (*Learner STEM Survey*) and in school premises (*Teacher STEM Survey*) on school days in February 2024. The informed consent was obtained by all participants at the beginning of each survey. The data collected were analyzed quantitatively using the SPSS tool for Windows, version 23.0 so that the results appeared both as percentage, median (M) and standard deviation (SD) values. To compare and interpret median values the following group boundaries were used: *very low:* 1.00 - 1.80; *low:* 1.81–2.60; *moderate:* 2.61–3.40; *high:* 3.41–4.20; and *very high:* 4.21–5.00 (Narli, 2010). Only *moderate*, *high*, and *very high* scores (M > 2.61) were considered positive attitudes. To interpret the responses to open-ended questions collected with the *Teacher STEM Survey* thematic analysis was carried out.

RESULTS AND DISCUSSION

Findings are organized into three sub-sections related to the study's research questions. The learner sample's interest results are presented in *Table 3* and *Table 4*, while teacher sample's results are shown in *Table* 5. All scores are given as M and SD values. Additionally, the learner sample's interest scores for English and STEM subject areas run in parallel for two age groups to enable easy comparison (see *Table 3*).

Table 3: Sample learners' interest scores of integrated English and STEM disciplines per individual subjects and per two age groups (AG1 & AG2, see Table 1) (on a scale 1 – 5, from strongly disagree to strongly agree).

No.	Item	Age Group	M	SD
English Language Learning				
1.	English is fun.	AG1	4.30	1.063
		AG2	3.18	1.551
2.	I love English.	AG1	4.09	1.083
		AG2	3.59	1.326
3.	I would like to have STEM Day in English more often.	AG1	3.91	1.311
		AG2	2.76	1.251
Mathematics				
4.	Math is fun.	AG1	2.70	1.608
		AG2	2.41	1.372
5.	I love math.	AG1	2.91	1.443
		AG2	2.71	1.572
6.	I like it when on STEM Day we solve interesting math problems in English.	AG1	3.39	1.672
		AG2	2.24	1.251
Technology				
7.	Technology is fun.	AG1	4.43	.945
		AG2	3.06	1.478
8.	I love Technology.	AG1	4.26	1.251
		AG2	2.88	1.219
9.	I like it when on STEM Day we use Technology with English.	AG1	4.00	1.279
		AG2	2.29	1.404
Science				
10.	Science is fun.	AG1	3.91	1.164
		AG2	3.47	.943
11.	I love science.	AG1	3.70	1.259
		AG2	3.47	1.007
12.	I like it when on STEM Day we do science in English.	AG1	3.61	1.469
		AG2	2.82	1.286
Engineering				
13.	Engineering is fun.	AG1	3.96	1.261
		AG2	2.82	1.551
14.	I love engineering.	AG1	3.61	1.373
		AG2	2.88	1.409
15.	I like it when on STEM Day we do engineering in English.	AG1	3.43	1.308
		AG2	2.53	1.328

Sample Learners' Interest in Integrated English and STEM

The results indicate that the affective category of interest varied in different STEM areas and English. Generally speaking, all sample learners expressed positive interest in English and individual STEM subjects. The highest interest was expressed for English (see scores for items 1&2, M between 3.18 – 4.30) and science (items 10 & 11, M between 3.47 – 3.91), while the lowest was shown for mathematics (items 4 & 5, M between 2.41 – 2.91). Although the scores for technology and engineering ranged from *moderate* (items 7, 8, 13, & 14, M between 2.82 – 3.06) to *high* and *very high* (items 7, 8, 13, & 14, M between 3.61 – 4.43), sample learners' motivation and awareness for these two STEM areas appeared to be lower than for English and science.

By expressing mainly *high* and *very high* interest in English, the sample learners indicated their high awareness (item 1) and motivation (item 2) for studying this foreign language. On the other hand, their preferences for mathematics were lower when compared to other STEM disciplines. These findings are contrary to the results of some previous studies (Mahoney, 2010) and may have been caused by their low mathematical proficiency and/or the way mathematics was taught in their teaching/learning context. On the other hand, both age groups' high interest in science may be the result of their shared curiosity in this area and the way science was taught in the particular context at both grade levels (Savić & Živković, 2024).

In reference to the long-term interest in integrating English with STEM Day activities, sample learners expressed *moderate* to *high* interest (item 3, M between 2.76-3.91). Regarding the integration of English with individual STEM disciplines, the interest was positive only for science (item 12, M between 2.82 – 3.61), while for the other three disciplines, it varied a lot depending on sample learners' age, being positive for AG1 (items 6, 9, & 15, M between 3.39 –4.00) and negative for AG2 (items 6, 9, & 15, M between 2.24 – 2.53). This aspect of research will be discussed in relation to RQ2.

The Effects of Age on Sample Learners' Interest for Integrated English and STEM

To answer the question related to the effect of age on sample learners' perceptions, their interest was measured for all five areas in the form of separate scores per two age groups (see *Table 3*). The findings show that younger sample learners (AG1) were more interested in English and STEM disciplines than the older ones (AG2), the largest interest gap between them being for technology (items 7 & 8), where AG1 expressed *very high* interest, while AG2 showed only *moderate* interest. Regarding motivation for English (item 1), AG1 expressed *very high* motivation, while AG2 indicated *moderate* motivation. Noticeable differences in motivation between the two age groups were also reported for engineering (items 12 & 13) and science (items 10 & 11), with AG1's motivation being consistently *high*, and AG2's motivation *moderate*, approaching *low* (negative) interest for engineering. Both groups expressed *moderate* motivation (item 5) for mathematics, while their awareness (item 4) differed, being *moderate* for AG1, but *low* for AG2. The higher preferences for STEM disciplines of younger learners are in line with previous studies (Mahoney, 2010; Puška et al., 2023; Zhang et al., 2021) and may have been the result of less complex STEM content in grade 5 curriculum as compared to grade 7 STEM subjects curriculum, especially for mathematics, that fostered younger sample group's self-confidence (Savić & Živković, 2024).

AG1 also expressed a highly positive interest for integration of English with technology, science and engineering (items 9, 12 & 15), while AG2's interest was negative for technology and engineering (items 9 & 15), and moderate for science (item 12). Mathematics received the least interest of all STEM areas, which was *moderate* for AG1 (items 4, 5 & 6), and negative, i.e. *low,* for AG2 (items 4 & 6). Generally, the younger sample group expressed more positive interest regarding language-integrated STEM than the older sample group, with the largest interest gap expressed for engineering. These findings are partly in line with previous studies documenting STEM age-related differences in learner attitudes (Puška et al., 2023; Zhang et al., 2021). They indicate that younger learners may have been more open to STEM education and the use of English in STEM activities, or that their experience in STEM Day activities was more favorable (Savić & Živković, 2024).

Mann-Whitney test showed that there was a statistical significance concerning age only in scores on interest towards technology ($U=79.500$, $Z=-3.311$, $p=.001$), while the difference in interest toward English, mathematics, science, and engineering was not statistically significant. This is in contrast to some previous studies that found statistically significant more positive attitudes of younger learners only for mathematics (Mahoney, 2010), but corroborates some other studies (Puška et al., 2023).

The Effect of Gender on Sample Learners' Interest for Integrated English and STEM

To answer the third research question, we measured differences in sample learners' interest in English and STEM disciplines in terms of gender. Table 5 shows the mean values and standard deviations of scores in all five areas for girls (1) and boys (2) in the whole sample and for two separate age groups (AG1 & AG2).

Table 4: Differences in means of scores on interest in English and STEM disciplines for girls (gender 1) and boys (gender 2) for the whole learner sample (N=40) and for two age groups (AG1, N=23; AG2, N=17) (on a scale 1 – 5, from strongly disagree to strongly agree).

No.	Content area		Learner sample N=40		AG1 N=23		AG2 N=17	
		Gender	M	SD	**M**	**SD**	**M**	**SD**
1.	English	1	3.52	1.365	3.77	1.235	3.13	1.553
		2	**4.26**	.872	**4.50**	.707	**4.00**	1.000
2.	Mathematics	1	2.48	1.436	2.23	1.235	**2.88**	1.727
		2	**3.21**	1.475	**3.80**	1.229	2.56	1.509
3.	Science	1	**3.62**	1.203	**3.77**	1.235	3.38	1.188
		2	3.58	1.121	3.60	1.350	**3.56**	.882
4.	Technology	1	3.19	1.436	3.77	1.481	2.25	.707
		2	**4.21**	1.182	**4.90**	.316	**3.44**	1.333
5.	Engineering	1	**3.48**	1.470	**3.62**	1.446	**3.25**	1.581
		2	3.11	1.370	3.60	1.350	2.56	1.236

It can be seen in *Table 4* that sample boys expressed more positive perceptions of English and technology in all three measures, while girls had more positive attitudes toward engineering in all three measures. Mann-Whitney test for the whole sample showed that the difference in interest towards technology was statistically significant (U=115.500, Z= -2.373, p=.018). In the younger sample, statistical difference based on gender was significant for interest toward mathematics (U=25.000, Z= -2.549, p=.011) and technology (U=30.000, Z= -2.494, p=.013), boys expressing more positive interest in these two disciplines, which corroborates previous studies (Erkut & Marx, 2005). Regarding the older group, Levene's Test for Equality of Variances and the t-test for Equality of Means showed that there was a statistically significant difference in attitudes towards technology between girls and boys (t(15)= -2.261, p=.039). It can be concluded that although there were differences in attitudes towards all four STEM areas and for English between girls and boys, the gender difference proved to be statistically significant only for technology and mathematics. These findings corroborate some earlier studies (Erkut & Marx, 2005; Mahoney, 2010), but are contrary to some other studies (Puška et al., 2023), asking for more research in the area.

Sample Teachers' Perceptions of Integrating English and STEM Disciplines

Teacher STEM Survey provided two sets of data: I. sample teachers' perceptions of the effectiveness and benefits of integrating English with STEM disciplines in STEM Day activities (see *Table 6*, items 1 – 11); II. sample teachers' perceptions of the challenges of planning and organizing STEM Day activities (see *Table* 6, items 12-19). As all items were positively phrased, the higher the score on a five-point scale (ranked 1 – 5, from *strongly disagree* to *strongly agree),* the higher agreement of the sample. The participants evaluated three aspects of STEM Day activities *very high* (M>4.21): integrating English and science at appropriate grade level, and encouraging learners to communicate in English while doing activities and working on tasks. These data support sample learners' highly positive attitudes to science and the integrated English and science curriculum described above. The other aspects were evaluated *high* (3.41<M<4.20): integrating mathematics at appropriate grade level, encouraging learners to use English to express their opinion, ask questions, communicate science and mathematics concepts, express engineering thinking, and find information on the internet. It can be concluded that sample teachers rated their experiences in STEM Day activities and the role of English rather positively, which is in line with the findings of studies of teacher STEM perceptions (Boice et al., 2021).

Regarding sample teachers' rating of their experiences of planning and organizing STEM Day activities, the participants' agreement was *very high* (M>4.21) about the following requirements: collaboration of teachers of different STEM and non-STEM school subjects (item 12); a lot of extra time and engagement (item 14); and co-teaching by the English teacher and STEM teachers (item 16). Their agreement was *high* (3.41<M<4.20) in relation to the need for the English teacher to learn concepts from STEM school subjects and to design new teaching materials. They also agreed that an extra budget for STEM Day activities was not needed, as the activities were inexpensive and did not require a large space with computers and the internet. These findings are in line with studies about successful STEM programs in low-resourced learning and teaching environments (Nawaz et al., 2023) and indicate sample teachers' highly positive attitudes to STEM Day experiences.

Table 5: Results from Teacher STEM Survey (N=7) on a scale of 1 – 5, from strongly disagree to strongly agree).

	I. STEM Disciplines		
No.	Item	**M**	**SD**
1.	STEM Day activities integrated mathematics concepts that are grade-level appropriate.	4.14	1.464
2.	STEM Day activities integrated science concepts that are grade-level appropriate.	4.29	1.496
3.	STEM Day activities integrated English skills that are grade-level appropriate.	4.43	1.512
4.	STEM Day activities encouraged learners to use English in communication.	4.29	1.496
5.	STEM Day activities encouraged learners to express their opinions in English.	4.14	1.464
6.	STEM Day activities required learners to ask questions in English to justify their opinions in English.	4.00	1.414
7.	STEM Day activities required learners to communicate science concepts (e.g., oral, written, or using visual aids such as charts or graphs) in English.	3.86	1.676
8.	STEM Day activities required learners to communicate engineering thinking in English.	3.71	1.604
9.	STEM Day activities required learners to communicate mathematics concepts in English.	3.71	1.890
10.	STEM Day activities require learners to use technology to solve a problem.	3.57	1.813
11.	STEM Day activities required learners to use technology to find information in English for the solution of a problem.	3.86	1.952
	II. STEM Day Planning and Organization		
No.	Item	**M**	**SD**
12.	Planning STEM Day activities required teachers of different school subjects to collaborate.	4.43	1.512
13.	Planning STEM Day activities required an English teacher to learn concepts from STEM school subjects.	3.86	1.464
14.	Planning STEM Day activities required a lot of extra time and engagement of the participating teachers.	4.43	1.512
15.	Planning STEM Day activities required designing new teaching materials.	4.00	1.414
16.	Organizing STEM Day activities required co-teaching by the English teacher and STEM teachers.	4.43	1.512
17.	Organizing STEM Day activities required an extra budget.	2.00	1.528
18.	Organizing STEM Day activities was expensive.	1.86	1.464
19.	Organizing STEM Day activities required a large space with computers and the internet.	2.43	1.512

CONCLUSION

Foreign language learning pedagogy advocates for contextual language teaching through the introduction of real-world issues into the language classroom (Shin et al., 2021). STEM education offers highly appropriate conditions for such integration primarily by responding to language learners' variety of interests and their natural curiosity. The study measured primary learners' perceptions towards integrating English and STEM, based on their experiences in STEM Day activities provided in a primary school context in Serbia. The perceptions were evaluated in terms of learners' interest in English and STEM subjects, and for their integration. The results showed that sample learners exhibited mostly positive perceptions, but their level of interest varied greatly in relation to their age. While younger sample learners expressed *very high* and *high* interest in English, science, technology, and engineering, and *moderate* interest in mathematics, older sample learners exhibited *high* interest only in science, *high* to *moderate* in English, *moderate* for technology and engineering, and *low* to *moderate* for mathematics. The interest gap was even broader in measures for integration of English with STEM content areas, being consistently *high* for younger sample learners, but *moderate* to *low* for older ones.

Although in our study statistical significance was detected for two age groups only for the content area of technology, and not for mathematics, science, and engineering, it is important to stress that younger sample learners exhibited higher levels of interest in these content areas and also for integration of English with each of them. Moreover, there were statistically significant differences in perceptions resulting from gender differences, with boys expressing a higher interest in technology and mathematics. It may be concluded that interest in English and STEM disciplines diminishes with age, especially the interest for integration of English with STEM subjects in STEM Day activities, and that gender also plays an important role in shaping primary learners' interest in STEM content areas, with boys expressing statistically significant more positive interest in technology and mathematics, and girls in engineering. The results related to sample teachers' perceptions towards integrating English and STEM disciplines support high interest of the sample in science, but do not reveal any factors responsible for older sample learners' lower levels of interest in STEM disciplines, and English and STEM integrated teaching. It is significant to point out the results regarding sample teachers' positive perceptions of introducing English and STEM, their enthusiastic approach to applying this innovative approach to teaching their respective content areas, and their commitment to organizing STEM Days in the future.

The results of this study cannot be generalized mainly because they are too context-specific and the samples were too small. In the future, larger and more varied primary learner and teacher samples should be surveyed. Also, interest in integrated English and STEM should be studied through primary learners' achievement in English and STEM school subjects to determine the effectiveness of the approach, especially to reveal how English and STEM integration foster language development and STEM content understanding. Moreover, longitudinal studies should be conducted to confirm or disconfirm the influence of age and gender factors on primary learners' interest in English and STEM. The findings of our study call for raising primary teachers' awareness of the positive interest of younger learners in integrated STEM curriculum, and of the need to regularly expose language learners to STEM Day activities so that their positive interest is sustained. Also, teachers should be aware that their encouragement may be crucial for enhancing the levels of older learners' interest in English and STEM integration, and for fostering girls' more positive attitudes toward science, mathematics, and technology. Positive perceptions of both learners and teachers in our study are promising.

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III

STEM/STEAM/STREAM APPROACH AND IT TEACHING MODELS

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EXPLORING PRIMARY SCHOOL STUDENTS' MOTIVATION AND ENJOYMENT IN LEARNING PROGRAMMING THROUGH GAMIFICATION

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Abstract: Globally, a growing trend and numerous initiatives are focused on reducing the age at which programming is introduced, leading to the implementation of updated computing curriculums in many countries. In Serbia, the informatics curriculum underwent a significant transformation in the 2017/2018 academic year, gradually becoming a compulsory course throughout all grades in elementary schools. Programming, a prominently featured subject, is primarily taught through gamification. Despite this, the research investigating the coding motivation and enjoyment among primary school students in Serbia when acquiring programming skills through gamification is fairly limited. These factors are crucial, given their documented influence on the practical application of games in programming. This study seeks to explore the variables that impact the motivation and enjoyment of primary school students in learning programming. Surveying 108 participants, a multiple linear regression analysis identified positive effects of enjoyment and social influence on students' motivation. Conversely, self-efficacy demonstrated no direct effect on motivation. Additionally, the results indicated a positive correlation between primary school students' self-efficacy and perceived enjoyment. The research offers practical insights for educators and policymakers. Understanding the motivational factors and enjoyment levels in learning programming through gamification can guide the design of effective teaching strategies. Educators can leverage these insights to tailor approaches, emphasizing the elements that enhance enjoyment and social interaction. Policymakers should consider these results when refining curriculum guidelines, ensuring alignment with students' motivation for a positive learning experience. Teacher training programs can incorporate these findings to better prepare educators for optimizing the gamified learning environment in programming education.

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Keywords: programming education, gamification, primary school, coding motivation, enjoyment

INTRODUCTION

In today's tech-driven world, there's a growing need to develop skills for navigating the digital era. Computational thinking (CT) has become vital, fostering analytical and problem-solving skills crucial for coding proficiency (Wing, 2006; Tsai et al., 2019). Integrating programming skills into education can enhance CT abilities, that are essential for future readiness, particularly among primary school students (Popat & Starkey, 2019; ISTE, 2016).

Educational resources promoting CT include various tools like digital games, robotics, and programming platforms (Shute et al., 2017). Digital games provide special benefits for student-centered e-learning environments within traditional classrooms (Giannakoulas & Xinogalos, 2018).

Many nations are updating their computing curricula by introducing programming at younger ages (Education Bureau, 2016). In Serbia, a significant shift occurred in 2017/2018, making informatics mandatory across all elementary grades, with programming taught mainly through gamification (Regulation I-IV, 2023; Regulation V-VI, 2023; Regulation VII, 2023; Regulation VIII, 2023).

Numerous global initiatives have integrated coding games into elementary curricula, resulting in improved problem-solving, coding skills, and learning attitudes (Kazimoglu et al., 2012; Bachu & Bernard, 2011; Theodoropoulos et al., 2017). While the reasons behind children's motivation in coding activities are not fully understood, emotions likely play a crucial role, prompting more research in this area (Papavlasopoulou et al., 2020).

Studies have shown that students gain confidence and enjoy programming, especially in block-based environments (Seraj et al., 2020; Bishop-Clark et al., 2006). Enjoyment and motivation predict the usage of coding games for learning computational thinking, highlighting their importance in programming education (Zhang et al., 2023; Milutinović, 2024).

Factors influencing motivation for learning programming include individual attitudes, rewards, challenging goals, and social pressure (Hawi, 2010). Nevertheless, the underlying factors driving children's motivation to engage in such activities remain incompletely comprehended (Papavlasopoulou et al., 2020). Collaborative work also boosts motivation, yet little is known about its connection with positive attitudes like enjoyment and motivation (Sharma et al., 2019). A deficiency exists in understanding the precise emotions encountered and their functions within technology-driven learning settings (Graesser, 2020).

To fill this research gap, our study focuses on factors influencing perceived enjoyment and coding motivation among Serbian primary school students. By understanding these variables, we aim to shed light on the role of enjoyment in motivating students to learn programming, informing the development of more effective coding education programs tailored to students' needs.

LITERATURE REVIEW

Using Gamification in Programming Instruction

Gamification, an educational strategy where learners tackle challenges within game-based environments to meet specific learning goals (Wang & Zheng, 2020; Zhan et al., 2022), has gained traction in educational contexts, enhancing students' motivation and enjoyment in learning (Alsawaier, 2018). In Serbia, the informatics curriculum underwent significant changes in 2017/18, becoming mandatory for all elementary grades, with programming integrated into lessons from fifth to eighth grades and block-based programming introduced from first to fourth grades through platforms like Code.org, Micro:bit, and Scratch (Ristić et al., 2016). Despite this, research on Serbian primary students' enjoyment and motivation in gamified programming instruction remains scarce (Lambić et al., 2021).

Scratch, a widely used tool in schools, fosters computational thinking, problem-solving, creativity, and collaboration, offering an engaging and enjoyable learning experience (Dúo-Terrón, 2023). Our study investigates the factors influencing perceived enjoyment and coding motivation in programming education through games, addressing a gap in research on primary school students' engagement with coding through gamification (Ortiz-Rojas et al., 2017). While previous studies have employed the Technology Acceptance Model to examine coding games' efficacy in teaching computational thinking (Zhang et al., 2023), few have explored primary students' motivation and enjoyment in coding education through gamification. Thus, our research seeks to fill this void by examining these factors among primary school students in Serbia.

Coding Motivation and Perceived Enjoyment

Coding motivation, the internal drive to engage in coding activities, is influenced by intrinsic factors like personal interest and task satisfaction (Kong et al., 2018; Mason & Rich, 2020). Understanding factors that influence motivation is vital for promoting effective learning experiences in programming education, as motivation significantly impacts students' confidence and computational thinking skills (Kong et al., 2018). Social influences also play a crucial role, with studies showing their positive effect on coding interest and attitudes, particularly in gamified learning environments (Mason & Rich, 2020; Garcia et al., 2021). Additionally, research emphasizes the importance of social interactions, including those with family members, in fostering coding motivation and identity, underscoring the need for confidence-building activities in curricula (Garcia et al., 2023; Budiyanto et al., 2021).

The perception of enjoyment in coding activities, referring to individuals' subjective satisfaction from programming tasks, significantly influences attitudes and behaviors toward coding (Mason & Rich, 2020; Zhang et al., 2023). When coding is perceived as enjoyable, individuals are more likely to engage willingly and persistently (Mason & Rich, 2020; Zhang et al., 2023).

Studies show that students' acceptance of Scratch, a programming language, is strongly influenced by perceived enjoyment (Arpaci et al., 2019). Emotions like happiness positively affect students' participation in programming environments (Giannakos et al., 2014). While enjoyment indirectly influences learning perceptions, it does not directly impact learning outcomes (Tisza & Markopoulos, 2021). Frequent engagement in coding activities enhances perceived enjoyment and fosters a positive attitude toward coding (Mason & Rich, 2020). Understanding the relationship between students' confidence and enjoyment in programming can inform the design of effective coding education programs and materials.

METHOD

Built upon the literature review in programming education, this research aims to explore the factors shaping the motivation and enjoyment of elementary school students during a gamified programming instruction. The variables of interest encompass social influence (SI), coding confidence (CO), perceived enjoyment (PE), and programming motivation (MOTIV). This study endeavors to answer the following research questions:

1. To what degree do the variables SI and PE predict primary school students' coding motivation (MOTIV)?
2. How accurately do CO and MOTIV predict primary school students' perceived enjoyment (PE) while engaging in coding games?

Research Participants and Procedure

The study involved 108 students from Serbian primary schools, randomly selected from one urban primary school, including both the first and second cycles.

The students from grades 1 to grade 5, who were engaged in block-based programming and gamification, were chosen as respondents. Each student provided informed consent, ensuring voluntary participation and data anonymity. The researchers were committed to strict adherence to ethical principles like autonomy, respect, justice, confidentiality, and compassion. The questionnaires, available in Serbian, were administered, and the participants were informed of their right to withdraw. On average, the survey took approximately 10 minutes to complete. The sample comprised students aged 9.48 years on average (SD = 1.67), with 43.5% being male.

Instrument and data analysis

This study employed a two-part research questionnaire to examine the interrelationships between various variables. The initial section gathered demographic information such as age, gender, and grade. Gender was assigned numeric codes: 1 for males and 2 for females. The subsequent section focused on participant self-assessments regarding four factors: perceived enjoyment (PE), social influence (SI), programming confidence (CO), and motivation for programming (MOTIV). Each factor comprised specific subscales, and responses were rated on a six-point Likert scale ranging from 1 (strongly disagree) to 6 (strongly agree). The survey items were drawn from credible scholarly sources with established reliability (Zhang et al., 2023; Mason & Rich, 2020). Translation and validation of the scales were conducted by the author and a bilingual expert to ensure linguistic precision and cultural relevance.

To analyze the data, we utilized SPSS 17.0 and conducted statistical analyses, such as descriptive statistics, correlations, and hierarchical multiple linear regression.

RESULTS

Descriptive analysis

We used SPSS to analyze primary school students' motivation and enjoyment in learning programming through gamification. *Table 1* summarizes descriptive statistics for each construct, showing predominantly positive responses with mean scores exceeding 4 (out of 5). The standard deviations ranged from 1.49 to 1.53, indicating limited variability, while skewness and kurtosis values met acceptable levels of univariate normality (|3| and |10|, respectively), as recommended (Kline, 2011).

Table 1: Descriptive statistics of the constructs.

Variable	Mean	Std. Deviation	Skewness	Kurtosis	Cronbach's Alpha (a)
SI	4.61	1.462	-0.983	0.156	0.835
CO	4.10	1.486	-0.576	-0.723	0.828
MOTIV	4.67	1.418	-1.077	0.214	0.824
PE	4.61	1.533	-1.162	0.347	0.790

Note. SI = Social influence; CO = Feeling of coding Confidence (Competence); PE = Perceived feeling of enjoyment; MOTIV = Coding motivation.

Evaluation of the Measurement Model

Correlation and multiple regression analyses were employed to investigate the interconnections among variables. Initial assessments indicated that the assumptions of normality, linearity, homoscedasticity, and absence of multicollinearity remained unaltered.

*Table 2: Correlation coefficients among the constructs and the discriminant validity assessment; **p<0.05; *p<0.1*

	MOTIV	SI	CO	PE
MOTIV	**0.839**			
SI	0.242^{**}	**0.861**		
CO	-0.007	-0.093	**0.763**	
PE	0.179^{**}	-0.052	0.144^{**}	**0.819**

Note. SI = Social influence; CO = Feeling of coding Confidence (Competence);
PE = Perceived feeling of enjoyment; MOTIV = Coding motivation.

We can observe from *Table 2* that perceived enjoyment (PE) and coding confidence (CO) show a positive correlation ($p < 0.05$), as do social influence (SI) and motivation (MOTIV), and perceived enjoyment (PE) and motivation (MOTIV). Additionally, the discriminant validity assessment, based on Fornell and Larcker's (1981) criteria, reveals that each construct's correlation with others in the model is less than its average variance extracted (AVE) or diagonal value, supporting the independence of latent factors. This indicates satisfactory discriminant validity, with each construct explaining more variation in its measures than in other constructs. Internal consistency, measured by Cronbach's alpha, ranged from 0.79 to 0.83, suggesting reliable results (De Vellis, 2003).

Regression analysis

As correlations were significant and positive between SI and MOTIV, and PE and MOTIV, we employed multiple regression analysis to test if SI and PE significantly predicted students' motivation to learn programming. The results of the regression indicated that the two predictors explained 7% of the variance in MOTIV ($R^2 = 0.07$, $F (2,105) = 3.957$, $p < 0.05$). It was found that SI predicted MOTIV ($\beta = 0.214$, $p < 0.05$), as did PE ($\beta = 0.165$, $p < 0.1$), although the significance of PE was only at the 0.1 level.

As seen in Table 2, PE was correlated with CO and MOTIV, and correlations were positive. Therefore, a second multiple regression analysis was used to test if CO and MOTIV significantly predicted students' perceptions of enjoyment in learning programming through gamification.

The multiple regression model with two predictors produced $R^2 = 0.056$, $F (2, 105) = 3.111$, $p < 0.05$, indicating that the two predictors explained 5.6% of the variance in PE. Predictor CO ($\beta = 0.177$, $p < 0.1$) had a significant positive regression weight, indicating that students with higher scores on this scale were expected to have higher perceived enjoyment in learning programming through gamification. The MOTIV scale did not contribute to the multiple regression model.

DISCUSSION

This study aimed to explore the determinants affecting the motivation and enjoyment of primary school students in gamified programming education, considering both prior studies on programming education and distinctive features of gamification. The variables examined encompassed social influence (SI), coding confidence (CO), perceived enjoyment (PE), and programming motivation (MOTIV).

Primary School Students' Motivation and Enjoyment

Our study findings indicated significant and positive correlations between social influence (SI) and motivation for programming (MOTIV) and perceived enjoyment (PE) and MOTIV, as well as enjoyment (PE) and coding confidence (CO). To delve deeper into these connections, we employed multiple regression analyses.

The first regression analysis aimed to ascertain whether SI and PE significantly predicted students' motivation to learn programming, addressing the primary research question. The findings revealed that together, both predictors accounted for 7% of the variance in MOTIV, with SI emerging as a significant predictor, while PE approached significance ($p < 0.1$). This finding is consistent with previous research (Mason and Rich, 2020), which found the positive impact of social influence on coding interest, perceived usefulness, and attitudes toward programmers. These results imply that the influence of peers and educators, alongside students' perceived enjoyment in programming tasks, significantly impacts their motivation to participate in programming education. When parents regard coding as a valuable skill and actively strive to convey its significance to their children, especially through the provision of immersive game-based learning experiences, it cultivates heightened motivation for children to engage in coding activities. Likewise, according to Social Comparison Theory, students evaluate their levels of motivation by measuring themselves against their peers, potentially spurring them to enhance their performance (Buunk & Gibbons, 2007).

The significant influence of enjoyment on motivation is in line with other studies (Mason & Rich, 2020; Zhang et al., 2023). Enjoyment significantly boosts primary school students' motivation for coding by making the learning process more engaging and fun. When students find coding enjoyable, they are more likely to participate actively, develop a positive association with the subject, and persist through challenges. This intrinsic motivation leads to greater creativity, exploration, and a deeper understanding of coding concepts.

Subsequently, a second regression analysis explored whether CO and MOTIV significantly predicted students' perceived enjoyment in learning programming through gamification, addressing the second research question. The results indicated that the two predictors collectively explained 5.6% of the variance in PE. Notably, coding confidence emerged as a significant predictor, suggesting that students with higher levels of coding confidence were more likely to experience greater enjoyment in learning programming through gamification. Therefore, efforts to enhance coding confidence among learners may contribute to fostering a more enjoyable and engaging learning environment in programming education, particularly when gamification strategies are employed. This finding aligns with the Expectancy-Value Theory of Achievement Motivation (Wigfield & Eccles, 2000). Additionally, Milutinović (2024) discovered that programming self-efficacy indirectly influences perceived enjoyment through perceived ease of use among primary school students. This implies that when students feel confident in coding, they perceive it as easier and more enjoyable.

Overall, these findings highlight the complex interplay between social influence, coding confidence, perceived enjoyment, and motivation in the context of gamified programming education. Educators can leverage these insights to design interventions and learning experiences that foster positive social interactions, enhance students' coding confidence, and cultivate an enjoyable learning environment, ultimately promoting greater motivation and engagement in programming education.

Implications for practice

The results of this research should assist policymakers and management at teacher training institutes, especially in Serbia, to devote particular focus on aspects that play a decisive role in enhancing positive motivation among students about programming. Future educational programs could benefit from emphasizing gamified learning environments to enhance motivation, focusing on improving coding skills to ease the learning process making it more enjoyable, and tailoring social influences that contribute to students' motivation to learn programming.

The implications of our findings highlight the crucial role of social influence and perceived enjoyment in motivation for programming education. Firstly, social influence has a major impact on students' motivation. This emphasizes how important it is for teachers to create friendly and cooperative learning environments. Students' motivation to actively participate in programming activities can be increased by fostering strong relationships with teachers and excellent peer interactions. The significant role of social impact, particularly from guardians and peers, in students' motivation for coding through gamification highlights the interconnectedness of social flow and learning experiences.

Furthermore, the significance of creating programming activities that are engaging and pleasurable for students is indicated by the impact of perceived enjoyment on motivation. Enhancing the overall learning experience can be achieved by incorporating gamification elements and providing opportunities for students to improve their coding skills. When students feel confident in coding, they perceive it as easier and more enjoyable (Milutinović, 2024). The research findings from Sevin and DeCamp (2016) highlight that engaging in video games significantly enhances both computer confidence and interest in computer science. This implies that exposure to video games as a recreational activity can improve players' proficiency in utilizing non-recreational coding and cultivate a more extensive interest in technology as a whole.

By leveraging parental support, peer influence, and gamification elements that enhance social impact, teachers can create a compelling and inclusive environment that fosters students' motivation for coding and promotes sustained engagement and learning. According to Milutinović's (2024) findings, addressing gender inequities and tailoring programming instruction to students' varying developmental stages are crucial components of developing a diverse and successful programming curriculum. Through the customization of programming gamified projects based on students' interests and skill levels, teachers may foster a pleasant learning environment that supports long-term engagement and intrinsic motivation.

In summary, these findings stress the significance of promoting favorable social interactions, fostering enjoyment, and instilling coding confidence in programming education. By addressing these aspects, educators can elevate students' motivation and enjoyment in learning programming, ultimately fostering a more positive and immersive learning journey.

Limitations of the Study and Future Research

The study's findings may not generalize to students in different grades or educational settings due to variations in motivation-influencing factors. Self-reported measures for coding competency, motivation, and perceived enjoyment may introduce biases or inaccuracies. The cross-sectional design limits establishing causal relationships between variables, and the low variance explained suggests other unmeasured factors may have a greater impact on motivation and enjoyment.

Future research should explore the evolving dynamics of social influence, coding competence, motivation, and enjoyment in programming education for elementary students. Longitudinal studies can track these factors over time, while comparative research across various educational settings and age groups can enhance generalizability. Qualitative methods like interviews can provide deeper insights, and investigating the impact of teaching practices on student motivation and enjoyment is crucial for refining pedagogical strategies.

CONCLUSION

This study explored factors influencing primary school students' motivation and enjoyment in learning programming in Serbia. The results showed that social influence and enjoyment significantly impacted motivation while coding competence influenced perceived enjoyment. These findings stress the importance of considering social influence and coding competence in programming education strategies for elementary students. This research contributes to understanding motivation in programming education, particularly in regions with lower technological advancement. It lays the groundwork for further investigation into elementary students' attitudes toward programming education, especially in culturally similar contexts with limited research.

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EDUCATIONAL POTENTIAL OF VIDEO GAMES FOR APPLICATION IN STEAM/STREAM APPROACH IN TEACHING

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Abstract: The paper analyzes the educational potentials of video games within modern teaching and learning approaches, such as STEAM and STREAM models. Video games are seen as products of the culture of the contemporary information society, which in interaction with children acquire new qualities, meanings, and potentials and can have significant educational value and application. The entire process that occurs in the child's interaction with the video game is considered, taking into account both the natural and social environment. The paper analyzes the potential of video games for developing a deeper understanding of the phenomena and processes occurring in nature and the systems of concepts, as well as for developing social relations, creativity, and emotions in children. First, the paper deals with the review and analysis of recent relevant research on the educational effects of video games, highlighting potentially positive effects for children's development, but also possible limitations and undesirable effects of the presence of video games in children's experience. The second section of the paper presents the results of the empirical research conducted with primary school teachers who use STEAM or similar approaches in their teaching on how they evaluate the pedagogical potential of video games. The preliminary results indicate that video games can be a very powerful medium in the effective implementation of the STEAM/STREAM model. The paper states that this is a very current topic that is constantly changing and that needs constant research and critical review.

Keywords: video games, STEAM/STREAM, educational potential, teaching methods, developing concepts

INTRODUCTION

The first video games appeared about sixty years ago in computer laboratories as a side effect of research and development of radar systems in the USA (Squire, 2005; Spring, 2015). During the last decades of the twentieth century, video games became commercial products, and today they are an important part of the daily life of children and adults.

Video games can be broadly defined as entertaining interactive computer programs that involve interaction between a device and a human (Ivory, 2015).

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There are many different definitions of computer games depending on which aspect of the phenomenon the authors attach more importance to. In the first studies focused on the impact of video games on children's behavior, the authors categorized video games according to the presence of violent or non-violent content (Dominick, 1984; Anderson & Ford, 1986), but later studies highlighted the division of video games according to their educational potential (Porter, 1995; Prensky, 2001), or according to the possibilities for the development of digital literacy (Gee, 2006). In recent years, authors have shown interest in video games that are purposefully constructed to have an educational character and can be used in school learning (Squire, 2005; Hayak & Avidov-Ungar, 2020; Kaimara et al. 2021).

Contemporary research in education emphasizes that the role of video games in STEAM (Science, Technology, Engineering, Arts, and Mathematics) and STREAM (Science, Technology, Reading, Engineering, Arts, and Mathematics) learning is increasingly recognized for its potential to enhance the effectiveness of education (Bayas et al., 2022). According to the recent research, video games offer an interactive and engaging platform that can foster critical thinking, problem-solving, and creativity among students (Kim & Bastani, 2017; Leavy et al., 2023). They provide immersive experiences that simulate real-world scenarios, making abstract concepts more tangible and accessible. In the context of STEAM/STREAM education, video games can serve as powerful tools for developing skills in programming, engineering design, mathematical reasoning, and artistic expression (Mayo, 2009; DeCoito & Briona, 2020). Therefore, it is right to assume that integrating video games with educational content can motivate and inspire learners, promote collaborative learning, and support the development of 21st-century skills essential for future success.

This study aims to explore the potential of video games in the implementation of modern teaching and learning approaches, such as the STEAM and STREAM models. As mentioned above, video games, as products of the contemporary information society, may help children to acquire new concepts, meanings, and ideas, offering significant educational value. The paper takes into account the entire process of children's interaction with video games, considering both natural and social environments. It analyzes the potential of video games to enhance understanding of natural phenomena and processes, conceptual systems, and the development of social relationships, creativity, and emotions in children.

The first part of the paper reviews and analyzes early and recent research on the educational effects of video games, highlighting both positive impacts on children's development and potential limitations and undesirable effects. The second part presents the findings of the empirical research designed as a survey questioning primary school teachers who use STEAM or similar approaches in their teaching. Also, the paper emphasizes that this is a dynamic and evolving topic that requires ongoing research and further critical review.

THEORETICAL BACKGROUND

Early Studies on the Effects of Video Games on Children's Behavior and Development

During the 1970s and 1980s, the first studies appeared that relied on then-dominant behaviorist learning theories, such as Alfred Bandura's learning theory (Bandura, 1977). The assumption of these studies was that video games, through the mechanisms of imitation and identification, can significantly influence the behavior of children and adults.

The conclusions of a study conducted in Georgia, USA, in which 250 high school students participated, linked aggressive behavior in adolescents with playing video games (Dominick, 1984). In a similar study, a group of authors from the New York College of Medicine conducted research on a sample of 208 male adolescents who answered questions about their experiences playing video games. The conclusions were that gaming serves to "relax" and has a "stress-relieving" and "blowing-out" effect (Kestenbaum & Weinstein 1985).

In experimental research conducted by Anderson et al., it was found that playing certain video games significantly increases the degree of short-term aggression and moderately affects anxiety, without a significant effect on the level of depressed mood in a sample of 60 university students (Anderson & Ford, 1986). In a study conducted by researchers at Utah State University on a sample of 160 students, it was found that students who played "violent video games" had less pronounced prosocial and helping behavior; the respondents engaged in cooperative and cooperative social interactions less immediately after playing these games, compared to a group of children who played video games identified as cooperative and non-violent. The same research showed that playing cooperative and non-violent video games encouraged prosocial and helping behavior in a group of children who played these types of games (Chambers & Askione, 1987).

At the end of the last century and the beginning of this century, the first studies appeared that indicated that video games can have a positive influence on the psycho-physical development of children and young people. Among the positive effects of video games on children with autism symptoms, researchers have highlighted the existence of visual schemes, fast interactive actions, and narrative elements that provide a basis for developing new and strengthening existing knowledge and skills (Porter, 1995; Edvardsen& Kulle, 2010).

Later research confirmed the therapeutic possibilities of video games in working with children who have developmental difficulties, namely in terms of the development of spatial coordination and orientation (Griffiths, 2003), then solving problems and understanding relationships (Hollingsworth & Woodward, 1993) and in the development of mathematical, especially arithmetic abilities (Okolo, 1992). Some authors have found a significant relationship between playing video games and the development of motivation to engage in school learning activities in children with various learning problems (Blechman & Rabin, 1986; Okolo, 1992).

Research conducted at the University of Nottingham has revealed that children and young people spend significant time playing video games, which hold substantial educational potential. To highlight the new qualities of video games, researchers coined the term "edutainment" media, which combines learning and entertainment (Griffiths, 2003). These researchers, who also examined the psychological mechanisms of pathological gambling, were the first to suggest that video games containing gambling-like elements can be linked to psychological addiction (Griffiths& Hunt, 1998). However, they noted that pathological discourse should consider micro and macro social contexts.

The use of video games in experimental pedagogical situations, where the focus is on learning through adventure and exploration, has been reported as a highly successful and advanced method with the potential for rapid expansion into formal and informal education systems. It has been established that educational content presented via computers can effectively supplement school curricula, and that video game-based programmed tasks can serve as an alternative to less popular homework assignments (Selwyn&Bullon, 2000).

Recent Studies on the Educational Potentials of Video Games

A characteristic of all the early research mentioned so far is that they were carried out by researchers who belonged to the generations of digital immigrants (Prensky, 2001), meaning they did not have extensive experience with video games by themselves. This is significant because recent research by younger scholars, who are more familiar with video games, has led to a significant shift in perspective on video games, information and communication technologies, and contemporary global culture (Squire, 2005; Gee, 2006). It is being increasingly recognized that video games can have substantial applications in education and that it is important to incorporate basic knowledge of educational video game design into teacher training programs (Foster & Shah, 2020). Furthermore, video games are frequently mentioned as an essential tool for developing specific talents and abilities in children identified by teachers as gifted (Budimir-Ninković & Stevanović, 2018).

Some research emphasizes that success in implementing video games in pedagogy requires an understanding of children's digital culture and their willingness to adapt the adult culture accordingly (Creeber & Martin, 2008). Studies analyzing the use of video games in educational practice have found that children, much like scientists, formulate hypotheses, discover laws, and encounter unanswered questions through gaming. Research has shown that children often learn facts, laws, and basic concepts earlier than what is outlined in the curriculum (Adachi & Willoughby, 2012).

These insights into the interaction between children and culture have led to a new approach in designing video games as educational tools. Several comprehensive studies have been published on the design and implementation of pedagogically effective video games (Edvardsen & Kulle, 2010). These studies highlight the importance of considering children's needs and their right to freely engage with the world around them. The authors stress that adults' perceptions of children's needs can significantly differ from the actual needs, emphasizing that video games are an intervention of adult culture into child culture, which must be considered in their design.

Recent findings on the potential effects of video games on the well-being of children and young people indicate that many games use manipulative techniques similar to gambling and are often targeted at young audiences (Molde et al., 2019). Although initial research on the link between gambling and video games appeared in the late twentieth century (Gupta & Derevensky, 1996), more contemporary meta-analyses on the use of gambling-based manipulative mechanisms in popular video games have been conducted only recently. These studies revealed that many game developers intentionally implement such mechanisms to ensure long-term player engagement and profit (Zendl, 2020). The public reaction to these findings led to changes in legislation in many countries regarding the creation and release of video games (Griffiths, 2018). These studies have also raised ethical concerns about the use of video games for various forms of manipulation of children (Shao & Henderson, 2021).

Multiple findings suggest that video games in STEAM education offer numerous benefits. They enhance student engagement by making learning enjoyable and motivating (Kim & Bastani, 2017; Bayas et. al., 2022; Leavy et. al., 2023. Video games provide interactive environments for experimentation and decision-making, deepening students' understanding of concepts. They foster essential skills such as problem-solving, critical thinking, and strategic planning, and simulate real-world scenarios, bridging abstract concepts with practical applications (Mayo, 2009; DeCoito& Briona, 2020). Some authors suggest that video games also encourage teamwork and communication through multiplayer settings and stimulate creativity and innovation in a risk-free environment.

They adapt to individual learning paces and styles, offering personalized feedback and challenges. The immediate feedback from games helps students learn from their mistakes quickly.

Additionally, video games involve coding and programming tasks, developing technical skills crucial for STEAM disciplines. They integrate multiple STEAM subjects, promoting cross-disciplinary learning and demonstrating the interconnectedness of different fields (Leavy, et. al., 2023). It may be assumed that video games provide a safe space for exploration and experimentation without real-world consequences, making them a powerful tool for dynamic and effective STEAM education.

Finally, it can be said that video games can be a valuable tool within the STEAM/STREAM approach, but they are also a complex social, cultural, economic, and psychological phenomenon that cannot be viewed monolithically, similar to music, film, or sports. Therefore, when determining the suitability of video games for educational practice, especially in the STEAM/STREAM approach, it is essential to consider the characteristics of the game itself, its content, themes, objectives, and various cultural, social, and individual factors.

RESEARCH METHODOLOGY

The basic problem that this research tries to engage in is to understand the perceptions of teachers who use STEAM/STREAM in their teaching practice, regarding the importance, roles, and effectiveness of video games. The study focuses on all video games that are available to children and that they independently choose, regardless of genre, features, and the type or nature of tasks. The idea is to approach video games as a general phenomenon that children and adults encounter daily.

The research specifically took into consideration the fact that teachers are not a homogeneous group when it comes to experience with video games, as well as that this topic gains importance in moments of the increasingly frequent application of distance learning and the rise of information technologies in education.

Bearing in mind the characteristics and complexity of the problem, it can be said that the aim of this research is to determine the opinions of STEAM/STREAM teachers about the possibilities of using video games in educational practice and their opinion on potential hazards for children's well-being.

Therefore, specific research tasks can be derived from the general aim:

- to determine to what extent teachers had direct experience with playing video games,

- to determine the level of positive or negative attitudes toward video games in the STEAM/STREAM approach,
- to determine the percentage of teachers who believe that video games can be used in the STEAM/STREAM approach, and
- to determine the opinions on the games' educational content application with the most educational potential.

The study uses a descriptive method and the data is collected via a survey. The Likert-type assessment scale with 16 items was specially constructed with Google Forms. The reliability of the scale is measured through internal consistency based on the average inter-item correlation and the value Cronbach's coefficient of 0.7942 shows that the scale can be considered reliable. The structure of the instrument was designed to contain three questions that collect basic data like age, gender, and years of service. 12 items were constructed in the form of statements about video games in the range of agreement from 1 to 5, where option 1 represents strong disagreement and option 5 strong agreement. The data collection was carried out in March–April 2024 and the survey was distributed via e-mail and through social networks and groups that bring together teachers and educators.

The sample consisted of a total of 116 teachers, who declared themselves as teachers who use the STEAM/STREAM approach, from 8 schools in 6 cities in Serbia (Belgrade, Kragujevac, Niš, Smederevo, Jagodina, and Paraćin), among whom there were elementary school teachers (1^{st} to 4^{th} grade) of N = 39, and middle school teachers (5^{th} to 8^{th} grade) of N =77.

It should be noted that one of the limitations of this study is that the survey was conducted via the Internet, which is more used by, conditionally speaking, younger teachers. It also can be stated that, having in mind structure of the participants, the findings reflect the opinions of the middle school teachers more than those who teach younger children.

DATA ANALYSIS AND DISCUSSION

One of the key data that can influence the opinion of teachers about the application of video games in STEAM/STREAM education is whether they play video games and how often they do so.

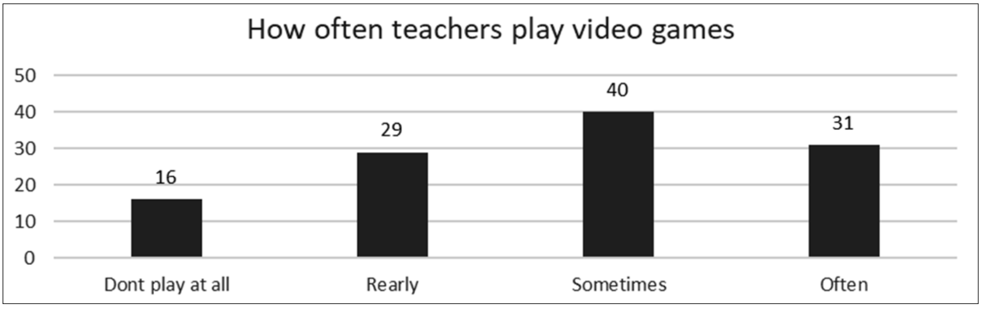

Chart 1: Structure of respondents according to how often they play video games

The obtained data indicate that the majority of teachers have had experience with video games, that is, that they have played video games. About two-thirds of teachers (N=71) belong to the category that plays video games often or sometimes. It should be noted that almost all respondents who play video games to some extent belong to the category of students or teachers with less than 5 years of work experience. 14 respondents, out of 16 who never play video games, are teachers who already work in schools and whose work experience exceeds 15 years. Considering these data, we can say that the majority of teachers have had direct experience with playing video games.

After examining to what extent teachers play video games in their free time, they were asked to express their degree of agreement to the claims that express the possible positive effects of video games on children's well-being.

Table 1. Degree of teachers' agreement with statements about the positive effects of video games.

No.	Statement	Do not play at all (n=16)	Rarely (n=29)	Sometimes (n=40)	Often (n=31)
1.	Video games are useful for acquiring knowledge	1.6	2.4	2.7	3.1
2.	Video games are useful for the development of thinking	1.5	1.6	2.0	2.9
3.	Video games are useful for developing social skills	1.4	1.5	1.8	2.5
4.	Video games are useful for language learning	2.9	3.0	3.4	3.6
5.	Video games are useful for spatial orientation	1.4	1.7	2.3	2.7
6.	Video games help children with developmental disabilities	1.9	1.7	3.2	3.1
/	**Average for all positive claims**	**1.8**	**2.0**	**2.6**	**3.0**

The data from *Table 1* indicate that all groups of teachers are very reserved in their attitudes on the positive effects of video games. The most affirmative attitude is held by teachers who play video games often, but it can also be characterized as mostly neutral. The positive effect of video games with which teachers agree the most is that "Video games are useful for language learning" and then that "Video games help children with developmental disabilities." The teachers generally agree that they do not see many positive effects of video games.

The following group of claims expresses the negative effects of video games on children's well-being.

Table 2. Degree of teachers' agreement with statements about the negative effects of video games.

No.	Statement	Do not play at all (n=16)	Rearly (n=29)	Sometimes (n=40)	Often (n=31)
1.	Video games are psychologically addictive	4.0	**4.3**	3.6	3.2
2.	Videogames encourage violence	**3.8**	3.7	3.3	2.8
3.	Video games evoke negative emotions	**3.1**	**3.3**	2.7	2.8
4.	Video games lead to antisocial behavior	**3.8**	3.6	3.3	3.4
5.	Video games can be a tool of manipulation	**4.2**	4.1	3.7	35
6.	Video games harm physical health	**4.5**	4.4	4.3	3.8
/	**Average for all negative claims**	**3.9**	**3.9**	**3.5**	**3.3**

The data show that teachers generally agree on the negative effects of video games, regardless of their group. Most believe video games harm physical health (e.g., eyesight, obesity, spine issues), can manipulate children, and lead to psychological addiction. There is slightly less agreement on video games inciting violence, causing negative emotions, and promoting antisocial behavior. Teachers who play video games sometimes or often are less likely to agree with the negative effects but still tend to have a neutral or moderate agreement.

The data presented in *Tables 1* and *2* indicate that there is a statistically significant difference (according to the t-test) between the groups of respondents who have had direct experience with playing video games and those who have not.

The research indicates a significant statistical difference in attitudes towards the positive effects of video games on children's well-being between frequent players (N=31, score 3.0) and non-players (N=16, score 1.8) according to the t-test (t = 5.8928, df = 47, p<0.0001, sed = 0.203). When combining frequent players with occasional (N=44) and rare players (N=31), the difference compared to non-players remains significant (t = 4.3215, df = 118, p<0.0001, sed= 0.174), though the average score drops to 2.6. This suggests a proportionality between personal experience with video games and a positive attitude toward their educational potential. Future and current teachers with direct video game experience generally view their effects positively, but the overall average score remains below 3.0.

Teachers who play video games are somewhat less critical of their negative effects, though, in certain statements (5 and 6), their opinions align closely with non-players, who hold very negative views. The statistical analysis shows a significant difference in opinions between frequent players (N=31) and non-players (N=16) (t = 3.9313, df = 47, p=0.0003, sed = 0.203). When combining frequent, occasional, and rare players, the statistical significance remains at the p=0.05 level but is lost at the p=0.01 level (t = 2.1667, df = 119, p=0322, sed = 0.184). For statement 5 alone, the significance is marginal (p=0.0559). This suggests differences in opinions about negative effects exist but are not as pronounced as those for positive effects. Most respondents agree that negative effects are significant and more pronounced than positive ones.

In accordance with the set goal and tasks of the research, it was crucial to examine what teachers think about the possibilities of applying video games in the STEAM/STREAM teaching approach. Teachers were asked several questions referring to the teaching contents that video games are pedagogically useful for. The following chart summarizes the teachers' opinions.

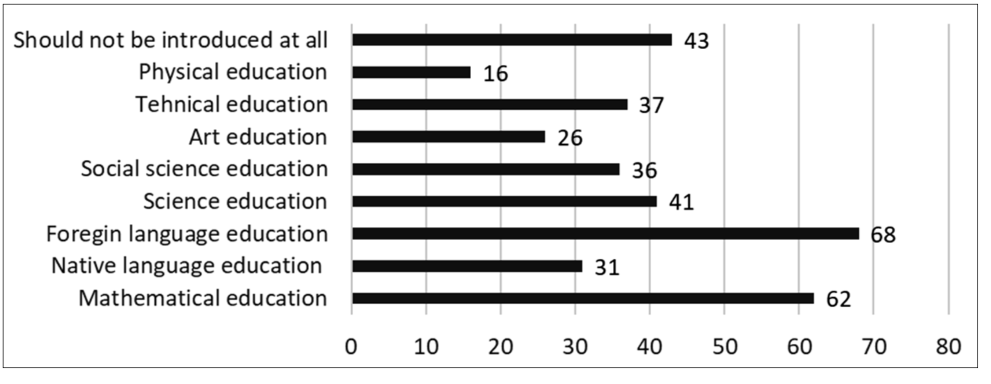

Chart 2: Educational STEAM/STREAM contents in which video games should be introduced (multiple answers possible)

Regarding the introduction of video games in teaching STEAM/STREAM content, especially during frequent remote teaching, over a third of respondents

(N=43) do not agree. Most negative responses came from teachers who do not play video games (N=16), but also from those who rarely (N=15) or occasionally (N=11) play them. However, about two-thirds (N=72) believe video games can be used in some teaching content. Most teachers (N=68) support using video games in foreign language teaching, followed by mathematics (N=62). Fewest teachers think video games are suitable for physical and health education, aligning with their concerns about video games' negative impact on health.

The results of this study are limited in terms of generalization due to the nature of the phenomenon, sample, and research circumstances. However, they align with the recent findings (Mayo, 2009; Squire, 2015; Kim & Bastani, 2017; DeCoito & Briona, 2020; Bayas et al., 2022; Leavy et al., 2023;), which increasingly view video games as a STEAM/STREAM pedagogical tool. Studies have shown that the inclusion of video games in the school curriculum enhances student participation, peer cooperation, problem-solving, and self-evaluation (Squire, 2015). Teachers with video game experience and more advanced professional careers have a more positive attitude towards using video games in education (Hayak & Avidov-Ungar, 2020), consistent with the findings that video games are used in the education of children with special abilities, supported by specially trained teachers (Budimir-Ninković & Stevanović, 2018). Recent research indicates that the main obstacles to using video games for educational purposes are insufficient information, lack of personal experience, and lack of ICT knowledge and skills among students (Kaimara et al., 2021). The findings support the idea that basic knowledge and principles of STEAM/STREAM learning through video games should be integrated into initial teacher education (Foster & Shah, 2020). Further research should explore how educational video games contribute to better school learning and overall children's well-being.

CONCLUSION

In addition to extensive scientific literature from the seventies and eighties on mostly harmful connections between video games, behavior, and educational effects, the topic remains very relevant for many researchers in education and social sciences today. The recent social and economic changes, along with the increased use of information technologies in education and the shift to distance learning, have led to a change in perspective favoring more positive aspects regarding video games.

The empirical research presented in this paper shows that most STEAM/STREAM-oriented teachers recognize the pedagogical potential of video games to some extent. They see benefits such as aiding the adoption of conceptual and functional knowledge, enhancing thinking, cooperation, social skills, language learning, and spatial orientation, and helping children needing additional support. However, teachers generally have a skeptical or neutral attitude towards the positive effects of video games on children's well-being and agree more on the possible negative impacts.

The positive effects highlighted here include foreign language learning, mathematical skills, and support for children with developmental disabilities. The negative effects noted are risks to physical health, manipulation of children, and psychological addiction. Teachers who play video games themselves have a slightly more positive attitude but still express significant concerns about the impact on children's well-being.

Due to the nature of the phenomenon and the influence of many factors, this paper cannot cover all important issues regarding the relations between video games and STEAM/STREAM education. One limitation of this research is that the survey was conducted online, primarily reaching younger teachers. Additionally, the findings mainly reflect the views of teachers of 5th to 8th graders, rather than those working with younger students. Finally, it should be noted that the participants' structure and limitations of the research method make it difficult to generalize the results. Therefore, this research should be seen as a starting point for further studies examining specific aspects of the educational potential of video games in STEAM/STREAM education.

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A CASE STUDY ON STEM PROBLEM-BASED LEARNING APPROACH IN DEVELOPING COMPETENCIES FOR RECOGNIZING PHISHING EMAILS

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Abstract: This research aims to explore if problem-based learning has an effect on employees' ability within an organization to detect phishing emails. Specifically, this paper tries to answer the following research question: Does the problem-based learning method in STEM affect the ability of an organization's employees to recognize potential phishing emails? The research was carried out through a case study involving a phishing simulation conducted within a Central European company. A total of 221 employees were targeted with phishing emails over two separate rounds, which lasted for four weeks. Between the rounds of the phishing campaign, problem-based learning education about phishing was provided to all employees. The research findings highlight several key points. Initially, there's been a reduction in the count of employees who clicked on links found in phishing emails. Second, there has been a decline in employees providing their user credentials to phishing websites. Lastly, the number of employees reporting suspected phishing emails to the IT department has also decreased. To our knowledge, this is the first paper that links STEM through problem-based learning with phishing.

Keywords: problem-based learning, PBL, phishing, STEM

INTRODUCTION

The STEM approach to education is designed not only to prepare learners (we use this term because it does not necessarily refer to pupils or students, it can be e.g. employees, as in this paper) for work but also to equip them with the necessary skills for living in the 21st century (Smith et al., 2022; Widya et al., 2019). The benefits of STEM education include connecting real-life problems with the content being learned (Elsayary et al., 2015). Some researchers believe that STEM education helps students develop the skills needed for

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problem-solving (Asghar et al., 2013; Capraro, Capraro, & Morgan, 2013; Casteldine & Chalmers, 2012; National Science Board, 2007, as cited in Elsayary et al., 2015). This can be achieved using the problem-based learning (PBL). PBL is a learner-centered education model that combines an investigative approach with the problem-solving process (Etherington, 2011, as cited in Elsayary et al., 2015), where the goal is not only to solve the problem but also to understand its origins, thereby developing students' thinking skills and integrating existing and new knowledge (Smith et al., 2022), as well as becoming an effective collaborator and increasing motivation for learning (Hmelo-Silver, 2004).

According to the Verizon Data Breach Report of 2023, 74% of all breaches in information systems involve a human element (Verizon, 2023). One of the initial activities of breaches is a phishing campaign. Phishing is the activity of faking internet websites or emails with the aim of tricking the victim into entering sensitive data for further criminal activities such as identity theft or financial crime by pretending to be another person or organization, often leaving open doors for subsequent attacks (Gavett et al., 2017; Iuga et al., 2016; Tomičić, 2023). The problem of phishing attacks is a known challenge within information security, especially since attacks are reported every year, and a decrease in the number of successful attacks in the near future is not anticipated (Iuga et al., 2016; Jampen et al., 2020), and attack vectors are becoming more sophisticated (Burda et al., 2020). Individuals, whether privately or as part of an organization, are an untapped resource for recognizing and timely responding to phishing attacks and are key to protecting the organization from potential threats. However, for individuals to successfully resist phishing attacks, they must be able to recognize potential phishing attacks, and to do so, education about them is necessary.

This paper tries to answer the following research question: Does the problem-based learning method in STEM affect the ability of an organization's employees to recognize potential phishing emails?

The rest of this paper is structured as follows. The second section presents a review of the literature and existing research. The third section shows the research methodology, including the research design and methods of data collection and analysis. The fourth section presents and comments on the obtained results. The final section summarizes the entire research.

LITERATURE REVIEW

When considering the relationship between employee information and cyber security education, there is no consensus among researchers on whether education (regardless of the form of education) has an effect on the ability of employees to recognize phishing attacks.

On one hand, it is believed that employee information and cyber security education cannot be linked to the ability to recognize phishing attacks (Broadhurst et al., 2020), partly because employees do not read the prepared materials (Caputo et al., 2014). Mandatory employee education programs do not lead to a reduction in the number of accesses to phishing websites (Gordon et al., 2019). Current methods of educating employees are not sufficient for recognizing sophisticated attacks (Burda et al., 2020). To achieve a better effect, it is necessary to educate employees several times to change their behavior (McElwee et al., 2018). However, one research has shown that conducting organized phishing campaigns in organizations, as well as educating employees about phishing, makes employees more susceptible to attacks (Lain et al., 2022).

On the other hand, researchers believe that employee education makes a difference in recognizing potential phishing messages (Carella et al., 2017; Heartfield et al., 2016). Employee education reduces the possibility of phishing messages affecting them (Alhaddad et al., 2023), thereby directly leading to a positive impact on the ability to recognize phishing email messages (Alwanain, 2021), as well as recognizing phishing websites (Alwanain, 2019), which leads to a reduction in the impact of potential phishing attacks. Also, researchers believe that targeted training on a conducted phishing campaign can be associated with a reduction in susceptibility to falling under the influence of phishing messages (McElwee et al., 2018).

After all that has been said, it is important to emphasize that in the search of relevant literature, not a single article was found that links STEM education, PBL, and phishing emails.

METHODOLOGY

The research was conducted in an organization in Central Europe that employs about 250 employees, most of whom communicate via email daily. The organization has established information and cyber security processes. The IT department regularly informs employees about phishing threats (regardless of whether they have occurred) and holds training sessions on information security at least once a year, where phishing is one of the sections covered. Each training also includes raising awareness of potential phishing attacks, given that phishing attacks are one of the frequent sources of attacks, and the employee (or user) is the most common attack vector (Burda et al., 2020). During training, IT employees explain examples of phishing messages on real cases and how to protect against them. Also, when phishing messages breach multiple email addresses within the organization, IT informs all email-using employees about the phishing attack, providing instructions on how to proceed. Additionally, when a new employee joins the organization, they undergo training to be alerted to possible information and cyber security, including phishing threats.

Furthermore, the organization has written standard operating procedures for responding to phishing attack detections. Employees can report a received phishing message, as well as information on whether they clicked on a link or filled out information, to the IT using the Helpdesk portal, email by phone, or directly to IT employees.

A case study was chosen for this research due to study employee behavior in their natural environment, i.e. without external influences (Mihelic et al., 2019).

An external contractor was engaged to conduct the campaign, with whom an NDA agreement was signed, in order to perform an information security check of the IT system using social engineering methods, i.e., phishing. Employees who do not use email and those who were informed about the campaign were excluded from the email addresses. The research design is shown in *Figure 1*.

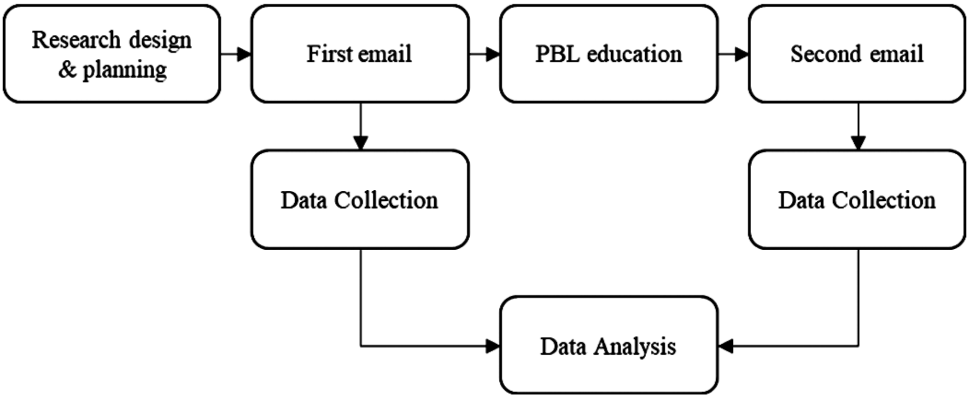

Figure 1. Research design scheme

The organization provided the external contractor with a list of 221 email addresses within the organization for the phishing campaign. From the phishing campaign, IT staff and employees who were aware that a phishing campaign would be conducted were excluded. The remaining users, apart from previously receiving training and email notifications, do not have an IT background and come from various other fields (e.g. law, economics, etc.).

Table 1. Users demographics

	Sex	*Frequency*	*Mean*	*St. Dev.*	*Min*	*Max*
Years	Female	173	43.47	8.7	25	65
	Male	48	41.48	10.25	26	64

The research and phishing campaign were divided into two rounds. The research and campaign were carried out over two working days separated by four weeks. On the first day, 120 minutes after the first notification of a phishing email was received, the IT sent a notification about potential phishing to everyone. On the second day when the second round of the phishing campaign took place, the IT sent a notification 70 minutes after receiving the first notification.

The first phishing email was sent to all employees within an hour to prevent security systems from recognizing it as phishing. The sender's address was: Notifications [Notification@organization.domain] MAILER-DAEMON@whytrustme.net, and the subject of the phishing message: "[IMPORTANT] Changes in entry rules at locations Location1 and Location2" (actual locations of the organization, which are publicly available were mentioned). The body of the phishing message stated that an unauthorized person was moving through the administrative area, even though the organization does not recognize this term, and therefore, it is necessary for all employees to be assigned PINs to enter the parking lot and organization's premises, stating a short deadline for accessing and filling out the information on the provided link.

A few days after the first round, IT organized an interactive PBL education, as a form of training, on phishing attacks. The education was not conducted *ex cathedra* but rather employees were encouraged to divide themselves into smaller groups and furthermore to identify whether a given set of emails were either phishing messages (not just in organized campaigns) or legitimate messages. Besides recognizing, employees were asked to identify clues that could determine whether the received email message was phishing or legitimate and how they could respond to such messages. The education concluded with a discussion among all employees. This education model was chosen to motivate employees to participate in the training (Elsayary et al., 2015).

The second phishing email was sent to all employees within an hour to prevent security systems from recognizing it as phishing. The sender's address of the phishing email for administrative staff was notification[notifications@eAdvertisement.hr] MAILER-DAEMON@whytrustme.net, and the subject of the phishing message: "New ergonomic chairs for Organization employees (EU-OSHA: Healthy Workplaces Good Practice Awards 2020-2022)". The body of the phishing message stated that the organization is purchasing new office chairs and it is necessary to access the link as soon as possible where the employee will choose the model of the office chair to be purchased for them.

After employees clicked on the links in both emails, a common interface opened. In the newly opened interface, employees were asked to enter their user's credentials (e.g. username and password for computer access). Users, after entering their user's credential, received a pop-up message stating that their username and password were incorrect.

According to the procedure for reporting phishing messages, employees should report any suspicious messages they received. An IT employee collected the data and updated it in a spreadsheet. After the campaign was completed, the external contractor provided the organization with relevant data in another spreadsheet. Both spreadsheets were merged into one using Microsoft Excel. Descriptive statistics were used for the statistical analysis of the data using the DATAtab software tool (DATAtab Team, 2024).

RESULTS AND DISCUSSION

The results of research will be shown in two parts. In the first part, the susceptibility of employees to phishing messages will be shown, specifically how many employees clicked and filled in the data in the requested forms. The second part will display the number of reported phishing email messages.

In the case of the first phishing email, the first employee of the organization clicked on the link two minutes after receiving the email, and the first data in the form were filled in three minutes after receiving the email. The last employee clicked on the link four days, 22 hours, and 10 minutes after receiving the email, and filled in the data four days, 22 hours, and 11 minutes after receiving the email. During this period, a total of 21 employees (9.5%) clicked on the link, and 14 of them filled in the data (6.3%). Before sending the email notification, 13 employees had clicked on the link, and 6 filled in the data; after sending the email notification, eight employees clicked on the link and filled in the data.

In the case of the second phishing email, the first employee of the organization clicked on the link seven minutes after receiving the email, and none of the employee filled out the form. The last employee clicked on the link 24 minutes after receiving the email. These are the only two employees (1.4%) who clicked on the link.

From the mentioned from above, it is evident that after attending PBL education, the number of employees who clicked on the link in the phishing email decreased, and none of the employee filled in the data on the page. However, it is important to emphasize here that users' specific credentials were not collected, only data about access and filled-in data were collected, so there is a probability that some employees filled in the form with false user credentials. This conclusion confirms the findings of previous studies (Alhaddad et al., 2023, Alwanain, 2019, Alwanain, 2021, Carella et al., 2017; Heartfield et al., 2016, McElwee et al., 2018), which highlighted the importance of employee education in recognizing phishing messages.

Table 2 shows the descriptive statistics of the time taken to recognize phishing emails before and after PBL education.

Table 2. Descriptive statistics results for reporting phishing email [in minutes]

	No.	*Mean*	*St. Dev.*	*Min*	*Q1*	*Q2*	*Q3*	*Max*
Before PBL	79	485.33	2494.79	2	4	13	43	15838
After PBL	52	253.02	1683.72	1	3	6	24.25	12158

Table 2 shows that the times needed for employees to report a potential phishing message have decreased. However, it was also observed that the number of employees who reported a potential phishing email decreased from 79 to 52, or by 34%. This can be interpreted as an increase in employee awareness and the belief that it is an obvious phishing email and that no further action is needed.

CONCLUSION

In this research, a phishing campaign was conducted targeting employees of a company. In the campaign, employees were sent two different emails in which they were asked to access phishing sites and fill in the requested data. Between the two rounds of the campaign, PBL education was conducted with employees. It concludes that PBL education has an impact on reducing the number of employees who will click on a phishing email, the number of employees who will enter the requested data, and also the number of employees who will report a potential phishing email.

This research has several limitations. Firstly, the research is geographically limited, i.e., it was conducted within one country and within one organization in that country, on a small sample size of 221 employees (users). Secondly, the research was conducted over a short period of time, meaning four weeks in total, and in only two rounds of phishing emails. Thirdly, the research did not perform a comparison between different traditional and STEM education methods. Future research is recommended to explore different STEM educational methods in comparison with traditional educational methods and their impact on developing employee competencies for recognizing phishing emails.

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MAPPING THE LANDSCAPE: A COMPREHENSIVE ANALYSIS OF ARTIFICIAL INTELLIGENCE INTEGRATION IN STEM EDUCATION THROUGH MIXED-METHODS APPROACH[1]

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Abstract. This study utilizes a mixed-methods approach, combining thematic analysis and bibliometric analysis, to explore the complex landscape of artificial intelligence (AI) integration in STEM education. Through a meticulous search of the journal articles in the Web of Science and Scopus databases, utilizing keywords "STEM" and "artificial intelligence," we identified 490 publications from various research domains, including Education, Social Sciences, Philosophy, History, Psychology, Arts and Humanities, Communication, and Behavioral Sciences. After a stringent screening and the removal of duplicates, 66 articles published between January 2009 and February 2024 were extracted. Our findings indicate a notable upward trajectory in the number of publications, particularly since 2021, with 2023 emerging as the pinnacle year, housing 50% of the total publications. The thematic analysis of the articles reveals five overarching themes: 1) Integration of Modern Technology in Education; 2) AI in Educational Support Systems; 3) AI in Curriculum Development; 4) Impact of AI on Student Learning Outcomes; and 5) Inclusivity, Diversity, Equity, and Policy Considerations. Furthermore, our study illuminates emerging trends, influential works, and collaborative networks within this field, while also exploring the extent of Open Access availability, thereby fostering opportunities for knowledge dissemination and collaboration. In sum, this research enriches our comprehension of the current landscape and future trajectories of AI integration in STEM education, offering valuable insights for researchers, educators, and policymakers.

Keywords. STEM, artificial intelligence (AI), bibliometric analysis, thematic analysis

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INTRODUCTION

The integration of Artificial Intelligence (AI) in education, particularly in STEM (Science, Technology, Engineering, and Mathematics) fields, rapidly transforms how learning and teaching occur in the 21st century. As educational systems worldwide grapple with preparing students for an increasingly complex and technology-driven world, AI offers promising solutions to enhance personalized learning, improve educational outcomes, and foster inclusivity. The advent of AI technologies, such as adaptive learning systems, intelligent tutoring, and automated assessment tools, has begun to shift the educational landscape from traditional, one-size-fits-all approaches to more tailored and dynamic experiences that cater to individual student needs.

This paper aims to map the current landscape of AI integration in STEM education through a mixed-methods approach, combining thematic and bibliometric analyses. By examining the breadth and depth of research published on this topic, the study seeks to identify key themes, emerging trends, influential works, and collaborative networks within the field. This comprehensive analysis not only highlights the rapid growth of interest in AI's educational applications but also underscores the importance of addressing ethical considerations, technological challenges, and the need for professional development among educators.

Through this exploration, we aim to provide valuable insights that can guide future research, inform educational practices, and support policymakers in harnessing AI's full potential to revolutionize STEM education. The findings from this study will serve as a foundation for understanding how AI is currently shaping educational environments and what opportunities and challenges lay ahead.

What is STEM?

STEM represents a modern interdisciplinary approach to the educational process (Hoi, 2021). As Sanders (2009) highlights, the acronym STEM was coined around thirty years ago, and the term was popularized by the U.S. National Science Foundation to promote an integrated approach to scientific knowledge in the areas of Science, Technology, Engineering, and Math, which are naturally interconnected. Instead of teaching subjects separately, the STEM approach is designed to connect and integrate subject content into a unified whole. These activities are based on projects and research tasks that involve problematic issues and situations, with a special emphasis on interdisciplinary learning (Golubović-Ilić, 2023; Filipović, 2023).

This teaching model is based on research and project activities to better equip students for solving complex situations in everyday life (Sneideman, 2013; Mejias et al., 2021; Cekić-Jovanović & Gajić, 2022; Filipović, 2023; Golubović-Ilić, 2023). To clarify the advantage of an integrative approach to teaching, authors highlight examples of applying mathematical knowledge in computing and vice versa, using computers to solve various mathematical operations and problems (Marić, in: Cekić-Jovanović & Gajić, 2022). Through an integrative or holistic approach to education, we achieve the overall development of all scientific disciplines involved and contribute to their better interconnection (Milić & Mladenović, 2022).

It is crucial for children to start developing skills recognized as necessary for living in the modern world from an early age. In other words, children must learn how to adapt to changes over time in a highly efficient way. Through integrative educational models such as STEM, students are introduced to an unknown, problem-based environment where they are required to use prior knowledge and experiences to solve the current situation and problem they are facing. Within these teaching models, students develop different stages of thought processes and cognitive activities such as reflection, connection, and reasoning, among others. This approach helps students "build a foundation of knowledge they can apply in everyday life" (Golubović-Ilić, 2023:192).

As the authors point out, there are no restrictions, i.e. no lower age limit for introducing and familiarizing children with the STEAM concept of learning. Some studies indicate that early childhood experiences are significant for developing brain structures, which later influence the types and levels of future abilities in adulthood. Accordingly, McClure and colleagues emphasize how early childhood experiences with STEAM learning can contribute to overall cognitive development, and mental, motor, and emotional aspects of personality (McClure et al., 2017). Since lived experiences form the basis for cognitive development (Van Keulen, 2018), early exposure to scientific phenomena enables better and deeper exploration of scientific concepts during formal education. In other words, when children are familiar with and exposed to scientific concepts through play and apply the STEM approach to learning, at that moment, "scientific literacy begins, or the seed of science is planted" (Eshach & Fried, in: Golubović-Ilić, 2023:197). Research has shown that children can adopt scientific terms and develop an understanding of scientific facts from an early age, and for that, they need a stimulating environment that provides opportunities for exploration, an encouraging space, and adequate communication (between teacher and student), whether in a formal or informal context (McClure, 2017; Golubović-Ilić & Ćirković-Miladinović, 2020). It is precisely in such "temporal spaces" that children develop various social relationships, socialize, improve communication skills, and gain knowledge about the world and scientific phenomena through play and exploration (Van Oers, 2013).

If we were to briefly describe the essence of the STEM concept and its derivatives (STEAM, STREAM, STEMIE), we could say that it mirrors life in a small and safe environment – it is a process of trial and error, searching for truth, testing ideas, or initial hypotheses. As De Jarnette optimistically states, for children, every mistake is an opportunity for a new beginning, as they are energetic, persistent, and full of enthusiasm like at no other stage of life (De Jarnette, 2018). Hence, they create opportunities for learning new truths about life every day.

What is AI?

Artificial Intelligence (AI) was formally introduced as a concept in 1955 during a seminal summer workshop at Dartmouth College, marking the beginning of AI research (McCarthy et al., 1955). At its essence, AI involves programming machines – be they computers, robots, or other systems – to perform tasks typically associated with human intelligence. While definitions of AI can vary, a widely accepted description by Copeland (2020) defines AI as the capability of a machine to execute tasks characteristic of intelligent beings, such as reasoning, symbolic thinking, generalization, and learning from experience. Despite extensive research, fully understanding AI remains a challenge, largely due to unresolved questions surrounding human intelligence, consciousness, and the mind.

In modern discussions, AI often evokes images of sophisticated systems that mirror human cognitive abilities – a notion that has both inspired and sparked debate. This debate, ongoing for decades (e.g., Searle, 1980), has gained renewed attention with the advent of advanced AI models like GPT-4 (https://openai.com/chatgpt/), which have expanded our understanding of AI's potential, particularly in natural language processing and problem-solving.

AI's potential in education is increasingly recognized, particularly for enhancing personalized learning and improving operational efficiency. However, this potential is coupled with significant concerns, including ethical dilemmas, technological challenges, and the need for substantial professional development to effectively implement AI in educational contexts (e.g. Aghaziarati, Nejatifar & Abedi, 2023; Tondeur et al., 2019).

For example, one significant application of AI in education is adaptive learning, where technologies are employed to tailor educational content to individual learners' abilities and progress (Capuano & Caballé, 2020). These systems aim to optimize learning efficiency by dynamically adjusting course materials to fit each learner's needs, using both automated systems and instructor interventions.

The concept of adaptive learning emerged in the 1970s, building on the initial AI applications in education that sought to emulate human teaching. However, the modern incarnation of adaptive learning, characterized by technologies like knowledge representation, user modeling, curriculum sequencing, and machine learning, took shape in the early 2000s with the rise of online education and a focus on personalized learning.

Recent advancements in AI-driven adaptive learning include:

(1) Conversational Agents: AI systems that engage with students in discussions, providing personalized guidance and motivation.

(2) Sentiment Analysis: Techniques that assess students' emotions in real time, enabling the delivery of targeted feedback.

(3) Recommender Systems: Systems that suggest additional learning materials based on a student's prior knowledge or observed learning patterns.

Despite the potential of adaptive learning technologies, their widespread adoption is limited by challenges such as the high costs of implementation and the complexities of integrating these technologies into existing educational frameworks. However, initiatives like the European colMOOC Project and the Precision Education Initiative (Hart, 2016) at National University (California, USA), among others, reflect the growing investment and interest in these technologies.

For example, a systematic literature review from 2023 (Heeg & Avraamidou, 2023) identified nine key AI applications in education, including automated assessment and intelligent tutoring systems, particularly within STEM fields like geoscience and physics. These applications have been shown to significantly impact educational outcomes, such as learning achievement and argumentation skills.

Similarly, a 2023 review by Gligorea et al. explored AI and machine learning in e-learning, emphasizing their role in personalizing learning experiences, optimizing learning paths, and enhancing student engagement. Despite challenges related to data privacy and system complexity, the potential of AI to revolutionize education remains significant.

Another prominent application of AI in education is intelligent tutoring systems, which have been extensively studied (Lin, Huang & Lu, 2023; Mousavinasab et al., 2021). These systems offer personalized instruction and feedback, further demonstrating AI's transformative potential in shaping the future of education.

METHOD

This study employs a mixed-methods approach, integrating thematic and bibliometric analyses, to investigate the integration of artificial intelligence (AI) in STEM education. The thematic analysis focused on identifying specific "facets" of this integration, including applications, challenges, and trends, which are detailed in a dedicated section of this paper. A comprehensive search was conducted in the Web of Science (WoS) and Scopus databases using the keywords "STEM" and "artificial intelligence." To reduce irrelevant results stemming from the frequent use of "stem" in biology, life sciences, and related disciplines, the search was restricted to fields such as Education, Social Sciences, Philosophy, History, Psychology, Arts and Humanities, Communication, and Behavioral Sciences. While the phrasing of these fields differed slightly between WoS and Scopus, the scope remained consistent. This search yielded an initial pool of 490 publications: 143 (29.18%) from WoS and 347 (70.82%) from Scopus.

The dataset was refined by filtering for journal articles, excluding conference proceedings, editorials, letters, short surveys, books, and book chapters. Duplicate entries (68 in total) were identified and removed using DOIs or, where unavailable, paper titles. Both authors independently assessed the remaining articles using predefined relevance criteria. The srticles were included if they explicitly addressed both STEM education and AI in a meaningful and interconnected manner.

A paper was considered "meaningful" if it provided substantive discussion or analysis of AI's role within STEM education, such as its influence on curriculum development, pedagogical strategies, or student outcomes. "Interconnected" was defined as demonstrating a clear linkage between STEM education and AI, including practical applications, theoretical frameworks, or empirical findings. For instance, studies discussing the use of AI-based tools to enhance STEM teaching and learning were included, while papers mentioning "stem" (lowercase) and AI in unrelated contexts, such as life sciences or robotics research, were excluded.

After applying these criteria, 66 unique journal articles remained: 38 (57.58%) from WoS and 28 (42.42%) from Scopus, published between January 2009 and February 2024.

To resolve discrepancies in eligibility assessments, a collaborative "matching phase" was conducted, during which papers with differing inclusion/exclusion decisions were reviewed and discussed until consensus was reached. This rigorous filtering and consensus-building process ensures that the final dataset comprises high-quality, relevant, and focused articles aligned with the study's objectives.

The final dataset's distribution by year of publication (WoS + Scopus) is as follows: 2024 – 5; 2023 – 33; 2022 – 12; 2021 – 9; 2020 – 2; 2019 – 1; 2017 – 1; 2016 – 1; 2011 – 1; 2009 – 1.

Thematic Analysis

Thematic analysis is defined as a scientific method used to identify, analyze, interpret, and report on recognized themes within the data being researched (Braun & Clarke, 2006). Thematic analysis is also described as "a systematic examination of qualitative material to identify broader patterns of meaning for grouping into higher-order categories/themes" (Ševkušić, 2019: 290). Due to its inherent flexibility, thematic analysis provides researchers with a wide range of possibilities for using it for various research purposes. However, it can also create difficulties if the chosen approaches are not clearly defined, explained, and specified (Vesić, Vujačić i Joksimović, 2018). The implementation of thematic analysis involves the researcher determining the criteria for the content that can be coded within a theme, as well as which and how many levels of meaning will be subject to interpretation (Ševkušić, 2019). Coding represents the fundamental process of developing themes by identifying specific items and labeling them with a predetermined symbol for coding. Since coding is a subjective act in the analysis, it is natural for it to be subject to categorical changes during the coding process itself. Considering that Thematic analysis is one of the most common forms of analysis within qualitative research, that emphasizes identifying, analyzing, and interpreting patterns of meaning (or "themes") within qualitative data, this approach is best thought of as an umbrella term for a variety of different approaches, rather than a singular method (Maguire & Delahunt, 2017).

When it comes to our research, through a meticulous search of journal articles in the Web of Science and Scopus databases, utilizing keywords "STEM" and "artificial intelligence," we identified 490 publications spanning various research domains including the following scientific fields: Education, Social Sciences, Philosophy, History, Psychology, Arts and Humanities, Communication, and Behavioural Sciences. After a stringent screening and the removal of duplicates, our analysis focused on 66 articles published between January 2009 and February 2024.

The thematic analysis was conducted based on a detailed search of two representative scientific databases. Five overarching themes include:

1. Integration of Modern Technology in Education;
2. AI in Educational Support Systems;
3. AI in Curriculum Development;

4. Impact of AI on Student Learning Outcomes; and
5. Inclusivity, Diversity, Equity, and Policy Considerations.

When discussing the first theme, *Integration of Modern Technology in Education*, it is important to highlight the leading sub-themes identified in the reviewed papers. The *Utilization of AI-supported game-based learning and project-based learning* demonstrates how artificial intelligence can enhance student engagement, creativity, and outcomes by making learning more interactive and personalized. There is also a growing emphasis on *ChatGPT and generative AI in STEM education*, where these tools are being used to support complex problem-solving and knowledge acquisition. A notable example is the exploration of students' perceptions of using ChatGPT as a virtual tutor in physics classes, where AI plays an active role in facilitating understanding and guiding learning. The conversation extends beyond the classroom, delving into the ethical implications of *ChatGPT for STEM research and higher education*, with media discourse highlighting concerns about AI's impact on academic integrity, research practices, and authorship. This is further expanded by discussions on ChatGPT's implications for industry and higher education, specifically the need for a transdisciplinary approach that bridges digital humanities and STEM. Lastly, research comparing the pairing of student teachers with in-service teachers versus ChatGPT shows intriguing results about its impact on critical thinking, learning performance, and cognitive load in integrated STEM courses, raising essential questions about the future balance between human and machine-led instruction.

The second topic, *AI in Educational Support Systems*, was developed based on three key sub-themes. The first sub-theme, *Application of AI for Didactical Approaches*, emphasizes how AI is transforming traditional teaching methods by providing personalized learning experiences, adapting content to individual student needs, and optimizing instructional strategies. The second sub-theme, *AI as a Learning-Supporting and Tutoring Tool*, highlights the role of AI as a virtual tutor, offering real-time assistance, guiding students through complex topics, and enabling more flexible, self-paced learning. The third sub-theme, *Focus on Educational Analytics, Assessment, and Evaluation for Precision Education*, explores the use of AI-driven analytics to gather and analyze big data in real time, allowing for precise assessments of student performance and personalized interventions, which help enhance learning outcomes. This approach supports the movement toward data-informed decisions in education, aiming for tailored learning experiences that meet the diverse needs of students.

The third topic, *AI in Curriculum Development*, is based on three subtopics. The first, the *Role of AI in Curriculum Design*, focuses on how AI can aid in the development of curricula by analyzing educational needs, predicting trends, and customizing content to fit diverse learning environments. The second subtopic, *Implementation of AI in Educational Programs*, discusses the practical integration of AI tools into educational settings, enabling educators to enhance their teaching methods and create more dynamic, interactive learning experiences. The third subtopic, *The Crisis of Artificial Intelligence: A New Digital Humanities Curriculum for Human-Centered AI*, addresses the ethical and philosophical challenges posed by AI in education. It calls for a shift towards a curriculum that prioritizes human-centered AI, combining technological advancement with the principles of digital humanities to ensure that AI development aligns with human values and societal needs.

The fourth topic, the *Impact of AI on Student Learning Outcomes*, encompasses several crucial aspects. The first sub-theme, *Effects of AI on Knowledge, Skills, and Attitudes*, examines how AI-enhanced learning environments influence students' cognitive development, skill acquisition, and shifts in their attitudes toward learning. It explores the extent to which AI tools help students better understand complex concepts, improve problem-solving skills, and foster more positive engagement with their studies. The second sub-theme, *Examination of Psychological Traits in the Context of AI Integration*, delves into how the incorporation of AI in education affects students' psychological traits such as motivation, self-efficacy, and emotional resilience. This sub-theme focuses on the need to understand how AI impacts students' mental and emotional responses to learning, including stress levels, adaptability, and overall well-being.

The fifth and last topic listed in this thematic analysis, *Inclusivity*, *Diversity*, *Equity*, *and Policy Considerations*, addresses the importance of ensuring fairness and accessibility in the integration of AI in education. The first sub-theme, *Exploration of Inclusion and Diversity in AI Integration*, highlights the need to design AI systems that are inclusive and account for the diverse backgrounds, abilities, and learning needs of all students. It emphasizes how AI can either bridge or widen gaps in educational access, depending on how it is implemented. The second sub-theme, *Policy Research and Implications for Educational AI* focuses on the policies needed to regulate and guide the use of AI in education. It addresses the ethical and legal frameworks that should be established to ensure AI tools are used responsibly, equitably, and in ways that promote diversity and inclusivity. This sub-theme calls for ongoing research into the policy implications of AI, ensuring that it serves all students fairly while supporting educational equity.

Based on everything written above about the presented thematic analysis, the exploration of AI in education reveals its profound impact on modern teaching methodologies and learning experiences. AI-supported game-based and project-based learning have been reshaping educational approaches, enhancing engagement and practical application. ChatGPT and generative AI's role in STEM education, including its use as a virtual tutor and the associated ethical implications, underscore the need for a balanced integration of technology that supports both pedagogical innovation and responsible usage. Addressing the effectiveness of AI versus human expertise in teaching, alongside discussions on transdisciplinarity and the broader implications for industry and higher education, highlights the ongoing necessity for thoughtful implementation and policy development to maximize AI's benefits while addressing potential challenges.

Bibliometric Analysis

Bibliometric analysis is a quantitative method used to analyze large volumes of scientific data, helping researchers understand the development, trends, and intellectual structure of a particular field (Donthu et al., 2021). It is particularly effective in handling extensive datasets from sources like Scopus or Web of Science and has gained popularity due to advancements in bibliometric software, such as BibExcel, which was used to conduct the present analysis.

This section addresses two key research questions: (1) Which journals are the key in the field of AI integration in STEM education? and (2) Which authors have published the most on the topic?

Key Journals. Table 1 lists the journals that have published the most research on AI integration in STEM education. Notably, *Education and Information Technologies* and *Frontiers in Education* lead the field with four publications each, followed by *Educational Technology & Society*, *International Journal of Educational Technology in Higher Education*, and *International Journal of STEM Education* with three publications each. This distribution indicates that AI integration in STEM education is a multi-disciplinary topic that spans educational technology, general education, and STEM-specific journals, reflecting its broad relevance and interdisciplinary appeal.

Table 1. Scientific journals where research on AI integration in STEM education has been published

Journals	No. of papers published
EDUCATION AND INFORMATION TECHNOLOGIES	5
EDUCATIONAL TECHNOLOGY & SOCIETY	4
INTERNATIONAL JOURNAL OF EDUCATIONAL TECHNOLOGY IN HIGHER EDUCATION	4
FRONTIERS IN EDUCATION	4
SUSTAINABILITY	3
EDUCATIONAL TECHNOLOGY & SOCIETY	4
INTERNATIONAL JOURNAL OF STEM EDUCATION	3
EDUCATION SCIENCES	2
IEEE TRANSACTIONS ON LEARNING TECHNOLOGIES	2
ACM TRANSACTIONS ON COMPUTING EDUCATION	1
ASIA PACIFIC JOURNAL OF EDUCATION	1
BORDÓN-REVISTA DE PEDAGOGIA	1
CONTEMPORARY EDUCATIONAL TECHNOLOGY	1
EDUCATIONAL STUDIES	1
FRONTIERS IN PSYCHOLOGY	1
INDUSTRY AND HIGHER EDUCATION	1
INTERNATIONAL JOURNAL OF HUMANITIES AND ARTS COMPUTING-A JOURNAL OF DIGITAL HUMANITIES	1
INTERNATIONAL JOURNAL OF SCIENCE EDUCATION	1
JOURNAL OF EDUCATION FOR BUSINESS	1
JOURNAL OF MEDICAL EDUCATION AND CURRICULAR DEVELOPMENT	1
JOURNAL OF NEW APPROACHES IN EDUCATIONAL RESEARCH	1
RESEARCH IN SCIENCE EDUCATION	1
REVISTA IBEROAMERICANA DE EDUCACIÓN	1
REVISTA PUBLICACIONES	1
SOUTH AFRICAN JOURNAL OF CHILDHOOD EDUCATION	1
THINKING SKILLS AND CREATIVITY	1
TOPICS IN COGNITIVE SCIENCE	1

Key Authors. Our analysis identified several key authors in the field, including Huang Yueh-Min (National Cheng Kung University, Tainan, Taiwan), Lee Hsin-Yu (National Cheng Kung University, Tainan, Taiwan), Lin Chia-Ju (National Cheng Kung University, Tainan, Taiwan), Wang Wei-Sheng (National Cheng Kung University, Tainan, Taiwan), and Wu Ting-Ting (National Yunlin University of Science and Technology, Yunlin, Taiwan), each of whom has published two papers. These authors are notably contributing to the evolving discourse on AI's role in enhancing STEM education through adaptive learning technologies. Their articles, such as "Leveraging computer vision for adaptive learning in STEM education: Effect of engagement and self-efficacy" and "Recognitions of image and speech to improve learning diagnosis on STEM collaborative activity for precision education", highlight emerging research focused on AI-driven tools to improve student engagement and personalized learning.

Current Trends. First, what can be noticed is that our findings indicate a notable upward trajectory in the numbers of publications, particularly since 2021, with 2023 emerging as the pinnacle year, housing 50% of the total publications. This period coincides with the popularization and significantly increased investment in research and applications of artificial intelligence in recent years, especially since the emergence of generative AI models like ChatGPT and similar technologies. It can be assumed that one of the reasons for this expansion is that this technology emerged during the COVID-19 pandemic (when people simply had the time to explore and experiment with it).

Second, it was noted that all levels of education are almost equally present (Preschool, Elementary, Secondary, and Higher Education). This finding is encouraging, as it suggests that, at all levels, so to speak, the possibilities of implementing new technological advancements in the education system are being equally researched and explored. The bibliometric analysis reveals several emerging trends in the field:

1. Increased Focus on Adaptive Learning: Many of the most cited works emphasize adaptive learning systems, which are AI technologies designed to tailor educational content to individual learner needs. This aligns with broader trends in personalized education and suggests a growing recognition of AI's potential to address diverse learning preferences and improve educational outcomes.

2. Collaborative Research Networks: The field is characterized by strong collaborative networks, with authors frequently co-authoring papers across institutions and countries. This suggests a high level of international interest and collaboration, which could accelerate the development of innovative AI applications in STEM education.

3. Diverse Applications of AI: AI applications discussed in the literature range from automated assessment and feedback systems to intelligent tutoring

and real-time learning analytics. These diverse applications underscore AI's versatility and potential to transform multiple facets of STEM education, from classroom management to content delivery and student support.

Limitations and Future Directions. Despite the progress, the field faces several challenges. First, there is a limited number of publications specifically focusing on ethical considerations, such as data privacy and algorithmic bias, which are crucial as AI technologies become more embedded in educational settings. Future research should address these gaps to ensure responsible and equitable use of AI in education.

Moreover, while the current literature covers a broad range of AI applications, there is a notable gap in longitudinal studies that evaluate the long-term impact of AI on learning outcomes in STEM fields. Addressing this gap could provide valuable insights into how AI tools can be sustainably integrated into educational practices.

Conclusion. In summary, the bibliometric analysis highlights the growing body of research on AI integration in STEM education, with key contributions from leading journals and authors in the field. The identified trends and gaps offer a roadmap for future research, emphasizing the need for continued exploration of AI's potential to enhance personalized learning and its long-term impact on STEM education.

CONCLUSION

This study provides a comprehensive analysis of the integration of Artificial Intelligence (AI) in STEM education, utilizing a mixed-methods approach that combines thematic and bibliometric analyses. The findings reveal a notable increase in publications on AI in STEM education since 2021, reflecting the growing interest and investment in this field. Key themes identified include the integration of modern technology in education, the role of AI in educational support systems and curriculum development, the impact on student learning outcomes, and considerations of inclusivity, diversity, and policy.

Our analysis highlights several emerging trends, such as the focus on adaptive learning systems and the importance of collaborative research networks, which demonstrate the potential of AI to personalize learning experiences and improve educational outcomes across all levels of education. However, the study also identifies significant challenges, including ethical concerns related to data privacy and algorithmic bias, as well as the need for further research into the long-term impacts of AI on learning outcomes.

As AI continues to evolve and permeate educational contexts, it is crucial that researchers, educators, and policymakers work together to address these challenges and harness AI's potential responsibly. Future research should focus on bridging existing gaps, such as exploring ethical implications more deeply and conducting longitudinal studies to assess the sustainability of AI tools in educational settings. By doing so, we can ensure that AI integration in STEM education not only enhances learning but also contributes to a more equitable and inclusive educational landscape.

In sum, this study maps the current state of AI integration in STEM education, offering a roadmap for future research and providing insights that can help shape the future of education in an increasingly AI-driven world.

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Appendix: *The list of the 66 articles that were analyzed in the paper*

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IV

THE ROLE OF THE STEM/STEAM/STREAM APPROACH IN TEACHING MUSIC, ART AND PHYSICAL EDUCATION

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MUSICAL-DIDACTIC GAME IN THE STREAM APPROACH: FROM CREATION TO OUTCOME

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Abstract: This paper presents the possibilities and significance of applying musical-didactic games in an integrated approach to early childhood learning. It introduces a specially designed musical-didactic game incorporating elements from various STREAM fields. The objectives of this theoretical research were: a) to highlight the importance of musical-didactic games for child development in terms of acquiring concepts and mastering knowledge from different areas; b) to specify the tasks and roles of educators in organizing planned learning situations using musical-didactic games. The research was conducted using the descriptive method and content analysis. The results confirm that musical-didactic games in an integrated learning approach stimulate curiosity in young children to acquire concepts and master knowledge from various domains. Additionally, the specification of diverse tasks and roles of educators is significant for organizing planned learning situations using such games. The implications of this research point to numerous possibilities for applying musical-didactic games to develop children's potential and enhance pedagogical practice.

Keywords: musical-didactic games, STEAM approach, integrated learning approach, concept acquisition and understanding, early childhood knowledge.

INTRODUCTION

In contemporary preschool education in the Republic of Serbia, as well as in other European countries (Slunjski and Lančić, 2022), the role of a project-based approach and integrated learning through play, planned learning situations, and practical life situations is emphasized, to lay the foundation for the development of key educational competencies in children. In the current

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Preschool Education Program Framework – Years of Ascent (2018), there is no classification of areas from which children acquire fundamental knowledge that contributes to specific aspects of their development: speech development, motor, musical, and artistic abilities, and logical and mathematical thinking. The educator's task is to simultaneously develop these children's abilities, connecting them with the development of communication, mathematical, digital, and social competencies. In this regard, there are no methodological guidelines for selecting and implementing content from these areas in work with children. There is often a question if methodologies still exist as scientific disciplines in preschool age. An affirmative answer is indicated in the basic requirement for applying the project-based approach to learning; an educator must know the content he or she presents to children and how they can learn about them (Pressick-Kilborn, 2022), meaning that they must possess certain methodological knowledge and competencies. This fact raises another question: How can the content of these areas (speech development, introduction to basic mathematical concepts and the environment, music, physical, and art education) be implemented in project activities initiated by children's interests? This question brings us back to the primary role of an educator—to be creative and ready to adapt his or her approach to children's abilities, skills, and interests. The requirements for content integration and creative approaches to teaching, in this sense, are not new to any educator, who can further develop, monitor, direct, and expand a child's idea within a project without time limitations. During the project implementation, in relation to the children's prior knowledge and experiences, as well as the educators' competencies, the content from various areas can spontaneously fit into a specific, jointly selected, and meaningful topic that gradually connects and unites different phenomena and concepts.

The STEM approach is a significant model of integrated learning. It can be successfully implemented in all segments of primary education, but its applicability to preschool age is insufficiently researched. Although it encompasses four areas—science, technology, engineering, and mathematics—the key aspects of the STEM approach are not limited to these disciplines but extend to the development of creative and critical thinking in a broader context (Hobbs & Clark, 2022). STEM involves a set of disciplines whose interconnection, through interdisciplinary and multidisciplinary approaches, leads to understanding content and acquiring integrated knowledge and experiences (Hobbs & Clark, 2022). There is no universal way to implement the STEM model/project/approach or a singular method of teaching; rather, STEM can be defined as a way of learning and a framework for teaching, by providing children with connected, functional knowledge (Hobbs & Clark, 2022). Application of this approach allows learners to transfer concepts and content from one field of application to another, to use ideas and concepts learned in one area to enrich the learning process in another, and to ensure that acquired knowledge and skills across different areas are firmly interconnected (Hobbs & Clark, 2022). A further step in the development of this model involves incorporating arts and renaming STEM to STEAM; "Art enables students to express ideas, especially at an early age, channel them, and apply them to STEM learning and problem-solving" (Gilbert & Borgerding cited in Hobbs & Clark, 2022: 162). Visual arts, music, dance, and drama, due to their expressive nature, can be integrated into various themes/areas in numerous ways, enhancing and advancing inquiry-based learning (Kuhlthau, Maniotes & Caspari, 2018). Artistic content provides significant and authentic opportunities for learning and teaching precisely because of its aesthetic and expressive dimensions (Quigley & Herro, 2019). Implementing artistic activities should not be limited to adding creative/artistic content as supplementary activities in the final stages of the learning process, such as drawing or listening to music while learning mathematical content. Instead, artistic activities should be integrated into the learning and problem-solving process as an integral part of reflection and integration (Quigley & Herro, 2019). Integrating arts into an integrated approach enables the demonstration (understanding) of content from different domains through artistic forms, linking artistic forms/content with other domains, thereby achieving goals in both domains (Quigley & Herro, 2019).

In the context of acquiring educational competencies for lifelong learning in the 21st century, where significant emphasis is placed on communication in native and foreign languages, and literacy spans across various domains (digital, informational, mathematical, musical, etc.), integrated areas of science, technology, engineering, mathematics, along with arts, are accompanied by language content, giving rise to a new acronym, STREAM. Language learning (native and foreign) can deepen children's interest and motivation, broadening their understanding of content in other disciplines. Knowledge of the English language is no longer viewed merely as additional knowledge gained in private language schools, but as essential for the 21st century and preparing children for future education (Ćirković-Miladinović, 2024). Integrated learning enables a deeper understanding of each discipline individually and the acquisition of basic foundational knowledge, upon which they can independently acquire new information later on (Kuhlthau, Maniotes & Caspari, 2018). Moreover, integrating natural sciences with artistic fields and language allows for shifting the learning process out of the classroom and formal frameworks, connecting it with life experiences through collaboration and interaction with both local and broader communities.

Starting from the common elements of STREAM learning and the current concept of preschool education, which is based on integrating various learning strategies within a project approach, we wanted to highlight the possibility of applying the STREAM approach not only in direct educational work with children and creating meaningful learning situations, but also in creating content that would be applied in this approach. In other words, by implementing the STREAM approach, we have created a music-didactic game that contains elements from various domains, through which children acquire musical knowledge and knowledge from other artistic fields and natural sciences. The possibilities of applying the music-didactic game, outcomes of integrated learning through play, the impact on children's competency development, and the role of educators in game implementation are presented in the following chapters.

Music-Didactic Games and an Integrated Approach to Early Childhood Learning

In brief, we will explain why we have chosen music-didactic games as a bridge/tool for integrating various contents in the learning process of early childhood education.

The development and learning in early childhood are focused on a project-based approach and creating stimulating learning situations, where play remains a significant component of educational work. Authors Minić and Jovanović emphasize that play is used "as a mediator for influencing children's development in the broadest sense" (Minić and Jovanović, 2018: 283), and its greatest benefits are realized in the spheres of cognitive, emotional, and social development. "The way a child thinks during play is fundamentally the driver of their intellectual development" (Minić and Jovanović, 2018: 283). Acquiring new experiences and emotional engagement in play encourages healthy emotional development in children, while collaboration with others in play develops social feelings and facilitates the process of child socialization. For these and many other reasons, "play must be an integral part of the educational process within institutions where the learning and development of preschool children take place" (Slunjski and Ljubetić, 2014: 129). On the other hand music plays an important role in children's development and lives. Sudzilovski and Ivanović (2013) cite numerous studies across various scientific disciplines regarding the impact of music on cognitive, affective, and psychomotor processes, emphasizing findings on the positive influence of music on physical development, phonological awareness, spatial abilities, and mathematical achievement. In the educational context, music operates within all educational domains and "influences intelligence, emotions, morals, aesthetics, creativity, and socialization" (Sudzilovski and Ivanović, 2013: 558).

As an integral part of holistic child development, their musical development also unfolds, encouraged and supported through the implementation of various musical contents and activities. The opportunities and benefits of learning through musical (artistic) content have been previously described within the STREAM approach, and in early childhood, in line with their interests, needs, and stages of psychophysical development, musical play holds significant importance.

Two key aspects contribute to affirming this musical activity: emotional response to musical content and movement as a way of expressing musical experience. The role of music in early childhood is particularly significant for the emotional development of children. Early exposure to musical content and favorable environmental influences, such as stimulation and support from parents and educators, contribute to fostering children's musical abilities (Mirković Radoš, 1996). On the other hand, "movement in the psychomotor domain can be used as a tool for learning and developing cognitive skills and abilities" (Tanasković, 2022: 405). "Movement stimulates many mental abilities, integrates information and experiences, and plays a crucial role in memory, speech, emotions, and maintaining attention" (Japundža Milisavljević, Đurić Zdravković, & Gagić, 2016: 331). The combination of these two components, music and movement, in the act of performing musical play, enables children to develop properly and synchronously.

Musical games, according to their purpose, function, and musical and play demands, can be classified into several groups, which authors title differently. Authors Sudzilovski and Ivanović note that the most common classification includes singing games, games with instrumental music, folk dances, and musical dramatizations (Sudzilovski and Ivanović, 2015). Adding to these types of musical games, Đurković-Pantelić (1998) includes creative games in the form of dance improvisations, emphasizing that games can be grouped based on the possibility of free expression, distinguishing between free children's games or spontaneous creation of movement to music and "games performed according to specific rules" (Đurković-Pantelić, 1998: 141). Today, most authors (Sudzilovski and Ivanović, 2015; Jeremić and Stanković, 2019) agree that the most precise classification of games for early childhood has been provided by Višnja Protić. Protić (1983) emphasizes that in working with young children, games should include individual and collective tactile contact games, imitative musical games, role-playing games, line games, circle games, and other musical games diverse in form and content, such as counting games, games with sound objects, and didactic games.

Apart from their common features, each of the mentioned types of games has a pronounced educational role in specific segments of a child's development, aimed at developing certain skills and competencies, or creating musical concepts as a basis for acquiring musical knowledge. Singing games, with their textual (thematic) content, initiate movements and imply the correct textual, rhythmic, and melodic performance of songs complemented by appropriate movements (Pantelić-Đurković, 1998). Folk dances, characterized by collective performance in various formations, contribute to the development of collective spirit, cooperation, understanding, individual responsibility to synchronize steps with others, and developing a sense of belonging while constructing cultural and national identity. Musical dramatizations encourage integrated learning and creativity by combining different elements and areas (acting, mime, music, movement, costumes, scenography, etc.). Games with instrumental music help children focus on the expressive means of music without the mediation of textual content, thereby encouraging the free expression of musical experience and the manifestation of creativity through coordinating movements with musical elements.

Children acquire specific musical concepts to the extent permitted by their stage of cognitive and musical development through learning musical-didactic games, which have specific goals and rules. Due to the predefined rules compared to the types of games mentioned earlier, they may not initially seem suitable for fostering children's creativity and initiative, which are important aspects of modern concepts of preschool education. However, when we consider the educational function of musical-didactic games and their role in enabling children "to experience and reproduce elementary musical concepts" (Stojanović, 1991: 145), we find potential and opportunities for integrated learning and development of young children in this type of musical game. Besides musical elements/concepts, musical-didactic games can also include elements from other areas. Moreover, the goal of the game does not have to focus solely on acquiring musical concepts (distinguishing sound characteristics, children's instruments, recognizing vocal qualities, performing quietly and loudly), but it can be oriented towards acquiring concepts from other domains (visual arts elements, mathematical concepts). Creating, preparing, and executing these musical-didactic games with elements of integrated learning is a specific task and challenge for educators, which is why their role and competencies will be discussed in the next chapter.

Professional competencies and roles of educators in implementing musical-didactic games

According to the *Regulation on Standards of Competencies for the Profession of Educators and their Professional Development* (2018), the competency of educators is specified through their knowledge, skills, and values in three areas: 1) direct work with children; 2) fostering collaboration and learning communities; and 3) developing professional practice. For our work here, the competency of educators in direct work with children is of particular importance.

The competency of educators in direct work with children implies the mutual dependence and interconnectedness of cognitive, motor, social, emotional development, and speech development (ibid.). These complementarities underscore support for an integrated approach to learning in project-based and other activities involving children and educators. In this context, organizing music-didactic games for children makes sense because these games are tailored to children's interests, capabilities, and needs, while also involving activities that support their holistic development and uphold the principle of wholeness and integrity. In these observations, we can recognize the importance and necessity of developing an integrated approach to the learning of young children, which enables their active participation in activities that stimulate the development of their overall potential. In music-didactic games, the focus is on potentials that can foster physical development (gross and fine motor skills), cognitive development (thinking abilities, memory, connections...), socio-emotional development (mutual assistance, help, and support, recognition, and cultivation of emotions...), as well as speech development (correct pronunciation, enriching vocabulary...).

At early ages, children are ready to experientially learn through various activities, to explore their environment, as well as their potential. Games like music-didactic ones are significant during this period for developing their initiative and cooperation. The initiative of preschool children arises from their curiosity, spontaneity, experiential learning, and receptiveness to influences from their environment. These developmental and learning specificities of children, before they start school, determine their actions toward themselves and other people.

The initiative shown by children in progressively complex play activities determines their social behaviors and relationships within a group. Curiosity and spontaneity encourage them to engage in activities where they explore their sensory world, increasingly expressing the need to communicate with other children, interact with them, adapt to the group, and begin to understand roles and others' perspectives. This social interaction entails cooperation with peers, which is both a need and a stimulus for further preschool development (Kopas-Vukašinović, 2012). As previously emphasized, music and musical activities play a significant role in children's upbringing and represent an integral part of their holistic development. The specificities of learning through musical activities such as music-didactic games stimulate children's initiative and cooperation, thus fulfilling their significant educational function.

While playing, which is a specific way of learning for preschoolers, children experiment, pose, and solve problems in a manner inherent to themselves. Through this process, children's latent experiences are systematized into a system of experiences, and subsequently into a system of knowledge.

Through play, it is possible to transform different patterns of children's behavior and stimulate new models, which contributes to further development of their overall potential (Hohmann & Weikart, 1995; Kopas-Vukašinović, 2006; Kopas-Vukašinović & Jovanović, 2012). In integrated activities, such stimuli are more intensive; for example, in the aforementioned music-didactic game, children are simultaneously encouraged to develop various abilities mentioned earlier, creating conditions for their further complexity as they grow older. Furthermore, by using such games and manipulating various materials, conditions are created for children to better navigate new situations later on, in solving similar problems or tasks.

In terms of established professional competencies, the current preschool program specifies the goals of preschool education directed toward the personal, active, and social well-being of children. These goals clearly define the tasks and roles of educators in working with young children, in terms of planned program outcomes and the mentioned well-being aspects. When it comes to the possibilities of an integrated approach in working with children, these well-being aspects for the child imply that they are fulfilled, content, and happy in terms of developing the mentioned abilities. Their needs and interests are respected, encouraged, and supported, and children are engaged in diverse and creative activities. Through integrated activities, children explore, imagine, expand, and exchange experiences, knowledge, and skills, expressing themselves in various ways that are characteristic to them. They initiate activities and are cooperative, and in doing so, they recognize and enhance their abilities in various aspects of development (cognitive, motor, social, emotional, communication, and creativity). In such situations, children are ready to make decisions, make choices, take responsibility in activities, communicate, negotiate, and collaborate with peers (Foundations of the Preschool Program, 2018). Regarding achieving these mentioned benefits for children, the roles of educators can be defined in the context of planning (a), organizing (b), and (c) evaluating play activities that are appropriate to the age, capabilities, and interests of children. When it comes to music-didactic games, these roles involve:

> a) Carefully selecting, understandable, and appropriately timed text, cheerful melodies appealing to children's ears, and effective motivational preparation of children for participating in a game;
>
> b) Encouraging and supporting children in the game, involving the educator as an equal member, observing and monitoring children's behavior during the game;
>
> c) Discussing the game with children (what they know, can do, and want after the game), evaluating the value of the game in terms of children's exhibited behaviors (engagement, curiosity, initiative, and collaboration) and concerning their demonstrated abilities and values (cognitive, motor, emotional, social).

All these roles of educators should be viewed in unity. In music-didactic games, they imply purposeful and comprehensive action by the educator, with the possibility of complicating the game and introducing gradual challenges according to children's capabilities and interests, up to creating new games.

RESEARCH METHODOLOGY

The aim of our theoretical research is to present the significance of music-didactic games in organized integrated learning activities, focusing on the development of children's overall potential.

This goal involves specifying examples of music-didactic games and potential developmental outcomes, as well as presenting the professional competencies of educators for implementing such activities and their roles concerning the program objectives aimed at children's well-being.

The research was conducted using a descriptive method and content analysis procedure.

RESULTS

Description of the Music-Didactic Game "Where is the Sea"

In accordance with the findings of contemporary psychology on children's learning and development, as well as current preschool education programs, educators are expected to listen to and respect children's interests, prior knowledge, and potentials. They are expected to creatively frame various contents and find approaches that will support and accelerate their development (Stanojević & Vukićević, 2020). For the purposes of this theoretical research, a music-didactic game *Where is the Sea?* has been designed. This game integrates elements from different fields, encompassing not only musical elements and movements but also language, natural sciences, mathematics, and visual arts. The authors' idea was to unify elements from various fields into one game and to apply a STREAM approach in creating the text and melody of the music-didactic game. As with other didactic games, a primary goal of the game has been predefined: to foster the understanding of mathematical relations through contents from other areas.

The poetic text of the music-didactic game, in its original Serbian version[1],

[1] When translating the song from Serbian to English, consideration was given to the content and purpose of the music-didactic game. Therefore, the rhymes in the second and fourth lines were omitted; the melody remains the same, with slight rhythmic changes due to the different syllable counts.

possesses the following characteristics: it includes familiar concepts for children, maintains a proper rhythmic organization of verses (with the same number of syllables in the first and third lines, and the same number in the second and fourth lines), and features a correct arrangement of rhymes to aid in easier memorization and motivate children to learn the musical game. The text is suitable for visual illustration, which children observe and follow while learning the lyrics and melody of the game, helping them perceive relationships and logically connect content with movement.

Figure 1. Musical notation (text and music written by Nataša Vukićević)

The melody is adapted to children's abilities and prior knowledge, ranging from C1 to A1, with a simple harmonic structure. Consequently, each melodic motif of every verse starts with lower or higher tones. The melodic line contributes to the aesthetic experience of the text (e.g., repeating the same tone and evoking images of a calm sea). Children simultaneously learn the text and melody through auditory processing, observing the visual illustration. After singing the song, children are tasked with demonstrating and following the content of the song through hand and body movements. This can be a spontaneous improvisation, supplemented with instructions from the educator to show, through movement, the place where the cloud is (above), the boat (in the middle, between the cloud and the shell), the shell and the pearl (below).

In addition to textual content, movement follows the melodic line and helps children demonstrate where certain phenomena and objects mentioned in the song are located (above, below, in something): waving their hand above their head to show the undulating movement of clouds, then making a straight motion at waist height to depict a straight line and calm sea where the boat sails, and finally squatting when singing about the shell and mimicking the opening of the shell in rhythm with the counting units (four hand movements for four beats). All movements are performed in rhythm, harmoniously, and uniformly, developing in children a sense of even rhythmic pulsation and rhythmic abilities. Learning does not end with the execution of the game but continues with discussion and reflection on the game elements and what they heard, saw, and demonstrated through tasks that define relationships for each concept: where the sea is in relation to the cloud, where the boat is in relation to the shell, and where the shell and pearl are located.

The title of the didactic game is formulated in the form of the question *Where is the sea?* and the answers to the question indicate the tasks and outcomes of the game.

In accordance with the new *Foundations of Preschool Education and Upbringing Program – Year of Ascent* (2018), which emphasizes that one of the important educational competencies is communication in the native and foreign language, the game can be enhanced with a new task of learning specific words in English and their understanding. The learning process also involves the integration of various activities of children (musical, verbal, logical, physical, dance, visual...). After performing the game, children are introduced to three key words in English. These are *cloud*, *boat*, and *shell*. Each of these words is accompanied by a specific movement in the previously performed musical game. Instead of pronouncing or translating the given word, the child should perform the corresponding movement.

Acquired Concepts/Knowledge within Individual STREAM Areas

The novelty of the presented concept of the music-educational game lies in integrated learning and acquisition of knowledge from various fields, specifically applying the STREAM approach in early childhood education. Through playing this music game, children acquire knowledge across several areas, which we list individually in the following text.

Language and speech development. Considering that the text of the music-educational game does not contain unfamiliar words, children do not acquire new terms; instead, their attention is focused on understanding the meaning of the poetic text. Interpreting the verses stimulates children's imagination, prompts a series of questions, and initiates the creation of new ideas. Moreover, discussing a specific segment of the text can lead to acquiring new knowledge from other areas. For example, interpreting the verse "A gray cloud sails through the sky" prompts thoughts about whether clouds really sail, why they are gray, whether clouds move, and whether there are other ways to describe the movement of clouds.

Art. Art elements mentioned in the song, such as gray and white, are just one aspect of the visual arts that children can explore. The visual content of the imagery can have multiple roles in the learning process: they help children determine relationships and also serve as a supportive tool for learning the text and melody of the music game. Additionally, such music-educational games can be a significant motivational vehicle in visual activities, since children can illustrate the song imagery creatively, in their unique way.

Mathematics. Determining the spatial relations between the objects (*above*, *below*, *in*, etc.) is the primary goal of learning with this musical-didactic game. An effective learning approach is supported by an integrated approach applied during the execution of the musical game itself, where mathematical concepts are reinforced through movement, text, visual, and musical elements. In addition to the primary goal mentioned, the *number 1* mentioned in the text can prompt a dialogue aimed at developing children's logical thinking, through tasks such as comparing one shell with one sky and discovering differences based on knowledge from other areas. Learning through reflection on specific phenomena and reaching conclusions through children's shared engagement contributes to functional knowledge and the acquisition of mathematical competencies.

Music Education. Performing a musical game, like other musical reproductive activities, is an important segment in developing children's musical abilities, especially their sense of rhythm and rhythmic pulsation. Music, in conjunction with other components, offers numerous educational benefits as discussed in our theoretical approach to this issue. The musical elements are aligned with mathematical relationships: words like sky and cloud, positioned *above* the sea and ship, are underscored with higher tones, while the concept *below* is emphasized with lower tones relative to preceding pitch heights in the song. The melodic line, characterized by specific features, contributes to the aesthetic experience of the text (repetition of the same tone in the second verse illustrates the image of a calm sea). Besides the alignment of pitch height with mathematical relationships, the type of movement assigned to a specific verse serves to focus attention on the musical experience of undulating and flat melodic lines or the rhythmic experience in the final verse.

Exploring the environment. Insights into phenomena, concepts, and objects such as clouds, sea, seashells, and boats, based on the emotional experience during the game performance, can extend to other related concepts important for understanding the environment and the world that surrounds them: precipitation, weather conditions, water, and air.

Physical education. Uniform and precise execution of movements in the rhythm of the game, as well as possible free dance movements, have multiple benefits for satisfying children's need for movement, exploring the possibilities of their own bodies, developing children's independence and autonomy in movement, developing children's basic movements, coordination, and improving general movement abilities of children (agility, speed, agility, flexibility...).

The Roles and Tasks of Preschool Teachers in Implementing Integrated Content in Music-Didactic games

The competencies of preschool teachers for conducting music-didactic games, which relate to achieving the personal, professional, and social well-being of children, are outlined in the theoretical approach. Therefore, this chapter will present specific tasks and roles of preschool teachers in preparing and conducting the game *Where is the Sea*, achieving the game's primary goal, and acquiring integrated knowledge. The choice of a didactic game in this case involved creating a text adapted to the possibilities of integrative learning independently and designing a melody in line with the textual content and goal of the game.

Besides the competencies of preschool teachers oriented towards creating a positive learning environment, child development, and well-being, creating a music-didactic game requires specific abilities across different domains. Regarding the two main components, textual and musical, creating a music-didactic game presupposes a certain level of literary, musical, and creative abilities in preschool teachers. Equally important are motivational aspects responsible for generating and operationalizing ideas. In this case, the motivation and desire of educators to facilitate, approach, and enrich the process of integrated learning for children, in the context of exploring different styles and learning situations, are the main drivers for preparing and conducting music-didactic games. It should be emphasized that preparing a music-didactic game, due to its complexity, poses an identical or even more complex demand on preschool teachers compared to implementing the game, its flow, and learning outcomes.

The first step is to create a text that, besides the primary requirement of being short, understandable, with a proper rhythmic organization of verses and the use of rhyme, should also subtly introduce the learning area to which the content and goal of the game belong (learning mathematical concepts/relations). The second step is to compose a melody for the given text; this is not a complex task and does not necessarily require a high level of musical knowledge and abilities from preschool teachers, considering that the melody is predetermined and conditioned by the characteristics of the text. An additional task for the educator may involve adjusting the melody and aligning it with the game's goal, highlighting specific textual moments through music. The final stage of game preparation involves designing movements and visual illustrations of the content. Besides building on previous components, designing movements can also be entrusted to the children as a form of creative engagement during the game. However, instructions from preschool teachers are permitted during this process, especially if children incorrectly demonstrate relations like above, below, in (something), or do not perform movements precisely in rhythm with the game.

The simplest task for preschool teachers involves the process of learning the game, which follows an established methodological pattern of adopting the text, melody, and choreography. The emphasis is on integrating movements, musical characteristics, and mathematical concepts. The game needs to be rehearsed so that, in addition to learning mathematical concepts, other aspects and abilities can also be developed.

Preschool teachers, in addition to all the roles presented in the theoretical approach and previous interpretations, have the additional role of integrating their knowledge, experiences, and abilities to meaningfully and effectively apply the STREAM approach in various early childhood learning situations.

CONCLUSION

Through theoretical research into the possibilities of applying music-didactic games in the STREAM approach with early childhood education, several conclusions have been drawn.

The implementation of the STREAM approach occurs on multiple levels and requires preschool teachers' readiness and competencies to enhance, expand, and adapt teaching strategies according to the characteristics and stages of children's holistic development at an early age. Integrated learning logically leads to the creation of an integral picture of the surrounding world, through integrative approaches suitable for cognitive, affective, and physical aspects of children's functioning in various learning situations. Considering that children learn through play and that the application of music has numerous benefits across all aspects of personality development, the opportunities of the STREAM approach were demonstrated through the preparation and execution of the music-didactic game *Where is the Sea*, specifically created for this research. The effectiveness of applying music-didactic games in the STREAM approach is conditioned by the choice and characteristics of the game, where its textual and musical content serves the simultaneous acquisition of knowledge from different areas, alongside the competencies of preschool teachers to design (within program frameworks) the game with specific objectives and subsequently implement it with positive outcomes of integrated learning through play.

Considering the age of the children whom the music-didactic game is intended for, the text, melody, and choreography are simple, making it possible to occasionally design such games within various themes/projects.

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PRESCHOOL TEACHERS' INTERCULTURAL COMMUNICATION IN THE CONTEXT OF TRADITIONAL MUSIC

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Abstract: Future preschool teachers have an important role in acquisition of the intercultural competence in early childhood education and care. Study programs in higher education could provide a lot of opportunities to promote intercultural communication. In this research we analyzed and compared a model of Dionyssiou (2017) and his three parameters – the *process of creation* (the moment when music is created and when a person understands it), the *music event* (sharing the tradition among the members of the community) and the *sense of place* (the moment when music becomes a symbol of tradition and identity). The aim of this research was to analyze the early and preschool education study programs in the context of intercultural communication. A total of 964 syllabuses from all Croatian faculties were analyzed. The implementation of intercultural communication is observed in terms of learning outcomes and topics. The results show that a special place for intercultural communication belongs to the music syllabuses (N = 72) whose content can motivate students to preserve traditional and intercultural culture. Regarding the model of Dionyssiou (2017) learning outcomes mostly belong to the *music event* (N = 53), and to a *sense of place* (N = 29), but there are the fewest learning outcomes that belong to the *process of creation* (N = 26). The implications of these findings can be explained by the suggestion that in the 21st century, intercultural communication should be addressed more in early childhood education and care to nurture traditional music.

Keywords: Croatian higher education, early childhood education and care, future preschool teachers, intercultural communication, music syllabuses.

INTRODUCTION

Children learn and acquire competencies from their preschool teachers and the environment at the beginning of their education. Preschool teachers have

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an important role in acquisition of the intercultural competence and have to be competent in the promotion and elevation of intercultural communication in early and preschool education. Study programs of early and preschool education at universities provide a lot of opportunities to promote intercultural communication. A special place belongs to music curriculums whose content can motivate students to preserve traditional culture.

Intercultural competence means "continuous development of understanding of the relationship between cultures, with the help of a study on the perceptions of the characteristic beliefs and behaviors of particular social groups within a society that emphasizes their particularity in relation to dominant culture, ethnicity, race, religion, body and/or mental ability, gender orientation with the aim of constructive action and solving issues that arise among cultures within one society" (Mlinarević & Tokić Zec, 2020: 1082, according to Hrvatić & Piršl, 2007: 402).

When we talk about a culture and the music of a society, we talk about national identity in music. In the middle of the 19th century and the beginning of the 20th century, composers wanted to present the culture of their people with folklore elements in their compositions, especially in newly formed countries, thus creating a national style in music. Lissa (1977) claims that "the greatest achievement of a composer is if he/she joins the musical tradition of his own nation and with it enriches the traditions of the musical culture of humanity as a whole" (Lissa, 1977: 269). She asserts that this is the pleasure of a very small number of composers.

Today, folk music heritage is gaining importance in preserving identity amid globalization. In the early and preschool age, work on intercultural competencies includes the preservation of folk folklore heritage such as singing folk songs, listening to folk compositions, familiarization with instruments and their performance, dances of national music as well as world music.

According to the *National Framework Curriculum for Preschool Education and General Compulsory and Secondary Education* (MSE, 2011: 153), one of the educational goals of the art field is "acquiring basic knowledge and a positive attitude towards Croatian culture and the cultures of other nations, towards cultural and natural heritage and universal humanist values." Dobrota and Topić (2018) state that by introducing children of early and preschool age with high-quality and diverse musical achievements of Croatian traditional music and world music, students and kindergarten children "observe how, compared to Western classical music, this is completely different phenomena that cannot be approached in an identical way (Dobrota & Topić, 2018: 200). This develops awareness of identity as a national concept and of a person's own identity as a citizen of the world. In this way, students become acquainted with different cultures and their music, develop values towards diversity, and develop their intercultural attitudes.

To succeed in this, Begić and Šulentić Begić (2018) state that intercultural competence is developed and upgraded throughout life, but its foundations should first of all be built during studies. "This is possible if teaching at higher education institutions is designed to develop the intercultural competence of future teachers, who should develop the intercultural competence of their students both in urban areas and in rural areas, where interculturality is not so pronounced" (Begić & Šulentić Begić, 2018: 161). The same authors state (Begić & Šulentić Begić, 2017) that the development of an individual's intercultural competence has become a necessity because a modern school must keep up with the times and events that surround us.

National Curriculum for Early and Preschool Education (MSE, 2014) is the starting point for the development of educational practice in kindergartens in the Republic of Croatia. The values on which this document is based are knowledge, identities, humanism and tolerance, responsibility, autonomy, and creativity. It is very important to know that music activities contribute to realizing all these values, completely identity and creativity. "Introducing children to the traditional music of Croatia and different world music helps them form their identity, but also understand and accept music of unfamiliar cultures (Mendeš & Dobrota, 2023: 650). Thus, children's intercultural attitudes are developed from the earliest days.

Bačlija Sušić & Fišer (2016) researched the possibilities of improving the educational process of early and preschool children by encouraging and enriching the musical experience with elements of traditional creativity. The obtained results indicated that children of early and preschool age (in the third and fourth years of life) show great interest in musical activities that include sound exploration of different traditional instruments as well as their use in musical performing. "Everyday enrichment of educational process with traditional music through rhymes, children's songs and singing games by using traditional instruments, encourages child's freedom and spontaneity, creative imagination and creativity and enrich their emotional experience of music" (Bačlija Sušić & Fišer, 2016: 125). They conclude that the kindergarten, as a preschool institution, has one of the fundamental missions in the development and preservation of awareness towards the musical traditional treasure of the child, the future cultural citizen. Therefore, it is very important to prepare future preschool teachers in this direction during their initial (higher) education (Boneta et al., 2013; Mrnjaus & Rončević, 2013; Bedeković & Šimić, 2017).

Zoe Dionyssiou (2017) presented a framework for promoting intercultural music education, referring to intercultural curriculum, concepts, and methodologies. It provides an overview of the literature showing the shift from multicultural to intercultural methodologies and proposes a framework for intercultural education that seems appropriate in early childhood. The model is based on the literature in ethnomusicology and music education; it recognizes the importance of creativity, locality, and communication that exist in national communities and suggests ways for their implementation (Dionyssiou, 2017, p. 117). In this research, we take into consideration the three parameters – the process of creation, the music event, and the sense of place (Dionyssiou, 2017), opening the question of the framework for an intercultural music curriculum. The *process of creation* means the process and the moment when a piece of music is created and when it is agreed from person to person. The *music event* belongs to research in ethnomusicology and sociology of music which are in accord with the need to study music as a music event. Thus, the music event in most traditional societies is defined as a social activity, based on sharing the tradition among the members of the community, interacting with it, and evaluating it at the same time. The *sense of place* means the moment when music becomes a symbol on a national or ethnic level. The domain of national music compares the local and the global movements and it appears with folk music.

METHOD

Research Aim

The aim of this research was to analyze the early and preschool education study programs in the context of intercultural communication and to compare the results with a model of Dionyssiou (2017) and three parameters: the *process of creation*, the *music event* and the *sense of place*.

Research Questions

The research questions derive from the research aim:

1. to investigate the extent to which syllabuses in all subjects of early and childhood education studies at Croatian faculties include the concept of intercultural communication,

2. to investigate the extent to which syllabuses in the field of music mostly include the concept of intercultural communication, and

3. to analyze and to compare all checked elements with three parameters presented by Dionyssiou (2017), i.e. the process of creation, the music event and the sense of place.

Sample

A total of 964 undergraduate (N = 658) and graduate (N = 306) syllabuses of early and childhood education studies from Croatian faculties were analyzed: in Pula (N = 220), Rijeka (N = 141), Zadar (N = 101), Split (N = 179), Zagreb (N = 83), Slavonski Brod (N = 94), and Osijek (N = 146). The sample included the syllabuses for full-time and part-time studies.

Instrument

A matrix was created which includes the following elements elements: course title, course objectives, course content, and learning outcomes. Also, the last three columns constitute the elements of the Dionyssiou (2017) model: the process of creation, the music event, and the sense of place.

Procedure

Syllabuses were found on the faculties' websites. They are clearly and explicitly published, and all their important information is available, such as a course name, objectives, learning outcomes, important topics, students' workload, their obligations, and literature. The implementation of intercultural communication is observed in terms of learning outcomes and topics. This means that when the syllabus elements were introduced in the matrix, they were analyzed, compared and marked regarding the elements of Dionyssiou's (2017) model. In other words, one or more model elements were recognized in the learning outcomes and topics. Even though we assumed that we would find the most elements in the syllabuses for music, we analyzed all syllabuses of early and preschool education. The content of the matrix was done by entering keywords: - *tradition*; - *music*; - *heritage*; - *intercultural*; - *communication*; and - *culture*.

RESULTS AND DISCUSSION

Intercultural Communication in Syllabuses of Early and Childhood Education Studies

The first research question is to investigate the extent to which syllabuses in all subjects of early and childhood education studies at Croatian faculties include the concept of intercultural communication. Based on the results of the research, we can conclude that (*Table 1*) the elements of intercultural communication are present in the syllabuses of the Croatian universities. Concerning the elements that we observed in this research, in a total of 128 syllabuses there is a connection with intercultural communication. It can be concluded that intercultural communication is represented approximately similarly in all studies in Croatia. This is proof that teachers are well aware of the important role of this topic in the preparation of future preschool educators, and in the growth and development of children as citizens who will promote innovative ways of living through their actions in the community.

A total of 72 syllabuses belong to the music courses, and there are 56 syllabuses of others courses in which we found elements of intercultural communication belonging. The chi-square indicates that the responses are distributed significantly differently (*Table 1*). The course titles were strongly associated with very different areas, from the Croatian language to pedagogy, kinesiology, etc. There are courses like: *Speaking and Writing Culture*, *Croatian Oral Literature*, *Visual Communication*, *Integrated Preschool Curriculum*, *Space, Time and Identity*, and very interesting courses like *New Media and Creative Practices in Preschool Education*, *Alternative Programs*, *Creating an Intercultural Curriculum*, *Intercultural Communication*, and *Early Education Curriculum Models,* etc.

Table 1. Inclusion of intercultural communication in the study programs of Croatian universities

The level of studies	Number of course areas (% of total courses)	Number of course objectives	Number of course content	Number of learning outcomes
undergraduate	101 (15.35)	21	40	232
graduate	27 (8.82)	9	12	58

$\chi2 = 1.7512$, df = 2, $p < .01$

The examples of the course objectives correlated with the theme of intercultural communication are: *to adopt the rich oral heritage of their homeland and its role nurturing that heritage in preschool education, to adopt the necessary competencies for intercultural communication as a prerequisite for successful communication in early childhood education and preschool age, to develop the aesthetic sensibility of the individual by getting to know him and bringing him closer to his cultural, musical and native heritage.*

The course contents are very interesting when we analyze them from the point of view different cultures and traditions of the very small regions of Croatia. The topics are dealt with in concentric circles and a topic that is in the middle is closely related to the region where the university is located and after that, it develops into a broader topic that includes the region and the national level. The names of some topics are: *Intercultural pedagogy, School culture in* *the context of intercultural and social competencies of preschool teachers, Identity in the intercultural context, Methods and forms of work in intercultural education of children in early and preschool age,* and *Traditional music and musical instruments.*

The learning outcomes are very well addressed. They are arranged according to the levels of Bloom's taxonomy; in the undergraduate studies, the learning outcomes target the first four levels (*to analyze professional activity in an intercultural and inclusive environment (respect for diversity; to analyze the fundamental elements of intercultural communication*) while in the graduate studies, the learning outcomes target the fourth, fifth, and sixth levels (*to plan one's own activity in an intercultural society in the direction of entrepreneurship and creativity, to create an integrated curriculum in the totality of all developmental areas (kinesiological, musical, artistic, language-communicative and research-cognitive) using activities and materials in accordance with modern development theories that interpret child development)*.

Intercultural communication in music syllabuses of early and childhood education studies

The second research question was to investigate the extent to which syllabuses in the field of music mostly include the concept of intercultural communication. The results show that a special place for intercultural communication belongs to the music syllabuses (N = 72).

In the analyzed syllabuses of early and preschool education, we come across:

a) The music courses in which students get to know world art music or an overview of musical stylistic periods (art music of the European continent) such as *Musical Culture*, *Playing Musical Instruments*, *Listening the Music*, *Choral singing*, and *Choir*. These courses contain basic musical knowledge and musical skills that students need for future music practice and music teaching.

b) The music courses in which students get to know local, regional, and national music, such as *Folklore Music*, *Folklore Musical Heritage and Children of Early and Preschool Age*, *Folklore for Children with a Practical Course*, *Croatian Musical Heritage*, *Music with a Practical Course, Choral Singing*, and *Choir*. These are the courses that raise awareness of heritage and regional identity in order for students to recognize and differentiate intercultural content.

c) The music courses that integrate music and other content, and that teach interdisciplinary practical work with children, such as *Music in Early and Preschool Education*, *Music in the Integrated Curriculum*, and *Structure and Form of Music in Children's Perception*.

d) The courses in which interculturality is expressed by permeating musical diversity and diversity in an integrated curriculum, such as *Heritage*, *Puppetry and Stage Culture*, and *Art Programs*.

Considering the complexity and pervasiveness of the content, some courses are included under both, points a) and b). Given that syllabuses of the same areas of all study programs for early and preschool education in the Republic of Croatia were observed, we can conclude that course professors create learning outcomes in the local, regional, national, and global context. Thus, for example, in *Choral Singing* or *Music Practicum,* sometimes only artistic music is performed, sometimes only folk music, and sometimes both are used.

The value that the music syllabuses contain intercultural communication can be recognized in the implicit statement of the author Hernandez (1989 in Drandić, 2013: 84) who, among other things, emphasizes that "in order to acquire intercultural competencies, teachers need to understand their own culture and their own cultural identity; get to know different cultural communities; understand and respect cultural differences; understand the benefits and necessity of learning about cultural differences; learn to adapt curricula, strategies and activities implemented in the educational process with different cultures in such a way as to improve the learning of all; understand and use acquired skills, knowledge and abilities in the teaching process; know the appropriate resources and know how to use them (literature, magazines, Internet, music, art...) with the aim of improve teaching, learning and teaching; explore new ideas, strategies, techniques, and different approaches to education in a multicultural environment."

Based on these results, it can be concluded that the content regarding intercultural communication in music syllabuses can motivate students to preserve traditional and intercultural culture. Many papers have been written that confirm the value of using traditional or folklore music for the development and perception of interculturality (Cf. Bačlija Sušić & Fišer, 2016; Dobrota & Topić, 2018; Begić & Šulentić Begić, 2018; Mendeš & Dobrota, 2023).

Analysis and comparison of results according to the elements of Dionysius' model

The third research question was to analyze and compare all checked elements in the Croatian syllabuses based on three parameters of Dionyssiou's model (2017): the process of creation, the music event, and the sense of place. Regarding the elements of the model, the learning outcomes mostly belong to the *music event* (N = 53) and the *sense of place* (N = 29). The fewest learning outcomes belong to the *process of creation* (N = 26).

The reasons why the learning outcomes mostly belong to the *music event* (N = 53) can be found in the fact that most music courses relate to European musical art that is performed in concert halls, theaters, or outdoors. *Sense of place* (N = 29) is related to local or regional musical heritage. Although it is folklore or traditional heritage that builds an individual's identity and intercultural foundations, these results confirm that artistic music that has a global character and is not tied to a place still prevails. The least number of the learning outcomes belongs to the *creation process* (N = 26). Namely, the process of creation is connected with creativity. In order for students to be able to approach musical activities creatively, they should have acquired and developed musical competencies. Therefore, it can be concluded that the music courses mainly comprise basic content that will allow all students to master theoretical musical knowledge and skills. In this way, they develop intercultural competence and communication (Piršl, 2011) which consists of intercultural knowledge, skills, and attitudes that need to be developed in contemporary global society.

CONCLUSION

This research presents the contribution to analyzing the intercultural communication in higher education, especially in early preschool education. The correlation of intercultural communication and the music is very hard, and can be described in the point of view of traditional and intercultural culture. Results of this research bring some conclusions: intercultural communication is represented approximately similarly in all studies in Croatia; there are a big number of syllabuses belonging to the music syllabuses; learning outcomes are very well addressed according to the levels of Bloom's taxonomy; the content regarding the intercultural communication in music syllabuses can motivate students to preserve traditional and intercultural culture; and regarding the model of Dionyssiou (2017) learning outcomes mostly belong to the *music event*, and to *sense of place*.

Based on the findings of this research, suggestions can be made for improving programs in higher education. Given that plans and programs are the foundation of quality teaching and learning, the integration of key contents in accordance with the STEM/STEAM/STREAM educational approach should already be visible in the syllabuses so that students can acquire competencies for integrated learning and their future educational work more effectively. Integration can be arranged through interdisciplinarity and connecting elements from all important areas, which would contribute to successful intercultural communication in education.

This research contributes to the elements of intercultural communication in the context of learning and promoting the traditional culture and music of the region. Teachers will educate children to learn about their culture and will be the ones who will transmit the values in the preschool environment. The implications of these results can be described by the proposal that in the 21st century, intercultural communication should be addressed more extensively in higher education teaching, especially in the area of early and preschool education, to foster traditional music as one of the important elements of a nation's culture and to be part of global music map.

This research has some limitations. The first is certainly that only study programs were observed. By analyzing teaching practice in higher education, it would be possible to observe more connections and determine the degree of connection between intercultural communication and traditional music. The second limitation is that this is only the first step in analyzing the connections between intercultural communication and traditional music. The second step can be to investigate the opinion of university teachers, especially the opinion of music university professors about many possibilities of teaching and learning in the context of intercultural communication in teaching music. There is also a third limitation. When we talk about traditional music, there are many elements of very rich Croatian tradition. The aim of some future research can be to examine various types of Croatian traditional music, which should and is just now an important basis for the development of intercultural communication at the national and international level among students – future preschool teachers.

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PRESENTATION OF THE PROJECT *MUSICAL FOR CHILDREN: A FAIRY TALE FROM THE PARK*[1]

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Abstract: The project named *Let's Improve the Quality of Student Education by Creating Better Conditions for the Implementation of Teaching and Student Learning through the Creation of Musicals for Children – UKO 1* is based on a new paradigm in learning, based on the system: communication, knowledge, and abilities. This project involved the preparation and realization of a drama piece in the genre of musicals intended primarily for children of preschool age, but also for a wider audience. The students got acquainted with different techniques in traditional and new media and recognized their natural potentials and inclinations in different fields of artistic expression within visual and musical arts, dance, literature, and dramatic creativity. The improvement of the teaching process was achieved by the introduction of innovative techniques in individual subjects, the use of professional audio-visual equipment specialized for the development of a multidisciplinary approach in teaching, the development of communication skills and team spirit in students, as well as the promotion of education oriented towards innovation and entrepreneurship. The application of such a multidisciplinary approach and the introduction of innovative methods into the teaching process represent a serious step forward in the field of pedagogical sciences and in the construction of an integrated curriculum that supports the new foundations of the preschool education program.

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[1] This paper is the result of the project *Let's Improve the Quality of Student Education by Creating Better Conditions for the Implementation of Teaching and Student Learning through the Creation of Musicals for Children – UKO 1,* supported and financed by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

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Keywords: improving the quality of education, musical for children, holistic approach, skills of future educators

INTRODUCTION

This paper will describe the project *Let's Improve the Quality of Student Education by Creating Better Conditions for the Implementation of Teaching and Student Learning through the Creation of Musicals for Children* – UKO 1, supported and financed by the Ministry of Education, Science and Technological Development of the Republic of Serbia. The project was created on a new learning paradigm, based on three terms: *communication*, *knowledge*, and *abilities* and it was realized in 2022 at the Academy of Applied Technical and Preschool Studies in Pirot. First, the project involved the preparation and realization of an original musical theatre stage intended primarily for preschool children, but also for a wider audience. The improvement of the teaching process was achieved by the introduction of innovative techniques in certain subjects and the use of professional audio-visual equipment specialized for the development of a multidisciplinary approach to teaching. Students and professors were engaged in directing work together, worked on making costumes, prepared and decorated the stage space, recorded and processed audio, photo, and video documentation, recorded and audio-processed original songs for children, and created short video forms and different types of animations which were done as regular class activities and extracurricular activities.

DIRECTING THE CHILDREN'S MUSICAL: *FAIRYTALE FROM THE PARK*

Children's drama play is always observed from the same positions that apply to drama art in general. Just as a child does not represent a diminished human being, there is no diminished art either. "Directing for children means achieving a total artistic, aesthetic and technical creation typical for drama, opera, film, radio or television directing creativity" (Petrović, 1994: 15). The specificity of directing for children is contained in the artistic conditioning of the ideological and aesthetic foundations of creativity for children, in the phenomenon of play, which leads to a distinct dynamic of the dramatic action, rhythm and melody, the poetics of brevity, the simplicity of the subject of the dramatic statement, to more simplified characters, strong contrasts, quick gradations, unusual metaphors, quick turns, i.e. towards elliptical forms of directorial conciseness (see Bojović, 2010; Boškan-Tanurdžić, 2004).

The problems of directing are numerous and very complex. They include the selection of the text, work with the actors, and cooperation with a scenographer, costume designer, composer, or sound engineer, as well as the question of the audience – as indispensable components of any theater. Professors of literature, foreign languages, visual arts, and music performed the directing duties. Before the work on the musical was initiated, the selected groups of professors and students were chosen for the following tasks: 1. to select the dramatic text, 2. to act, 3. to compose and record the audio-drama, 4. to create costumes and scenography, and 5. to create promotional material.

Selection of a Dramatic Text

The dramatic text *Fairytale from the Park* by Đurđa Lili, a stage cocktail-fairy tale, seemed very suitable for realization on our open stage in the schoolyard and the number of participants. The basic features of this text, such as the combination of well-known characters from fairy tales, short and concise lines, simple and lively humor fully meet the requirements of the audience for which the play is intended – preschoolers and children of younger school age. It is especially important for the musical that the dramatic text *Fairytale from the Park* contains enough rhyming and rhythmic segments that can be composed and sung.

Working with Actors

The second phase included the creative work of those who will perform the dramatic event in front of the audience. So, in the second phase, we started working with student actors. Due to the Coronavirus pandemic, we were forced to hold the first reading rehearsals through the Teams platform, which meant that we were not able to realize the usual dramatic exercises and games that serve to practice voice and movement (Viktorović, 2004; 2005; Group of Authors, 2012). Initially, it seemed like an aggravating circumstance, but it soon turned out that the physical absence and the absence of facial expressions and gestures, allow one to better hear and notice the shortcomings of intonation, articulation and diction. At the first reading rehearsals, we assigned the roles to the actors. The roles were assigned according to the requirements of the text, on the one hand, and according to the possibilities of the ensemble, on the other. In the original text, the character of Mum does not exist, but the character of Dad is present. Since our Drama Club consisted of only female students, it was decided that the text should undergo this change, which essentially did not affect the lines and plot. The first few rehearsals were organized for text reading, and to checking the accuracy and text shortening. Text processing is sometimes approached already in the first phase, but in this case, it took place simultaneously with the reading rehearsals. Our changes to the *Fairytale from the Park* text were not extensive and did not affect the semantic layer of the original: only a couple of lines were removed, and some of them were partially reformulated to make it easier and more natural for the actors to achieve the character-actor unity. Also, the Prince utters his lyrics with a French accent, so a few lines in French (in the dialogue between the Prince and the Fairy) have been added, as well as a song in French sung by the Prince. When the entire team that participated in rehearsing the text was satisfied, it was decided to record an audio recording of the play.

Music

The musical *Fairytale from the Park* represents learning through practical work, i.e. mastering the necessary knowledge and skills through the preparation of a musical and stage piece. As the text had already been chosen, the music that had to be composed had to be in harmony with the theme and characters on the one hand, as well as with the psychophysical and musical abilities of the target audience, which is children aged 3–7.

Guided by the musical abilities of the children, we respected the principles of music pedagogy (see Durkovic-Pantelic, 1998; Jović and Đorđević, 2002). The goal was set that the melody should not have a range higher than a fifth, possibly a sixth, to be singable, easy to remember, and in harmony with the character it represents. The tempo of the composition also determined the character for whom the melody was composed. Depending on whether it was an angry witch or a gentle fairy, the melody had to reflect characters' emotional states. Creating the voices in this way, the students easily learnt about the character, major and minor, about tempo, slow and fast, diction and agogics, the relationship of emphasis in speech and music, or the emphasis in the pronunciation of the sung text which emerged as the music was being created. Students encountered the problem of dividing syllables in text and music ("ecological hearing," etc.) when the previous verse had a different number of syllables. Regarding the rhythm, the request was that the rhythm should be adapted to the age group of children, i.e. to be simple and repetitive, so that the children could easily follow the rhythmic motif during the performance.

The singing voice is also an integral part of this joint project. During the work, we set the goal that the voice should be adapted to the character it represents. The students understood their roles and found the appropriate "voice" in representing Gretel, the angry witch, the gentle forest fairy, the prince, and Little Red Riding Hood. In the course of their studies, future pre-school teachers master the necessary knowledge and skills, including playing certain instruments. All the compositions that were created during the work on the musical were played by the students themselves.

Scenography

The action of the dramatic text that served as inspiration for the musical for children takes place in the park. Since the dramatic text does not specifically imply specific elements of the scenography, the artists had complete creative freedom in creating the park's ambiance. The contemporary character of the text, as well as the characters who build it, contributed to the idea of constructing a non-standard image of the park through the artistic processing of the attributes that make it up. The main task of this approach was the idea to enrich and individualize the image of the objective world through the abolition of standardized frameworks and the release of children's imagination and creativity.

The trees were the supporting element of the image of the park. The structure of the tree is made of corrugated cardboard that is bent into a cone shape (tree trunk) and fixed with polyurethane foam for an organic-shaped base. Tree branches are constructed according to a similar principle of forming a conical shape, only with a smaller diameter and with the addition of transverse "branches." A conscious deviation from naturalism in the depiction of trees is evident. The expected brown color of the tree and the green color of the leaves were replaced by stylized color surfaces that are not related to the apparent reality of a tree. The final appearance of the trees was made by discreet drawing with sprays of different colors, while the chosen colors deliberately deviate from the real coloring of the trees. Tree branches end with flowers instead of leaves.

Pictures 1 and 2: Appearance of trees and flowers

Flowers were an essential element of the scenography. By cutting out the outline of the flower from a hard cardboard, two-dimensional flower shapes were made, preparing the shape with white paint to achieve the intensity of the final coloring. The three-dimensional forms of the flowers were made by gluing the petals of multi-colored paper to a circular base, which was later mounted on a rustic stand made of corrugated cardboard. The dimensions of these flowers are in unnatural proportion to the trees: some flowers have a giant shape, which is again in line with the attitude that promotes freedom of experience and creativity. The third form of flowers adorns the ends of tree branches and is made similarly to the three-dimensional giant flowers. The deviation from natural coloring and proportions is motivated by the modern trends that promote the child's individual experience that should not be conditioned by the apparent reality of the object.

A Costume

The costumes, as well as the scenography, should match the overall visual concept of the performance. An important task in creating a costume is its innovation and relevance. For the actors to feel comfortable and confident and for the recipients to accept the message of the dramatic performance in the right way, it was necessary to design the costumes to be stylistically interesting and of a fashionable cut to match the trends. The modern and simplified costumes were designed with the intention and in an attempt to deviate from the standardized costumes usually worn by actors in children's plays.

The plot of *Fairytale from the Park* takes place in an urban environment, and its actors are partly real people and partly characters from fairy tales. Hansel, Gretel (Ivica and Marica in Serbian) and Mum wear modern clothes like we see every day in our real environment. Marica is an ordinary girl wearing ripped jeans and a printed T-shirt, Ivica is a boy dressed in tracksuits and a collared T-shirt, wearing a cap on his head, and Mom resembles just an ordinary modern mom.

The witch retained the black outfit, which was complemented by an elegant and streamlined cut. Little Red Riding Hood is not dressed up all in red and what defines her is only the red cloak. The forest fairy costume is cut in pastel shades of pink and green matching the fairy's characteristics. It is decorated with flowers and transparent tulle that allows the effect of transparency when one color is covered with another. The prince wears an avant-garde eccentric suit in a combination of red and orange. The wolf costume is made of a simple tunic sewn from artificial fur and a mask made of hard cardboard that he wears on his head.

Picture 3: Costumed actors on the summer stage

Project Promotion

The acquisition of software and digital equipment had an impact on innovating approaches in the teaching process and developing the creative potential of all participants. The students recognized the possibilities of working in a new digital format and the need for further improvement of their digital competencies and creative work in the field of photography, video editing, and the creation of new didactic content, cultural and educational, which would be presented in a wide media space and which would be intended for the youngest audience. An initiative was launched to form a creative media center that would work on the production of such content.

Education oriented towards innovation and entrepreneurship enables better placement on the market and faster access to work. In this process, students got to know their capacities and potentials, as well as the possibilities for starting a private business or engagement in the field of children's education. In the work process, special emphasis was placed on the issue of project management and leadership, in advertising and promoting the project, attracting an audience or users of services, and developing business skills in future work and starting one's own business. Through this project, students also developed their entrepreneurial skills, i.e. how to master the financial elements of preparation and how to plan and organize larger multimedia projects. The specific skills required for design, stage and costume construction, lighting and music, digital imaging and animation can be the basis for further training in various fields and related occupations and jobs. A participation in projects constitutes another necessary competence that will be valued by future employers.

Performance

The third phase is the assembly of all the components into a whole work of art. It takes place on a stage or space intended for the performance in front of an audience. Only if all three mentioned factors are obtained: stage event, action, and audience, one can speak of a theatrical performance. The audience is therefore a necessary factor: without it, there is no play, just like there is no play without stage events. Every actor knows well that his/her own performance depends on the audience. Actors sometimes feel carried away only when they perform the play and only then do the characters come alive. The performance is not only the action of the stage event on the audience but also the reaction of the audience to that event. Our performance of the musical went as expected. Even though experiencing slight trepidation, the student-actors enjoyed the drama, and after the play they danced, laughed, and socialized with the children spectators.

CONCLUSION

The development of vocational education is an open process within the reform of higher education. The acceptance of the Bologna Declaration in Serbia, more in terms of the organizational and systemic structure, and less in terms of structural changes in the program, while ignoring the humanistic aspects of education and disregarding the needs of students, did not lead to significant results. It was noted that it is necessary to operationalize study programs and subject syllabi that would start from the specific needs and interests of students and that would enable differentiation and individualization in the acquisition of new competencies. This humanistic-developmental approach to learning also implies a holistic approach to the development of a complete personality. Various planning and strategies contribute to this, which implies the active role of students and autonomy in work.

Students got to know different techniques in traditional and new media and recognized their talents and preferences in different fields of artistic expression within visual and musical arts, dance, literature, and dramatic creativity, which enabled them to interact better with children in modern working conditions. They are directed towards cooperation that is established with certain institutions, business entities interested in hiring future educational staff, local self-government bodies and public enterprises in the region and the entire country. One of the goals of the project was to influence the development of students' communication, negotiation, and agreement skills, but also to develop a higher level of empathy and team spirit.

The active involvement of artists and experts from various fields through consultative work and guidance of students and professors led to the improvement of the quality of that part of the teaching process that has a direct role in the creation of musicals for children. The development of future collaborative projects with cultural institutions also means the inclusion of children's musicals, as a special genre, in the permanent repertoire on the big stage in the City of Pirot, guest appearances and participation in international festivals, as well as the initiation of the Small Stage of the Academy. The multidisciplinary approach and the introduction of innovative methods and modern digital tools into the teaching process represent a serious step forward in the field of pedagogical sciences and interdisciplinary methodical procedures in the construction of an integrated curriculum that supports the new preschool curriculum framework.

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INFLUENCE OF THE COVID-19 PANDEMIC ON THE ART TEACHERS' UTILIZATION OF BLENDED LEARNING (BL) IN CROATIA

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Abstract: Reflecting on models in which digital technology and online learning are combined with live teaching has become necessary in today's education. The research aims to determine whether visual arts teachers have developed digital competencies during the COVID-19 pandemic significantly and what they think about the effectiveness of blended learning. It will determine whether attitudes about distance teaching depend on their digital competence. The research results show that half of the teachers had satisfactory digital competencies because they used blended learning before the COVID-19 pandemic. During the COVID-19 pandemic, digital literacy in using technology has been developed more than multimedia didactic competencies. Those teachers who used blended learning before the COVID-19 pandemic are more inclined to have positive attitudes about the effects of distance teaching. They think that they will apply new teaching skills during face-to-face teaching after the COVID-19 pandemic, that methods and tools for teaching in the digital environment develop students' interest and abilities, and that the independent creation of digital teaching materials has improved their methodical capabilities.

Keywords: blended learning, COVID-19, digital literacy, multimedia didactic competencies, visual arts teachers

INTRODUCTION

During the COVID-19 pandemic, new conditions were made in which teachers were forced to change their methodologies from face-to-face teaching to distance teaching. Such new circumstances have left their mark on all education systems and all levels. They have encouraged reflection on teachers' existing digital competencies, the possibilities of developing them in new circumstances, and their applicability even after returning to face-to-face teaching. Anđelić et al. (2020) showed that at the time of the COVID-19 pandemic, 58.1% of teachers considered that they possessed a satisfactory level of competence for

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the implementation of distance teaching, 32.9% were not sure, and only 5.2% felt that they did not have such competence.

Over the last two years, several studies of the attitudes of teachers, parents, students, and university professors on distance teaching experiences have been published in Croatia (Ćurković et al., 2020; Bulić et al., 2021; Ivanković & Igić, 2021), but no research was applied on visual arts teachers. Due to the subjects' creative and experiential character, it was a challenge to replace direct contact with work of art and creative work with distance teaching and learning.

This paper explores the impact of the COVID-19 pandemic on the adoption and utilization of blended learning (BL) by art teachers in Croatia. The sudden shift from traditional face-to-face teaching to distance learning highlighted the importance of digital competencies and adaptive teaching strategies. Given the unique challenges of teaching visual arts—where direct interaction with artworks and hands-on creative processes are central—this study examines how visual arts teachers integrated digital tools and methods into their practice. The research focuses on the extent to which blended learning was employed before, during, and after the pandemic, as well as its perceived effects on teaching methodologies, student engagement, and learning outcomes.

LITERATURE REVIEW

The literature analysis found that there is no single definition of blended learning. Quite a few authors agree that blended learning combines face-to-face and online learning and teaching (Allan, 2007; Horton, 2006; Roger, 2007; Voos, 2003; Sophonhiranrak et al., 2015). Many authors share the standard view that blended learning combines the potential of internet-assisted learning with classroom techniques (Delialioglu & Yildirim, 2007; Ginns & Ellis, 2009). Some authors have pointed out that blended learning improves traditional face-to-face teaching because learning becomes a meaningful activity (Gülbahar & Madran, 2009; Garrison & Kanuka, 2004), while others have pointed out that it changes students' experiences and improves achievement, expands resources, boosts confidence, deepens knowledge (Davis & Fill, 2007; Chen & Jones, 2007). The Council of the European Union (2021) has recommended using blended learning in formal education and training, implying that a school, teacher, or student applies multiple approaches to the learning process: combine spatial and distance learning environments and combine different digital and non-digital learning tools within educational content.

Growing up in a digital environment has changed how children and young people perceive the world and how they learn. While teachers in such a world are digital immigrants, students are digital natives (Prensky, 2001). Such generations are also called net generations, digital generations, or homo zappiens, born after the 80s and raised alongside the Internet and digital media from a young age (Veen, 2007; Jenkins, 2006). Dimmock (2019) classified living generations as Silent Generation (born 1928–1945), Baby Boomers (born 1946–1964), Generation X (born 1965–1980), Generation Y or Millennials (born 1981–1995), Generation Z (born 1996–2010), and McCrindle (2020) added generation Alpha that appears after 2010. Generation Alpha is also known as the e-generation or the first generation born in the 21st century.

At the European level, digital competence has also been singled out as one of the eight critical competencies of knowledge-based citizens (ISPL, 2006; Vrkić Dimić, 2013). Information and computer literacy skills are also singled out as valuable skills of modern society regardless of socioeconomic status (Catts & Lau, 2008; Vrkić Dimić, 2013). It distinguishes between two digital competencies that a teacher must possess to integrate computer technology into teaching effectively: basic computer literacy (teaching competence for the use of ICT) and multimedia didactic competencies (developed methods of work and strategies with ICT in teaching) (Vrkić Dimić, 2013). This second competence, which ensures the practical application of ICT in learning processes, is crucial for raising learning levels and knowledge construction.

RESEARCH METHODOLOGY

Research Objectives

The research objectives are to determine the frequency of BL by teachers of visual arts education before the COVID-19 pandemic and whether the percentage increased significantly during distance learning. Is there a statistically significant correlation between how classes were held before the pandemic and social demographic variables? Then, what are teachers' attitudes about the impact of distance teaching on their professional development and student competencies?

Population Sample

The population comprises 119 teachers who teach art subjects in Osijek-Baranja and Vukovar-Srijem County. Fifty-six teachers responded to the survey, accounting for 47% of the total population.

Analysis of the sample showed that 64.3% of teachers who participated in the survey were female, while 35.7% were male. According to the academic education, 82.1% of Master of Arts Education, and 17.9% of academic artists with pedagogical-psychological-methodical-didactical (PPMD) exam. In Vukovar-Srijem County, 28.6%, and in Osijek-Baranja County, 73.2% of teachers completed the survey.

According to the seniority, the sample is almost equally distributed because the study shows that: 26.8% of teachers with a working experience of 0 to 5 years, 30.4% from 5 to 10 years, 26.8% from 10 to 20 years, and 16.1% with 20 or more years of service. Most teachers are aged 30–35 years (26.8%) and 35–40 years (21.4%), while the number decreases by the edges, so there are 17.9% at the age 23–30, 14.3% at the age 40–45, 7.1% at the age 45–50 and 12.5% at the age 50 or more.

Measuring Instruments

A questionnaire was created for this research as a measuring instrument for teachers' attitudes toward blended learning during the COVID-19 pandemic.[1] It consists of three constructs that examine different teachers' data. The first construct includes socio-demographic variables of nominal and ordinal type. It consists of 7 particles that collect data on gender, education, workplace, county, years of service, age, and teacher's title.

The second construct consists of 11 particles of the nominal type and has the possibility of multiple choice. This construct assessed teachers' digital competence before and during the COVID-19 pandemic. The first particle refers to blended learning experiences before the COVID-19 pandemic. The following two particles are dependent variables that depend on the previous answer and clarify the last choice. Questions of other particles relate to ways of teaching before and during the COVID-19 pandemic. They provide information on how they organized teaching, testing, and learning and with what kind of materials.

The third construct consists of 6 particles, according to the Likert scale of 5 degrees (I completely disagree, disagree, neither agree nor disagree, agree, fully agree). It examines teachers' opinions and experiences on acquiring new skills during the pandemic, applying new skills after the pandemic, developing students' interests in the digital environment, improving methodical abilities by creating digital teaching materials, and the experiences of distance learning effect. The third construct proved to be a reliable measuring instrument with normal data distribution.

[1]https://drive.google.com/drive/u/0/folders/1odRZZCl06z4LMyeXa_0yCCyYcR4F7W-1
https://docs.google.com/forms/d/e/1FAIpQLSday6AaNwaEIyFhkIhVxvsTBSUvg9vZTnTlcxH-00jkSHH4oIg/viewform?usp=sf_link

Testing with the G*Power test with a probability of 80% that the statistical power of the test is correct showed that a sufficient number of individuals tested is 52. The internal consistency of the measuring construct based on the Cronbach Alpha coefficient is a = 0.913, meaning the particles are excellently consistent. Tests of all six particles show deviation from skewness and kurtosis. Still, the values are within the prescribed normal limits, so we can conclude that normal data distribution is present (*Table 1*).

Table 1. Distribution normality of the third construct

	Mean ($\overline{x}$)	Median	Mode	SD	Sk	Ku
My experience with distance learning has been primarily positive.	2.98	3	3	1.213	-0.155	-0.741
During distance learning, I gained new teaching skills in the digital environment.	3.7	4	5	1.361	-0.858	-0.433
I will also apply new knowledge and skills during post-pandemic class learning.	3.73	4	4	1.328	-0.982	-0.117
Methods and tools for teaching in the digital environment develop students' interests and abilities.	3.46	4	4	1.293	-0.573	-0.584
Self-development of digital teaching materials has improved my methodical abilities.	3.46	4	4	1.307	-0.629	-0.667
Preparing distance classes requires more time than preparing frontal classes.	3.48	4	4	1.321	-0.573	-0.699

Data processing methods

Descriptive statistics were applied to socio-demographic variables to obtain answers to the first research question**.** The second research question used a nonparametric methodology of independent variables (phi,p, Risk). In this way, it was determined whether age, gender, seniority, education, and teaching status were associated with blended learning before the COVID-19 pandemic.

The Independent Sample T Test was applied to show whether there is a statistically significant difference between the way classes were conducted before the COVID-19 pandemic and attitudes about the effect of distance teaching. Dependent variables are measured by a Likert interval scale, while the independent variable is of nominal dichotomous type. It determines whether teachers before the COVID-19 pandemic used blended learning or exclusively class teaching.

Research questions

- RQ1: What was the frequency of blended learning before and during the COVID-19 pandemic?
- RQ2: Is there a statistically significant correlation between blended learning before the COVID-19 pandemic and socio-demographic variables?
- RQ3: Is there a statistically significant difference in teachers' attitudes about the impact of distance teaching and blended learning before the COVID-19 pandemic?

Results

The response analysis for the variable "*Which forms of teaching did you use before the COVID-19 pandemic?*" shows that BL had been used by 53.6% of teachers before the pandemic. In comparison, only face-to-face teaching was used by 46.4% of teachers. Teachers who did not use BL before the COVID-19 pandemic cite various reasons. 34.6% believe that face-to-face teaching is the most appropriate for the social development of students, and 7.7% believe that using digital teaching materials harms students' cognitive development. 26.7% of the teachers who used BL even before the COVID-19 pandemic used mobile learning, 43.3% used flipped classrooms, and 33.3% used mixed reality and web materials 56.7%. Answers to the question "*Which ways of teaching did you use during the COVID-19 pandemic?*" showed that most used are web materials (64.3%) and mixed reality (57.1%), and slightly less M-learning (32.1%) and flipped classrooms (33.9%.). The results (*Table 2*) show that during the COVID-19 pandemic, only the use of materials on the Internet (33.9%) and mixed reality (39.8%) grew significantly. Mobile learning and flipped classrooms have been used between 10 – 20% more.

Table 2. Ways of teaching before and during the COVID-19 pandemic

	Mobile learning		**Flipped classroom**		**Mixed realities**		**Web materials**	
	n	%	n	%	n	%	n	%
Before COVID-19 pandemic	8	14.3%	13	23.2%	10	17.9%	17	30.4%
During COVID-19 pandemic	18	32.1%	19	33.9%	32	57.1%	36	64.3%
Difference	10	17.8%	6	10.7%	22	39.8%	19	33.9%

When asked "*How did they hold classes during the pandemic?*", 75.0% of teachers used distance teaching via virtual classrooms, 58.9% via video calls, and 26.8% hybrid and face-to-face teaching. Half of the teachers (50.0%) combined remote video calls and virtual classrooms for teaching, while only virtual classrooms were used by 30.4% and video calls by 19.6%. Most often, 32.1% of them conducted trials by combining video calls and virtual classrooms, followed by 37.5% with tests and assignments in virtual classrooms, and most rarely, 12.5% via video calls.

The results of the variable "*What kind of material did you use during distance learning?*" showed that 45.6% of teachers used video lessons recorded by the Ministry of Science and Education, 38.6% recorded their video lessons, 64.9% used their material made in digital tools, 38.6% foreign digital material downloaded from the Internet, and 36.8 % digital material from the selected publisher. Teachers most often used virtual galleries and museums (52.6%), while even 31.6% of teachers did not use them at all. 29.8% of teachers created virtual galleries for teaching purposes, and only 10.5% taught students to make them.

To demonstrate a statistically significant correlation between BL before the COVID-19 pandemic and socio-demographic variables, correlation analysis by nonparametric tests was conducted because abnormal data distribution was established. For individual variables, the results are as follows (*Table 3*):

Table 3. Correlations between socio-demographic variables and BL before the COVID-19 pandemic

	Phi	p	R
Gender and BL	0.128	0.338	1.711
Education and BL	0.314	0.019	6.222
Curricula and BL	-0.05	0.709	0.782
Teaching status and BL	-0.040	0.763	0.075
Seniority and BL	0.134	0.315	1.727
Age and BL	0.089	0.505	1.458

There is no statistically significant correlation between the use of BL before the COVID-19 pandemic and gender, curriculum, teaching status, seniority, and age. According to the data, we can only see a statistically significant correlation between teacher's education and BL before the COVID-19 pandemic (Phi>0.30 and p>0.05). So, it was found that 61% of MAs had been more inclined to use BL than teachers of other professions (2%) before the COVID-19 pandemic.

The Independent Sample T Test was used to determine the statistically significant difference in the effect of distance teaching attitudes between those teachers who used BL before the COVID-19 pandemic and those who did not (*Table 4*).

Table 4. The relationship between the use of BL before the COVID-19 pandemic and teachers' attitudes on the impact of distance teaching

		t	df	p
H1	My experience with distance learning has been mostly positive.	2.688	54	< 0.05
$_{H}2$	During distance learning, I gained new teaching skills in the digital environment	1.006	54	> 0.05
H_3	I will also apply new knowledge and skills during face-to-face classes after the COVID-19 pandemic	2.086	54	< 0.05
H_4	Methods and tools for teaching in the digital environment develop students' interests and abilities	2.391	54	< 0.05
H_5	The development of digital teaching materials has improved my methodical abilities	2.602	54	< 0.05
$_{H}6$	Preparing distance teaching requires more time than preparing face-to-face teaching	1.764	54	> 0.05

Based on the T-test results, at a significance level of 5%, there is no significant statistical difference in teacher attitudes between those who used BL before the COVID-19 pandemic and those who did not. Although the vast majority of teachers (66.1%) still agree with the statement that during distance learning, they acquired new teaching skills in the digital environment, the difference is not statistically significant because $p > 0.05$ and obtained results are a product of chance. Also, there is no significant statistical difference in teachers' attitudes about the complexity of distance teaching and face-to-face classes between those who used BL before the COVID-19 pandemic and those who did not ($p > 0.05$). However, 55.4% of teachers believe that distance teaching is more demanding to prepare than frontal.

H_1, H_3, H_4, and H_5 can be accepted because $p < 0.05$ and there is a statistically significant difference in the attitudes of teachers about the stated claims between teachers who used BL before the COVID-19 pandemic and those who did not. Teachers who used BL before the COVID-19 pandemic are more inclined to think that experiences with distance teaching are overwhelmingly positive.

There is also a statistically significant difference in teachers' attitudes about applying new knowledge and skills even after the COVID-19 pandemic between teachers who used BL before and those who did not. Most teachers (69.6%) still see a valuable contribution to distance teaching because they will apply new knowledge and skills in the future, while 17.9% disagree. We conclude that the differences in frequencies are not accidental ($p < 0.05$) and that teachers who used BL before the COVID-19 pandemic are more inclined to think that the new knowledge and skills acquired during distance learning will also apply during face-to-face classes after the COVID-19 pandemic.

There is a statistically significant difference in teachers' attitudes toward the impact of teaching methods and tools in the digital environment between teachers who used BL before the COVID-19 pandemic and those who did not. From the frequencies, we see that most teachers (53.6%) believe that teaching methods and tools in the digital environment develop the interest and abilities of students. The conclusion is that teachers who used BL before the COVID-19 pandemic are more inclined to think that teaching methods and tools in the digital environment will develop students' interests and abilities ($p< 0.05$).

A statistically significant difference was established in the attitudes of teachers who used BL before the COVID-19 pandemic and those who did not. The data shows that 24.2% of teachers disagree that the independent creation of digital teaching materials will improve their methodical abilities, and 17.9% do not have a built-in opinion about it. In comparison, 58.9% of teachers believe this is true to a lesser or greater extent. The difference in frequencies is not accidental ($p< 0.05$) and teachers who used BL before the COVID-19 pandemic are more inclined to think that independent production of digital teaching materials will improve their methodical abilities than those who are not.

DISCUSSION

It is assumed that teachers who had positive experiences with distance learning even before the COVID-19 pandemic experimented with digital technology and E-learning and used specific models, sources, and forms of BL. Although the paradigm of traditional frontal teaching has remained because 34.6% of those who used only face-to-face classes before the COVID-19 pandemic as a reason state that teaching face-to-face is the most appropriate and highest quality for the social development of students.

It is evident that during distance classes, the use of materials on the web and the use of virtual reality increased significantly, which was expected because it became necessary to use digital sources. The conclusion is that the digital competence of teachers to use computer technology in teaching has significantly increased, but they are less qualified in the methodical application of constructivist teaching in cooperation with digital technology.

Although there are differences in frequencies in the use of BL before the COVID-19 pandemic between Generation X (19%) and Generation Y (37%), no statistically significant correlation has been established. Only a statistically significant correlation between teachers' education was shown, so it turns out that Master of Art Education (61%) was more inclined to use BL before the

COVID-19 pandemic than those who graduated from an art academy or some other related faculty (2%). The reason could be better methodical training.

Teachers who used BL before the COVID-19 pandemic are more inclined to think that their experiences with distance teaching are primarily positive (t 2.688; df 54; $p < 0.05$). Openness to digital teaching has also facilitated their further development of competencies, so from the results, we can see that teachers who used BL before the COVID-19 pandemic are more inclined to think that they will apply new knowledge and skills during frontal classes after the pandemic (t 2.086; df 54; $p < 0.05$). They are primarily aware of the positive impacts of digital technology on learning, which we see from the results of the t-test because teachers who used BL before the COVID-19 pandemic are more inclined to think that methods and tools for teaching in the digital environment develop students' interest and abilities (t 2.391; df 54; $p < 0.05$).

The teachers who used BL before the COVID-19 pandemic were mainly developing their digital competencies in the methodical field and they think that the independent creation of digital teaching materials improved their methodical abilities (t 2.602; df 54; $p < 0.05$). 66.1% of teachers believe they have developed skills, but no statistically significant difference exists between those who used BL before the COVID-19 pandemic and those who did not (t 1.006; df 54; $p > 0.05$). There is also no statistically significant difference in attitudes about the complexity of distance teaching and face-to-face teaching (t 1.764; df 54; $p > 0.05$) between those teachers who used BL before the pandemic and those who did not. Although 55.4% of teachers believe that the preparation for distance teaching is more demanding than face-to-face, such classes are resistant due to higher teacher engagement, more preparation, and more learning (Matijević et al., 2017).

CONCLUSION

This study provides valuable insights into visual arts teachers' digital competencies and teaching methodologies during the COVID-19 pandemic. The digital competence of visual arts teachers was visible even before the COVID-19 pandemic because such teachers included computer technology and multimedia methodology in teaching, believing that they were developing students' interests and abilities. During the COVID-19 pandemic, they set their digital skills even further, making digital teaching materials on their own and instructing students to use them in solving tasks, considering that this is how they improve their methodical abilities.

However, it has several limitations. The sample was limited to visual arts teachers in Croatia, which may affect the generalizability of the findings to other regions or disciplines. The reliance on self-reported data introduces the possibility of response bias, as participants may overestimate or underestimate their competencies and experiences. The study focused on BL and digital competencies without delving deeply into other potentially significant factors, such as institutional support or access to technology.

The findings have important implications for educational practice. The results highlight the necessity of ongoing professional development to enhance basic digital literacy and advanced multimedia didactic competencies. Additionally, the positive experiences of teachers who used BL before the pandemic underscore the potential of this approach to enrich face-to-face teaching. Schools and policymakers should consider integrating BL into standard curricula, emphasizing its benefits for fostering creativity and engagement in education.

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THE ROLE OF PHYSICAL EDUCATION IN STEAM LEARNING

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Abstract: This paper investigates the integration of Physical Education (P.E.) into STEAM (Science, Technology, Engineering, Arts, and Mathematics) education, set against a backdrop of declining physical activity and increasing health concerns among European youth. The question is how P.E. can enhance STEAM learning and address these health challenges. Utilizing a comparative analysis of P.E. programs across Europe, the study reviews educational policies and curricula to understand the current positioning of P.E. in schools. This involves examining the time allocation and emphasis on P.E. in different educational systems. Current findings reveal a consistent underrepresentation of P.E. in academic settings, with significant discrepancies in the attention and resources allocated to it. This neglect is juxtaposed against the recognized need for holistic education that synergizes physical well-being with academic proficiency. Some examples of interdisciplinary work is given in the paper.

Keywords: physical education, STEAM, physical activity, youth and health concerns

INTRODUCTION

In the rapidly evolving landscape of modern education, STEAM—an acronym for Science, Technology, Engineering, Arts, and Mathematics—stands out as a beacon of interdisciplinary learning. This educational framework, celebrated for its holistic approach, seamlessly integrates these traditionally separate disciplines, fostering an environment where innovation, creativity, and critical thinking are not just encouraged but are fundamental. STEAM education transcends the conventional boundaries of subject-specific learning, preparing students for a future where interdisciplinary knowledge is not just valuable, but essential.

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STEM is an integrated educational approach to learning and teaching, which requires an intentional connection between curriculum learning objectives, standards, assessments, and lesson design/implementation. STEM literacy means "(1) awareness of the roles of science, technology, engineering, and mathematics in modern society; (2) familiarity with at least some of the fundamental concepts from each area; and (3) a basic level of application fluency (e.g., the ability to critically evaluate the science or engineering content in a news report, conduct basic troubleshooting of common technologies, and perform basic mathematical operations relevant to daily life)" (Margot & Kettler, 2019).

In recent years, various concepts and modifications of STEM have been introduced with the idea of implementing other areas into the STEM concept such as STEAM – Science, Technology, Engineering, Arts and Mathematics (Aguilera & Ortiz-Revilla, 2021; Diego-Mantecon, et al., 2021; Tran, et al., 2021), iSTEM – Integrated Science, Technology, Engineering and Mathematics (Razi & Zhou, 2022; Wilson, et al., 2022), i-STEAM – Integrated Science, Technology, Engineering, Arts and Mathematics (Ortiz-Revilla, et al., 2021), STEMM – Science, Technology, Engineering, Mathematics and Medicine (Lee, et al., 2015).

The extension of the STEM concept is mostly focused on the implementation of Arts into STE(A)M to enhance the role of creativity and innovation in contemporary learning. STEAM applies meaningful science, technology, engineering, arts, and mathematics content to solve real-world problems through hands-on learning activities and creative design. Including the arts in STEM learning enhances teaching and student achievement, inquiry and problem-solving skills, and creative thinking, raises students' interest in science and its application, and provides multiple access points for students to engage in the creative process and meet objectives in all subject areas (Dell' Erba, 2019).

What stands out as a special question is whether it is possible—and if so, how—to incorporate the field of physical education into the STE(A)M model (Erwin, 2017; Osada, et al., 2022). The priority of today's educational policies is the advancement of students in the field of technology and information systems, but in addition to improving problem-solving skills, and collecting and analyzing information, an individual's personality should be depicted through the integrity of mind and body (Osada, et al., 2022).

The current status of society characterizes technological development and an overall decrease in physical activity (P.A.). P.A. levels are declining in all parts of the world. Wealthy, middle or low-income countries share a decline in physical activity (WHO, 2018, 2022). The World Health Organization reports that the extent of the obesity problem has reached "epidemic proportions." Already at deadly levels, the WHO asserts that obesity rates are "still escalating," meaning that the stop to the increase in overweight and obesity rates is not in sight. Childhood obesity is at a constant rate of increase. A Large-scale pre-epidemic study published in *Lancet Journal* suggests that in 2017 there were 10 times more obese children than four decades ago (Abarca-Gómez et al., 2017). Statistically, Serbia is among the five European countries hit by the obesity epidemic the hardest (WHO European Regional Obesity Report 2022). A similar situation is in the USA where childhood obesity is a serious problem as well. Obesity prevalence among children and adolescents is still too high. The prevalence of obesity was 19.7% and affected about 14.7 million children and adolescents (Stierman et al., 2021).

Even during the last decade, studies in Europe and the U.S. found that moderate-to-vigorous physical activity among children attending elementary school age is significantly decreasing (Riddoch, 2004; Nader, 2008). In Europe, there is a cut in half from 9-year-olds to 15-year-old children (48% for boys & 54 % for girls); in the US, physical activity dropped by 75% within the same age period. The last published estimations (Lee, 2017) from the US suggest that only 32% of 8-11-year-old children have sufficient physical activity (exercise for 25 minutes a day/three days a week according to the guidelines by the Sports and Fitness Industry Association), which is significantly below the WHO recommendations. Maintaining the current level of physical activity will result in 8.1 million of these children being overweight or obese by 2020 in the US. A significant amount ($21.9 billion) in additional medical costs and lost wages could be avoided if only half of the children obtained sufficient physical activity (Lee, 2017).

P.E. in school is the only sure opportunity for every school-age child to access health-enhancing physical activities. It is estimated that for over 80% of the children, P.E. is only physical activity during the day (EC, 2015). It is formally recognized and is a mandatory subject in the curricula in all European countries. The relative share of time allocated to P.E. is around 9-10% but some countries have even less than 5%, even in primary education. Additionally, there are many problems in the implementation and realization of P.E. classes in schools. Many elementary school teachers consider P.E. as a nonessential subject and neglect it. In order to respond to the increased demands for achievements in core subjects, teachers often devote more time during total school time to those subjects and decrease time for nonessential subjects such as physical education. In the U.S., after No Child Left Behind Act of 2001, in the efforts to hinder decreased funding for schools, 44% of school administrators reported that instructional time for evaluated subjects (literacy and mathematics) was increased at the expense of time devoted to P.E. physical education and other nonessential subjects (Center on Education Policy, 2007, 2008). Similar trends in school ranking and funding is being considered at the moment in

Serbia and some European courtiers. Also, the perceived importance and total teaching time allocated to P.E. is lower compared to other subjects (Eurydice, 2012b). The difference between the total time allocated is highest in primary education where in some countries from one-sixth to one-fifth of teaching time is devoted to P.E. compared to language or mathematics (Eurydice, 2013). The legal and perceived actual status of P.E. and its teachers is a contentious issue. The majority of P.E. teachers considered that their subject has an inadequate status. The evidence of the lower status of P.E. can be observed in little interest in P.E. such as: low levels of awareness of its usefulness and intrinsic/extrinsic values; being non-examinable, less curriculum time allocation, greater emphasis on other subjects, etc. In comparison to the rest of the world, the situation is the best in Europe where only 46% of P.E. teachers considered that P.E. has a lower status than other subjects (UNESCO report, 2013). In practice, many teachers find themselves asking how they are supposed to achieve educational goals in key subjects without increased time allocated to these subjects or taking the time from some other less important subject like P.E.

The importance of P.E. is increasing since most diseases become clinically manifested mainly during adulthood, but the actual problem begins in childhood when lifestyle habits such as physical activity are established (Summary report Pediatrics, 2011). Increases in the level of physical activity by encouraging involvement in everyday physical activity can be one of the most effective ways for the magnitude decline and for overcoming this problem.

Similarly, there are recommendations for STEM education to begin from the earliest years (Campbell & Speldewinde, 2022) and that fundamental STE(PA)M; science, technology, engineering, physical education, arts, and mathematics skills should be established in primary school. The primary years are the time when students develop a self-belief in their ability as STEM learners. Students' experiences in the primary and early secondary years of schooling establish a sense of competence that students have in the foundations of mathematics and science and can encourage their interest in science related fields (Ainley, Kos & Nicholas, 2008). At the same time, early childhood is the ideal time for establishing healthy lifestyle habits (Summary Report Pediatrics, 2011).

APPLICATION OF SCIENCE, TECHNOLOGY, ENGINEERING, AND P.E.

In Physical Education (PE), the fusion of Science, Technology, and Engineering creates a multifaceted learning environment that enriches students' understanding and experience of physical activities. The scientific aspect is deeply rooted in understanding human biology and physiology, where students explore the biomechanics of movement, the physiological impacts of exercise, and nutritional science. This comprehensive approach enables them to grasp how muscles function, the significance of cardiovascular health, and how various physical activities affect their bodies.

Complementing this, technology plays a pivotal role in PE through advanced tools like fitness trackers, health apps, and virtual reality systems. These technological interventions allow students to delve into data analysis by monitoring their physical activities, comprehending heart rate variations, and understanding how technology is employed by athletes for performance optimization.

Moreover, engineering principles are seamlessly integrated into PE, enhancing the practical experience. This integration is evident in the design and utilization of sports equipment and facilities. Students learn about the engineering concepts behind protective gear, the aerodynamics of balls, and the intricacies of designing athletic footwear. Material science also comes into play, offering insights into the development of better, safer, and more efficient sports gear and equipment.

A notable instance of the successful integration of science into physical education is the *Physical Education in Physics* (https://pefja.kg.ac.rs/fizicka-priprema/) project, an initiative supported by the National Center for Science Promotion. This project conducted a few years ago serves as an exemplary model showcasing the synergistic potential between physical education and scientific disciplines, in this case, physics.

The project aimed to blend the theoretical concepts of physics with the practical applications found in physical education. By doing so, it provided students with an immersive and engaging learning experience, where theoretical physics was not just a subject confined to the classroom but a living, breathing part of their physical activities.

The *Physical Education in Physics* project, known in its native language as *Физичка припрема* (https://pefja.kg.ac.rs/fizicka-priprema/), represents an innovative educational initiative aimed at intertwining physical education with the principles of physics. The project's primary objective is to familiarize participants, particularly students in younger grades who have not yet started formal physics education, with the laws of physics as they apply to various physical activities and sports movements.

Organized by the Faculty of Education, University of Kragujevac, the project targets students in the 4th and 5th grades. Through a series of diverse and engaging workshops, the project brings to life concepts such as the human body and movement, lever systems, force, and power; *Newton on the Horizontal Bar*; *Archimedes in the Water Park*; statics and dynamics in martial arts; and the physics in football, among others.

These workshops, conducted within the framework of Physical Education – a subject often favored by most students – aim to spark curiosity and foster an interest in learning and studying the physical laws governing our world. The approach is both creative and captivating, making complex scientific principles accessible and relatable to young learners.

By bringing these content areas closer to the students in an engaging manner, the project not only enhances their understanding of physical laws but also increases their interest in future physics lessons in higher grades. This proactive approach to education serves as an exemplary model of how interdisciplinary teaching methods can significantly benefit student learning and engagement.

The *Physical Education in Physics* project is a testament to the effectiveness of integrating academic disciplines, in this case, physics, with physical education. It exemplifies how teaching methods that combine physical activity with theoretical learning can lead to a deeper understanding and appreciation of both subjects, ultimately resulting in a more holistic educational experience for students.

Picture 1. Workshop Physical preparation – preparation for Physics

ART IN PHYSICAL EDUCATION

Art holds a significant place in physical culture, permeating all its areas, including physical education, sports, and recreation. Physical education fulfills numerous educational, health-hygienic, recreational, and educational tasks. The educational aspects are directed towards the complete, harmonious, versatile, and creative development of personality, of which aesthetic values and abilities are a crucial part. These can be successfully developed within physical culture. During the process of physical education, aesthetic values are realized through the development and perfection of body movements, as well as by nurturing a sense of harmony, gracefulness, and the beauty of movement.

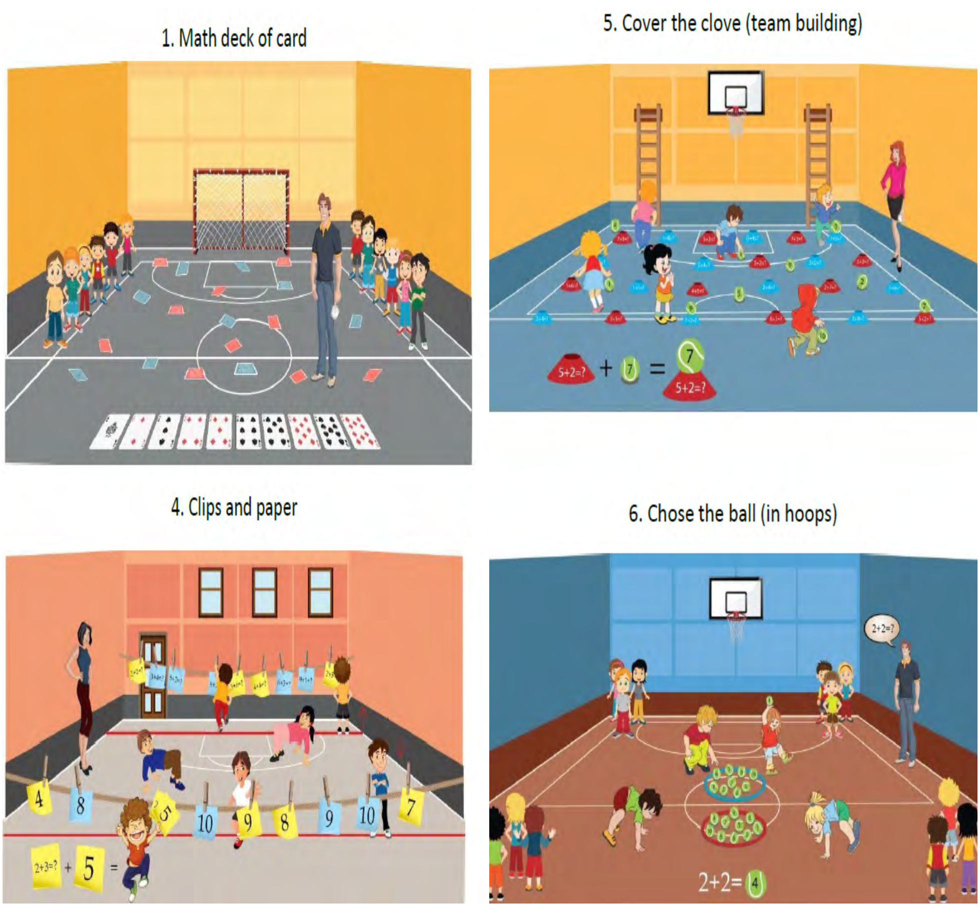
Art is also considerably present in sports. Athletes, with their movements, strokes, and skills, can be said to create their artistic works. Moreover, music and painting often explore themes from sports activities. The performance of choreographies in certain sports is unimaginable and unfeasible without musical accompaniment, while sports photography holds an irreplaceable place in the media, with frequent exhibitions of such photographs (Ignjatovic et al., 2009).

INTEGRATION OF MATHEMATICS IN PHYSICAL EDUCATION

Finally, most of the work on the topic was given on interdisciplinary approach to mathematics and physical education. By integrating mathematics into physical education at the elementary level, educators can create a more dynamic and inclusive learning environment. This approach not only enhances children's mathematical skills but also promotes physical health, teamwork, and problem-solving abilities. It demonstrates the versatility and fun of mathematics, encouraging students to appreciate and enjoy the subject.

The authors of this study have recently conducted research on this topic. They analyzed and highlighted the significance, standing, and practical implementation of logical-mathematical games within an integrated teaching framework for physical education. The process for selecting pertinent studies involved searching through electronic databases to identify those incorporating an integrative approach in this research area. Out of 51 publications reviewed, only 9 published in the last two decades fulfilled the criteria of this study. The findings underscore a clear necessity for more comprehensive research in this field. This need stems not only from the limited number of existing studies but also from the importance of exploring how this integrative teaching method in physical education impacts the motor skills and abilities of younger students (Miloradovic, et al., 2024). The examination of the literature reveals a substantial volume of literature on the use of integrative methods in teaching physical education in conjunction with traditional "classroom" subjects. While the utilization of logic-mathematical games has been shown to positively influence student performance, there is a notable gap in research specifically focused on the application of these games within an integrative approach to physical education. This is particularly evident for younger school-aged children and in studies evaluating the impact on motor skills and abilities following experimental programs. The findings from the reviewed studies highlight the necessity for more extensive research across a broader age range, encompassing students from primary through to secondary school, to gain a deeper understanding of these methods' effectiveness (Miloradovic, et al., 2024).

The prevailing body of research primarily emphasizes theoretical approaches, with a lesser concentration on empirical experimentation in the field. Additionally, there is a noticeable deficiency in standardized and comprehensive materials pertaining to this subject area. This indicates a gap in practical, experiment-based research and a need for more elaborately developed resources and guidelines to support the integrative approach of incorporating logic-mathematical games in physical education, particularly for younger students. In this regard, the previously mentioned PEMath guidebook is under preparation.



Picture 2. PEMath gudebook, Ignjatovic, under preparation.

ENHANCING ARITHMETIC AND MEASUREMENT IN PHYSICAL EDUCATION FOR FIRST GRADERS: INSIGHTS FROM PEMATH

Using *PEMath* as a guideline, elementary school teachers can create a vibrant learning environment where first graders enjoy the dual benefits of physical activity and foundational arithmetic skill development. This approach not only enhances their mathematical abilities but also promotes physical health, coordination, and cognitive development.

A whole new universe of learning opens up for young kids in the creative and dynamic world of *PEMath*, a manual that skillfully integrates math with physical education. With the help of this creative method, the gym becomes a dynamic learning environment where math and exercise combine to create a joyful tango between health and knowledge.

A whole new universe of learning opens up for young kids in the creative and dynamic world of *PEMath*, a manual that skillfully integrates math with physical education. With the help of this creative method, the gym becomes a dynamic learning environment where math and exercise combine to create a joyful tango between health and knowledge. For instance, imagine a place where each activity and game offers a chance to explore mathematics. This is when a straightforward activity turns into a numerical lesson: kids leap, hop, or toss with great enthusiasm, each motion representing a solution to a mathematical problem. For example, when they solve a problem and the solution is 15, the air bursts into the rhythm of fifteen perfectly timed jumping jacks, fusing mental and physical agility.

Interactive learning is further enhanced through the use of props like numbered cones, mats, or stepping stones. A “number path” sprawls across the floor, inviting students to leap from one number to the next, adding and subtracting as they go, transforming each step into a numeral adventure. The excitement peaks during relay races, ingeniously adapted to include arithmetic challenges. Before dashing across the room, each child pauses to solve a math problem, their physical sprint preceded by a mental leap, effectively integrating calculation with cardiovascular activity.

CONCLUSION

In conclusion, the exploration of integrating physical education with elements of STEAM – Science, Technology, Engineering, Arts, and Mathematics – presents a revolutionary approach in the realm of education. It goes beyond conventional teaching techniques by combining academic rigor with physical activity to create a comprehensive learning environment. Initiatives such as *PEMath* are prime examples of this integration; they make learning both multifaceted and captivating by fusing logical-mathematical games and exercises with physical instruction. This method fosters students' intellectual, artistic, and analytical abilities in addition to addressing the requirement for physical health and fitness. Nevertheless, the literature now in publication indicates a deficiency in useful, experiment-based research, particularly for younger pupils, despite the apparent advantages. This emphasizes the need for more thorough research and resources to certify and standardize these integrative techniques.

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V

THE EFFECTS OF THE STEM/STEAM/STREAM APPROACH IN TEACHING SCIENCE

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FUTURE IMPACT OF STEM CONCEPT APPLICATION ON REPLACING AND/OR RECONSTRUCTING MISCONCEPTIONS

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Abstract: This paper presents the results of a preliminary study conducted in two fourth-grade classes at Primary School "9. Oktobar" in Prokuplje. Based on the results of some previous research, we wanted to examine whether and how the application of the STEM approach in lower primary school grades affects students' misconceptions about electric current. Although the teaching and learning programs in Serbia do not sufficiently allow for the implementation of the STEM concept, by comparing students' knowledge before and after lessons where such an approach was applied, we found that the application of the STEM approach positively influences the elimination and correction of students' misconceptions about electric current, electrical circuits, electrical conductivity, conductors, and insulators.

Keywords: STEM concept, misconceptions, primary school, electric current

INTRODUCTION

The purpose and goal of modern education are to equip students to be prepared for the changes that time brings and to adapt to them quickly. Due to numerous scientific discoveries, changes, and transformations at all levels, it has become necessary for students to develop logical, hypothetical, and analytical thinking, the ability to observe, compare, connect, draw conclusions, and find efficient and creative solutions to everyday life problems during their education. It is essential to educate them scientifically, providing them with as many opportunities as possible to explore and experiment, and it is precisely the STEM concept that can contribute to the development of students' educational

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competencies for lifelong learning, literacy, and mental, motor, and emotional development (McClure et al., 2017).

The STEM concept was created by the U.S. National Science Foundation in the 1990s with the intention of connecting and integrating the learning content from science (S), technology (T), engineering (E), and mathematics (M). It involves the integration of various disciplines (STEM fields), which are well-connected, „interwoven", project-based, and problem-oriented, with an emphasis on interdisciplinary learning (Sanders, 2009; Golubović-Ilić, 2023). This concept "today, in addition to the original, also has many sub-variants" (Miljački, 2020: 103), where, knowledge is also integrated from the arts (STEAM - Art), reading (STREAM – Reading), physical education (STEPAM – Physical education), and others. STEM fields are well-connected, "interwoven," project- and question-based, with an emphasis on interdisciplinary learning. With this way of learning, skills are acquired in a way that will be used, both in the workplace and in life in general. It is necessary for children to excel at the skills needed in the modern world, learn to be ready for the changes brought by time, and to adapt to them quickly (Golubović-Ilić, 2023).

Although the STEM concept has been known and present worldwide for more than 30 years, it arrived to our country with a delay and has gained relevance only in the last few years (Ilić, Škorić, & Subotin, 2020; Stantić Miljački, 2020; Cekić-Jovanović & Gajić, 2022; Filipović, 2023; Golubović-Ilić, 2023). Given that the theoretical foundations and empirical research on the various effects of this concept are very much needed and significant, national scholars are increasingly focusing their attention to this topics, while the direct implementers of the educational process, as is often the case with other innovative approaches, models, and concepts, remain on the sidelines. Class teachers and teachers, who are supposed to apply and directly implement this method of teaching, are deprived of systematically designed and organized professional training, development, and enhancement of professional competencies for STEM education. The development and strengthening of their abilities to apply the STEM approach are left to their personal affinity, enthusiasm, initiative, and desire to modernize and innovate their direct work with children, as only three professional development programs[1] on this topic are available to them in the ZUOV Catalogue. Furthermore, research results show that teachers have positive attitudes toward the use of modern technology and the STEM approach in teaching, but that the majority of respondents (45.6%, N=160) "have not attended any professional development seminar on the application of STEAM" (Cekić-Jovanović and Gajić, 2022: 193). Such data indicate a problem with the

[1] ZUOV – Institute for the Improvement of Education of the Republic of Serbia (catalog numbers of the programs: 1128, 394, and 893)

diffusion of the STEM concept as a pedagogical innovation within the education system of our country (Filipović, 2023). The demand for STEM education is constantly increasing, and some predictions suggest that STEM competencies will become a key element in future employment. This is because future workers are expected to be ready for the challenges of the 21st century, to have innovative, creative, and inventive potential, and to possess technologically sophisticated skills and the ability to connect science, art, engineering, and mathematics more deeply. In Serbia, however, many studies and analyses "point to a continuously insufficient level of knowledge and skills acquired by students in primary schools, underdeveloped essential competencies for further education and daily life, and low student motivation for learning and intellectual work (Education Development Strategy in Serbia by 2020)" (Ilić et al., 2020:85). This may be due to the fact that the curricula of primary schools and high schools do not include a STEM subject that implies the integrated study of content from different areas (science, technology, engineering, mathematics, art), but rather these "subjects are studied exclusively in isolation" (Ibid., 86). On the other hand, there is a problem that class teachers and teachers who are supposed to deliver this subject do not have adequate competencies, and their level of readiness to apply the STEM concept in direct work with children/students is unsatisfactory. Additionally, the class teachers themselves do not feel prepared for STEM teaching and believe that their theoretical knowledge from different disciplines is not sufficient for integrating content and implementing such a method in real conditions (Filipović, 2023).

WHY IS THE APPLICATION OF THE STEM CONCEPT SIGNIFICANT AND NECESSARY?

The application of the STEM concept positively affects various aspects of personal development— it encourages curiosity about the world, openness, and readiness for collaboration, and in well-designed problem situations, "contributes to the development of all competencies for lifelong learning" (Miljački, 2020:107). The STEM approach helps students to understand more deeply the importance of scientific concepts; it enables them to understand how to approach and solve problems from both teaching and everyday life. Technology within the STEM concept helps students become aware of the technological demands of the world we live in and apply some technological solutions in their professional work and daily life. STEM ensures that students achieve high academic goals by primarily understanding the subjects they learn, finding their application in everyday life, and managing to connect them with the demands of rapid and modern living (Educational Center STEM[2]). This concept involves acquiring knowledge about the functioning of natural, scientific, and technical laws and principles, developing skills that include problem-solving, analytical and divergent thinking, "developing and making logical conclusions, and acquiring practical knowledge" (Ilić, Škorić, Subotin, 2020:84) with the aim of solving everyday problems from the real world through practical work (Cekić-Jovanović and Gajić, 2022). STEM learning environments promote creativity using the inquiry approach, offer opportunities for teamwork, and emphasize inquiry rather than the memorization of information (Wang et al., 2011). During STEM activities, besides cognitive skills, students also develop social competencies, as problem-solving work involves collaboration, "interaction and communication among students, as well as providing support in situations where there is a need" (Filipović, 2023: 183). We can also understand the STEM approach as play, especially in early childhood education, as it represents a fun activity that, through experimentation, hypothesis formulation, and testing, leads to certain knowledge and conclusions. It contributes to holistic education, stimulates imagination, allows children to try out and execute whatever they envision, and is a key factor and method of working and learning that prepares them for life. Through everyday activities and play, children often encounter situations in which they have to come up with solutions on their own and should be let go because this is the best way to develop independence, self-confidence and a sense of self-worth (Golubović-Ilić, 2023).

MISCONCEPTIONS OF PRIMARY SCHOOL STUDENTS

Guided by curiosity and interest, young children explore their environment and create concepts and ideas based on their everyday experiences. The way they describe and explain the world is often driven by logical but scientifically inaccurate understandings. Experiential, scientifically unfounded, and unverified knowledge represents the spontaneous concepts with which children begin their schooling. Over time, and under the influence of education, these concepts are modified, developed, and become pseudo-concepts, eventually maturing into true scientific concepts by the age of 11–12 years (Petrović, 2006).

Students come to a classroom with prerequisite knowledge (existing schemas), and as they progress through their education, these schemas are progressively (or sequentially) built upon (Thompson & Logue, 2006). "Although spontaneous concepts, or experiential knowledge, are of fundamental importance for children's understanding of their environment and the relationships within

[2] 7 reasons why STEM must be part of every teacher's instructional approach - stemzbornica@gmail.com

it, their meaning is often, to a greater or lesser extent, in conflict with scientific facts and can pose a barrier to the acquisition of scientific concepts, especially in the natural sciences" (Blagdanić, Radovanović, Bošnjak-Stepanović, 2019:17). Based on unfounded generalizations and assumptions, experiential concepts can be found in the literature under various names-prejudices, alternative ideas, naive beliefs, and misconceptions. The term misconception is used to describe a situation where students' ideas differ from scientists' ideas about a concept (Smolleck & Hershberger, 2011).

Considering that the exploration of the world (phenomena, processes, and relationships in the environment) begins well before primary education, it is important to note that the spontaneous concepts a child forms through direct interaction with their environment represent the experiential base upon which scientific concepts are built in the educational process (Blagdanić, Radovanović, Bošnjak-Stepanović, 2019). Children's interpretations, although spontaneous and intuitive, do not consist of individual, immediate perceptions related to a given phenomenon; their content exceeds the meanings present in immediate perceptual data to the extent that these are interpreted according to intuitive principles (or knowledge) that children have previously acquired through their practical experience (Petrović, 2018). In their effort to understand the world around them, students create an intuitive explanatory framework that often operates outside their conscious control during the school learning process and limits their understanding and proper acquisition of new information, leading to various learning failures throughout their education. Considering that students' previous experiences serve as the foundation and context for further learning, and that partially accurate ideas can either present a barrier or be used as a basis for further development and "building" of scientific knowledge, teachers should not ignore or underestimate the power of misconceptions. The problem is that once a misconception is formed, it is extremely difficult to change (Eggen & Kauchak, 2004), and possessing incorrect understandings (misconceptions) can have serious consequences for learning. According to Fischer (1985), misconceptions have some common characteristics:

1. They are in contrast with scientific concepts;
2. There is a tendency for the same misconceptions to frequently occur among a larger number of people;
3. They are very resistant to change, especially when traditional lecturing methods are used in teaching;
4. They sometimes involve entire alternative systems that are logically coherent and are often used by students;
5. Some are historical, meaning they arise from theories that have been superseded in science;

6. They can result from the automatic processing of linguistic structures without correction of meaning; and
7. They can be the result of certain experiences that are typically common to a larger number of individuals, or they can arise from classroom instruction, specifically due to incorrect interpretations of textbook material or misunderstandings (Lukša et al., 2013).

There are several ways in which children develop misconceptions. Some sources of incorrect understandings include everyday observations, religious or mythological teachings, and so on. Additionally, there are multiple contexts in which young learners encounter information that promote misconceptions. First, not all experiences lead to accurate conclusions, or they lead students to see all possible outcomes. Second, when parents or other family members are faced with the children's questions, instead of admitting they do not know the answer, it is common for them to provide an answer that is inaccurate, incomplete, or unclear. Other sources of misconceptions can be various written, audiovisual resources, media, the internet, and even teachers. The fundamental issue is that students consider all these sources to be "trustworthy," leading to their ready, uncritical acceptance and absolute belief in the truthfulness of the information received (Pine, Messer, St. John, 2001). Younger learners are capable of providing correct answers to certain questions but may simultaneously hold misconceptions in which they strongly believe. One way to correct these misconceptions is through teaching for conceptual change. "Misconceptions are rarely expressed verbally or in writing and therefore often remain undiscovered... but before the process of disputing and correcting misconceptions begins, the teacher must uncover the misconceptions that their students have" (Shultz, 1987: 21). By understanding the concepts and misconceptions of younger learners, teachers can better tailor their teaching methods, strategies, and approaches in an attempt to guide students toward accurate and more sophisticated understandings of science (Hoi, 2021).

In Serbia, fourth-grade primary school students, although they have not officially covered the topics of electricity and electric current in the previous three grades according to the curriculum, have prior experiences and some background knowledge on the subject. However, foreign researchers believe that misconceptions about electric current are nearly universal, resistant to change, and maintained by teachers, textbooks, and collective experience (Hasanah, 2020; Şenyiğit, 2021). Considering previous research on the possibilities and methods for addressing students' misconceptions (Taufiq, Muntamah, Parmin, 2020; Uswatun, 2020; Aligo, Branzuela, Faraon, Gardon, and Orleans, 2021), we selected content from the Nature and Social sciences[3] curriculum

[3] Official Gazette of the Republic of Serbia – "Educational Gazette," No. 11/2019

program. Specifically, we used the teaching theme of *Materials*, and within it, the teaching units: *Charging Objects with Different Materials*, *Electrical Conductivity – Conductors and Insulators*, *and Rational Use of Electrical Energy and Proper Handling of Electrical Appliances in the Household.* With the intention of examining the impact of applying the STEM concept on addressing and correcting students' misconceptions about electric current, electrical circuits, electrical conductivity, conductors, and insulators, we designed the implementation (processing) of these contents using the STE(PA)M concept.[4]

RESEARCH METHODOLOGY

Considering that most "domestic" research on the application of the STEM concept pertains to subject teaching and working with high school students, our research focused on the misconceptions of fourth-grade primary school students about electric current and the possibility of correcting these misconceptions using the STEPAM concept.[5] The aim of the research was to examine whether and how the application of the STEM approach in younger grades of primary school affects students' misconceptions about electric current, specifically to determine the impact of using the STEM concept on correcting and removing these misconceptions.

The starting point of the research was the fact that the education and learning programs in Serbia do not sufficiently allow for the application of the STEM concept. Therefore, both in the everyday practice of class teachers and in our case, it was necessary to first select content and choose appropriate teaching units/themes that could be integrated from specific subjects. The second phase in applying the STEM concept involves "fitting" or designing ways to implement STEM activities during regular lessons without disrupting the existing schedule. We addressed this problem by planning a double class (90 minutes) during which the mentioned content from the Nature and Social Sciences subject would be realized using the STEPAM concept, scheduled during the regular classes of that school subject and Physical Education. The research was designed as an experiment with parallel groups, where the students of one fourth-grade[6] class represented the experimental (E) group, and the students of another class represented the control (K) group. The research consisted of three phases: (1) initial testing of both groups' knowledge about electricity and

[4] Detailed structure and organization of the class can be found in the Journal Uzdanica, vol 22/1, 2025..

[5] STEPAM = S - Science, T - Technology, E - Engineering, P - Physical Education, A - Art, M - Mathematics

[6] Primary School "9. Oktobar" from Prokuplje

electric current, (2) teaching using the STEPAM concept with the experimental (E) group and using the conventional method with the control (K) group, and (3) re-testing the E group's knowledge to determine the impact of this teaching method on previously identified misconceptions. The research objectives were: 1) to identify existing misconceptions among primary school students about electric current, and 2) to determine if there are significant differences in the number and type of misconceptions about electric current before and after the Nature and Social Sciences classes where the STEPAM approach was applied. Knowledge tests (initial and final) contained 12 questions of varying levels of difficulty (basic, intermediate, and advanced), both open and closed-ended, with a maximum of 20 points. Based on the responses to the initial test, we identified characteristic misconceptions about electricity and electric current for both the E and K groups. We then compared the results (responses) of the E group with those of the K group in the final test to determine the differences in the number and type of misconceptions before and after the Nature and Social Sciences classes where the STEPAM approach was applied (E group), compared to the conventional teaching method (K group).

RESEARCH RESULTS

Although this is a study of smaller scope and with a small sample[7], the data indicate that, after the research, the extent and quality of knowledge about electrical phenomena among students in both groups significantly increased. Before the start of the experimental part of the study, that is, before the implementation of the double lesson with the E group and the conventional teaching of the same content with the K group, the results of the initial testing showed that the knowledge of both groups of students about electricity and electrical phenomena was very limited, at a level of recognition, guessing, and with significant "gaps" regarding objects that can be electrified, methods of using and generating electric current, and dangers of electric shock. The reason for this is that students in the first three grades have not studied electrical phenomena in any subject, so the results were entirely in line with our expectations. For the question of why we should be cautious when using electrical devices and appliances, 55% of students in both groups selected one of the incorrect answers[8] (options *a* and *v*). A large number of incorrect answers (60%) were also given for the question, "Which of the listed devices can operate without electrical

[7] This is a preliminary study research preceding a doctoral dissertation.

[8] Suggested answers: a) because it is dangerous to use electrical devices without gloves; b) because it is dangerous to use electrical devices with wet hands; v) because it is dangerous to use electrical devices at a great height.

energy?[9]" Additionally, for question 4, which required students to recognize and name the instrument used to measure electric current, there were no correct answers. Although this is a closed-type question (with options: *voltmeter*, *electromagnet*, *ammeter*, and *wattmeter*), the misconceptions of students across the entire sample stemmed from everyday life on one hand, and logical reasoning at that age on the other. The most frequent answer (82%) chosen by the students was "wattmeter."[10] A considerable number of students in both groups gave partially correct answers[11] to the question, "What is a source of electrical current?" because they had not previously learned about this concept within their schooling. For the same reason, a large number of students (75%) gave a negative response to the question, "Can you make a circuit?| Some of the characteristic answers included: "No, because I'm not an electrician;", "No, because it requires knowledge;", "No, because I don't know what materials I need;", "Yes, but I'm not sure: battery, plastic, thread..."

The responses from students to the third-level complexity questions (open-ended questions) are particularly interesting because they reveal the most pronounced misconceptions. For the question, "Why do birds that land on power lines not get shocked?" the students' answers included: "Because electricity is only in the wires, not outside;", "Because the wires are wrapped in something;", "Because they have a thin layer on their feet;", "Because magnets do not connect plus and minus, and birds do not stand on two wires." Two students from the control group wrote "I wonder too" instead of an answer, and only one student across the entire sample provided the correct answer. For the last two questions, which required students to consider and explain the dual nature of electricity - its ability to be useful when used correctly and dangerous when not used properly[12] - the responses were as follows: "Electricity is evil.", "Electricity can help us if we need something.", "It is good when you control it, not when it controls you." The fact that the students who participated in the study had many incorrect ideas, spontaneous and intuitive understandings, misconceptions, and opinions about electricity and electric current at the beginning is confirmed by the number of incorrect and partially correct answers (*Table 1*):

[9] Suggested answers: remote control, stove, hairdryer, refrigerator, heater, clock

[10] Electricity is measured by – a wattmeter, a note by the author

[11] Partially correct answers were considered to be responses to closed questions (with provided answers) where students select some, but not all, correct answers, or responses to open-ended questions that do not contain complete explanations, justifications, or interpretations – a note by the author

[12] Explain the proverb "Electricity is a good servant but a bad master" (Question 11) and explain the verses: "Where there is electricity, be wise and do not touch its wires; this way, you will never experience an electric shock!" (Question 12).

Table 1: Students' answers on the initial test

Question number	Correct answers	Incorrect answers	Partially correct answers	No answer
1.	13	7	-	-
2.	15	5	-	-
3.	9	11	-	-
4.	-	20	-	-
5.	17	1	2	-
6.	3	12	5	-
7.	4	1	15	
8.	3	2	13	2
9.	2	-	5	13 (don't know)
10.	3	8	5	1 + 3 (don't know)
11.	7	3	9	1
12.	16	-	4	-

The effects of applying the STE(PA)M concept in the E group can be observed based on the results of the final testing. On the final knowledge test, students in both groups generally did not have problems with basic-level questions – they recognized situations representing the consequences of electricity generation, correctly selected materials to charge a glass, and identified the characteristics of water that requires caution when using electrical devices. For second-level complexity questions, both groups of students performed better on the final test compared to the initial test; however, the number of correct answers from the E group students was significantly higher than that of the K group students. For the question that required students to recognize and name the instrument for measuring electrical current (an ammeter), all students in the E group provided the correct answer, while the number of such students in the K group was lower. Additionally, the number of E group students providing completely correct answers[13] to the question "Which of the listed vehicles can operate without electrical energy?" was also higher compared to the K group students, whose answers were partially correct. Thanks largely to the video material that students in the E group watched during the lesson using the STE(PA)M concept,

[13] Offered answers: electric scooter, tram, bicycle, car, roller blades.

their number of correct answers was higher compared to the K group, even for multiple-choice questions. Similar data are found for the questions related to the practical application of what was learned (Level III of complexity), as all students in the E group were able to correctly identify the necessary components and describe the process of creating a circuit. They also ruled out the possibility of using thread as a conductor, and, unlike students in the K group, precisely explained that thread cannot be a conductor because it is not made from a material that conducts electricity.

Significant safety improvement when working with electricity compared to the initial test was demonstrated by almost all students in the E group. They, in contrast to a few students in the K group, understood the importance of using insulating materials (e.g., rubber gloves) to protect against electrical shocks. The positive impact of the STE(PA)M concept on the development of cognitive skills and the ability to interpret abstract concepts among students is evident from the comparative analysis of answers from the IT and FT regarding metaphorical expressions, proverbs, and verses about electricity (e.g., "*Electricity plays its song in the wires, but if you're not careful, the risk multiplies...*" translated from Serbian). There were significantly fewer incorrect, incomplete, and inadequate interpretations by students in both groups on the final test compared to the initial test. However, students in the E group, compared to the K group, provided much more accurate answers—more complete explanations and justifications for why electricity should be used carefully and responsibly.

CONCLUSIONS

Fourth-grade students have a range of misconceptions, ideas, and inaccurate but logical understandings about electricity and electric current. To determine whether the application of the STE(PA)M concept would affect the correction and/or removal of observed misconceptions, we designed a study with parallel groups. One group (K) learned about electric current in the usual way as prescribed by the curriculum, while the other group (E) integrated content from science, technology, engineering, physical education, art, and mathematics. The results show significant changes in the understanding of electrical phenomena on one hand, and the acquisition of much "broader" and higher-quality knowledge among the E group compared to the K group on the other. Students acquired and expanded their knowledge about electricity, electric current, conductors, and insulators, understood electrical phenomena, and gained new skills that will be useful in everyday life. They also explored independently the components of an electric circuit and the materials needed for its construction, tested the electrical conductivity of various materials, understood the difference between conductors and insulators, and developed not only technical skills related to making circuits but also a deeper understanding of electricity concepts.

The implementation of the lesson in the E group confirmed that the STEM approach allows students to learn interactively, explore scientific concepts through experiments, and apply knowledge in real-world situations (Quigley & Herro, 2019). The students were active, focused, and engaged throughout the lesson; in certain parts of the lesson, peer and experiential learning were clearly observable. Elements of Physical Education helped prevent monotony, provided an unusual and active way of reviewing content globally, and combined mental with physical activity. The results confirmed that this approach fosters critical thinking, a deeper understanding of scientific concepts, problem-solving, and collaboration, while also contributing to the elimination of incorrect or inaccurate thinking and misconceptions. Based on the comparison of results from the initial and final tests, we conclude that lessons organized using the STE(PA)M concept significantly improve the quality of students' knowledge compared to traditional teaching methods. This approach in younger grades affects students' misconceptions about electricity, showing significant differences in the number and type of misconceptions about electricity before and after lessons in Nature and Social sciences using the STE(PA)M approach.

The results confirmed the hypothesis that applying the STEM approach positively impacts the removal and correction of students' misconceptions. However, for the validity of the results, the study should be repeated or conducted similarly with a larger sample. Additionally, a similar study should be designed and implemented with other content areas by selecting and integrating topics from different subjects according to STEM principles, to verify and determine the effects of this approach on other content and subjects. This would also create new examples of lessons—ideas and models for designing STEM instruction—that would contribute to the promotion and dissemination of the STEM concept in our regions, as teachers who incorporate such methods into their practice currently lack adequate resources and, in this context, any form of support. Furthermore, research has highlighted the need for considering students' misconceptions during the development of curriculum, teachers' learning methods, as well as the teaching materials. Instead of applying traditional teaching methods in science education, teachers should provide space for students to reflect on their thinking by discussing with a partner or by reporting back to a group or class (Hasanah, 2020).

STEM encourages, stimulates, provokes, and prompts students to solve problems, find answers to various questions, try different ideas, consider alternative solutions, exchange opinions and ideas, and make mistakes and try again, thereby creating a knowledge base and skills needed for everyday life. In this context, this approach represents one possible solution for low student motivation for learning and intellectual work, as it addresses common student questions such as "Why are we learning this?" and "When will we need this in life?". The STEM approach opens space for students to express and test their ideas, assumptions, and opinions, to share and exchange them with peers, thus encouraging them to think outside traditional frameworks (Strutynska & Umryk, 2019). For the STEM concept to be more frequently applied in our country, especially with young learners of primary school, it is necessary to not only reform and innovate the curriculum but also to create a support and professional development system to increase teachers' competencies and preparedness for implementing the STEM concept in their direct work with students. In this regard, we hope that this study and its results will encourage class teachers and future class teachers to embrace and surprise their students with STEM-based teaching.

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THE ROLE OF THE STEMS CONCEPT ON THE DEVELOPMENT OF LANGUAGE ABILITIES AND THE FUNCTIONALITY OF KNOWLEDGE FROM MATHEMATICS AND NATURE AND SOCIETY[1]

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Abstract: Scientific literacy is one of the shared aspirations of numerous educational systems. The importance of learning is reflected in the student's acquaintance with the key concepts and laws on which the world in which we live is based, and then in the development of a scientific way of thinking necessary for satisfying personal and social needs (Antić, Pešikan, & Ivić, 2015; Rutheford & Ahlgren, 1990, according to Marušić Jablanović & Blagdanić, 2019). For a student to be considered scientifically literate, he or she must exhibit measurable behaviors that are recognized on international knowledge tests (such as TIMSS or PISA). When it comes to the lower primary schools in Serbia, two school subjects primarily deal with the development of scientific literacy: Mathematics and Nature and Society. The goals of the STEMS concept are to enhance reading comprehension skills via different types of texts used in Mathematics and Nature and Society, to encourage students to connect the grammatical concepts covered in The Serbian Language course with the content proscribed for Mathematics and Nature and Society, to promote the proper use of orthographic and grammatical rules in open-ended questions used in Mathematics and Nature and Society, and to improve the understanding of vocabulary used in textual tasks to teach the content of Mathematics and Nature and Society. This paper demonstrates that the lexico-semantic abilities and knowledge in Mathematics and Nature and Society can be improved through integrated activities. We present the possibilities for integrating the content of The Serbian Language course with the scientific content taught in Mathematics and Nature and Society.

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INTRODUCTION

Scientific literacy, i.e. learning natural sciences, is one of the shared aspirations of numerous educational systems, including Serbia. The importance of learning science manifests as students' acquaintance with the key concepts and laws that the world in which we live is based on, and then as the development of a scientific way of thinking necessary for satisfying personal and social needs (Antić, Pešikan & Ivić, 2015; Rutheford & Ahlgren, 1990, according to Marušić Jablanović& Blagdanić, 2019). For a student to be considered scientifically literate, he or she must exhibit certain measurable behaviors that are recognized on the international knowledge tests used globally to determine the level of scientific literacy (such as TIMSS and PISA). The PISA (Programme for International Student Assessment) measures 15-year-olds' ability to use reading, mathematics, and science knowledge and skills to meet real-life challenges (OECD, 2023). TIMSS (Trends in International Mathematics and Science Study) can be considered a better tool for measuring school effectiveness, as it relies on the knowledge levels proscribed by the national curricula of the countries participating in a study (Mullis & Martin, 2017).

TIMSS results are an essential source of data since it is the only international research on the scientific literacy of students attending lower primary schools in which Serbia participates. In addition, they allow us to observe and identify the factors of better achievements. When it comes to lower primary schools in Serbia, the development of scientific literacy two school subjects primarily deal with the development of scientific literacy: Mathematics and Nature and Society. When the TIMSS survey results are analyzed, one can determine the factors contributing to the students's achievements in natural sciences. The factors differ: some stem from the characteristics of students, some depend on teachers, and some originate from the school itself (Marušić Jablanović & Blagdanić, 2019). The TIMSS survey conducted in 2019 demonstrates that the knowledge of the mother tongue and language skills impact the understanding of the content taught in mathematics and science (Đerić, Gutvajn, Jošić, & Ševa, 2021). The analysis of incorrect answers in biology, taught in all four grades through science, indicates that a multitude of errors results from misunderstanding the lexicon in the tasks; additionally, open-ended tasks abound in vague answers that, inter alia, suggest insufficient verbal competence among students (Stanišić, Blagdanić& Marušić Jablanović, 2021: 212). Weak lexico-semantic abilities lead to misunderstanding instructions given in a task and poorer achievements in solving the tasks that require language production. According to the findings of a recent study, fourth-grade students have difficulty understanding the lexical metaphors used in their science textbooks; however, the curriculum does not include the explanations of metaphoric concepts that should serve as a semantic bridge, i.e. to establish a parallel between abstract contents that cannot be understood through the everyday experiences (Blagdanić, Cvetanović, & Lukić, 2022).

Another recent study demonstrates that in teaching biology, the STEM approach can increase students' performance and involvement, reduce students' mental effort, and improve both the quality of the acquired knowledge and its preservation (Županec, Radulović, & Lazarević, 2022). Elsayed (2022) explored the effectiveness of teaching mathematics by developing mathematical proficiency through the five components: conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition (Elsayed, 2022). The findings showing the higher mean scores for the experimental group taught mathematics with the STEM approach prove significant differences in mathematical proficiency between the experimental and control groups. Similarly, in a study conducted by Nursafitri and Anriani, the students learning mathematics via the STEM approach scored better than the students taught with the traditional approach (Nursafitri & Anriani, 2023). Eshaq determined that the inclusion of STEM education into the curriculum encourages students to think critically, collaborate with their peers, and utilize their creativity to solve complex problems (Eshaq, 2024).

Furthermore, games have a great impact on developing mathematical proficiency and improving inclinations toward mathematics (Russo, Kalogeropoulos, Bragg, & Heyeres, 2024).

The results of the studies focusing on lexical-semantic abilities of children with developmental dysgraphia are the starting point for our paper. Namely, the students attending the third, fourth, and fifth grades were tested with *the semantic test* (Vladisavljević, 1983) and *the fluency test* (Vasić, 1988). The results show that insufficiently developed lexico-semantic abilities must be recognized in time and that through appropriate exercises, we can prevent further progress of language disorders and their unfavorable outcomes on children's ability to read and write (Ćalasan, Vuković, & Arsić, 2021: 121).

The activities presented in this paper aim to facilitate the proper development of lexico-semantic abilities in third- and fourth-graders that would concurrently enhance the development of scientific literacy.

From STEM to STEMS

STEM concept is commonly defined as an approach to learning in which science, technology, engineering, and math are co-integrated and applied to real-world problems that connect school and community, promote student achievement, and prepare them for global competitiveness (Dell'Erba, 2019: 2). Many hybridized forms of the STEM approach have been described in the current literature, such as STEAM (i.e., science, technology, engineering, arts, and mathematics) (Herro & Quigley, 2017), STREAM (i.e., science, technology, reading, engineering, arts, and mathematics) (Qu et al., 2021), and iSTEM (i.e., integrated STEM) (Struyf et al., 2019), among others (Canlas, 2023).

In this paper, we propose a novel model of the STEM approach: the STEMS approach where the last letter *S* stands for *speech*. It represents an improvement of the existing approach since it co-integrates speech, science, and mathematics via Web 2.0 technologies. The STEMS approach, as a unique integration of science, technology, engineering, mathematics, and speech, aims:

- to promote reading targeted at understanding the texts of different types that are used in Mathematics and Nature and Society;
- to enable students to connect the grammatical concepts taught in The Serbian Language course with the content covered by Mathematics and Nature and Society;
- to promote the proper use of orthographic and grammatical rules in open-ended questions used in Mathematics and Nature and Society; and
- to enhance the understanding of the vocabulary used in textual tasks in both Mathematics and Nature and Society.

How to Apply the STEMS in Teaching?

This paper presents the model activities for the integrated lessons of The Serbian Language, Mathematics, and Science, which include language games that can be used in a classroom setting to improve the lexical-semantic abilities of fourth-grade students.

The games presented here integrate the content taught in The Serbian Language with other subjects. They concurrently promote learning through entertainment, collaboration among students (can be played in pairs or groups), and different learning styles. In other words, they promote learning through different forms of work and integrate knowledge, while respecting age and prior knowledge of students.

The first lesson model refers to the unit entitled *Botanical World of Serbia* taught within the subject of Nature and Society. The main goal is for students to acquire knowledge about the botanical world of their country through the integration of grammatical concepts (The Serbian Language) and science terms with digital language games. The games are available to be used in a classroom setting and can be used to improve the lexico-semantic abilities of fourth-graders. Language skills are crucial in other contexts where science teaching takes place. During any research activity, such as a trial and an experiment, in addition to data collection techniques (such as observation, measurement, and experiments), students are required to seek, explain, conclude, and present research results to others. The lesson model is presented below.

Step 1. At the beginning of the lesson, students are asked to solve the Plants crossword using the frontal form in order to increase their motivation and spark their interest.

Figure 1. Interactive game: Plants Crossword.

Step 2. The central part of the lesson is reserved for processing the new content by using the multimedia through various forms of work organization. Students are divided into groups, and each group is provided with a tablet or a phone that they are supposed to use to play the game. Handouts with the content and tasks should be distributed. The matching game is launched by scanning a QR code. Students are expected to match the words with their definitions. This material is used to revisit the third-grade content and gain new knowledge about natural habitats and living communities.

Figure 2. Interactive game: Matching Words and Defining Terms.

Step 3. The handout contains the names of deciduous and coniferous plants. After reading the information from the handout, students play the game in groups. They are expected to match botanical terms of the flora found in their country with the appropriate word category. As evident, this game combines grammar and biology.

Figure 3. Interactive game: Matching Plant Life and Word Types.

Step 4. The world-known game Hangman is used here to discover the names of the plants inhabiting Serbia. Students are expected to solve the task in groups based on the hints provided as brief descriptions. These hints also rely on the rhyming, antonymous, and homophonic words to support students in their quest for the correct answer.

Figure 4. Interactive game: Discover the Names of the Plant Life in Serbia (Hangman).

Step 5. Consolidating the new knowledge through question-answer interaction.

Step 6. A short animation presents a drawn 2D character and a task expecting students to discover the meaning of the word *treasure* when used literally and as a lexical metaphor in *A forest is our green treasure*.

Figure 5. A short animation: Understanding the Lexical Metaphor "Forests are our green treasure."

Step 7. Homework: Students are assigned a homework assignment to write a poem on plants. They are expected to describe their favorite specimen of the Serbian flora. They are allowed to use the rhymes they hear or invented during the class.

Through the integrated activities, students can learn about the flora and fauna in Serbia. The multimedia content can contributes by expanding the knowledge on Serbia's national parks and the importance of preserving the rare and endangered animal and plant species.

The second lesson model refers to the mathematics unit for fourth graders, which focuses on geometry. Language games created with Web 2.0 technologies can facilitate the process of overcoming the common obstacle of memorizing and differentiating fundamental mathematical concepts with similar names. An example of a class consolidating the knowledge about a square, a cube, a net of a cube, the area of a square, and a rectangle is presented below.

Step 1. At the beginning of the lesson, students solve anagrams, as a warm-up activity in which they create the names of geometric concepts by moving the given letters.

Figure 6. Interactive game: Anagrams with the Names of Geometric Concepts.

Step 2. During the central part of the class, students' geometry knowledge is consolidated by using technology. Students work in pairs, and each pair is supplied with a worksheet containing a printed task and a tablet that they are expected to use. Using the GeoGebra application, students can view a graphic representation of the problem given in the task. The graphic display serves to facilitate the visualization of the problem and the relationship between the quantities given in the task, and, finally, to simplify the process of solving the problem (Milikić, Maričić, & Vulović, 2022).

Step 3. Between solving more demanding problems, students are given a brief break when they are expected to play the game *Faces of Geometric Bodies*. In this game, they are required to connect the graphic representation of a geometric solid and the corresponding name of its face.

Figure 7. Interactive game: Faces of Geometric Solids.

Step 4. The language game *Who Wants to Learn Geometry?* is inspired by a world-known TV show *Who Wants to Become a Millionaire?*. Students use this game to test their knowledge of geometric concepts.

Figure 9. Interactive game: Who wants to learn geometry?

Step 5. Students' homework assignment is to write a story about geometric figures and solids. The story can describe what will happen if a square and a cube collide (e.g. the cube will break into six squares). What would a rectangle say to a cube? Students are encouraged to invent humorous dialogues between the characters. If artistically inclined, students may be inspired to make a comic.

The digital games proposed here are subject to modifications and can be adapted to different units and topics. They can also be altered to match the capabilities and interests of our students.

The approach proposed here is an advanced derivate of the STEM approach in that it co-integrates speech development, science, and mathematics by using the available Web 2.0 technologies. We strongly believe that the utilization of these STEM-based models can improve reading comprehension skills with diverse texts present in the handbooks used to teach Mathematics and Nature and Society. The activities presented here can provide an opportunity for acquiring grammatical terminology concurrently with the concepts taught in Mathematics and Society. In addition, the activities can be used to promote core literacy. Namely, students must be required to comply with the orthographic and grammatical norms of their mother tongue while formulating their answers to open-ended questions checking their knowledge of Mathematics and Nature and Society. Finally, by raising their awareness of the figurative, i.e. metaphorical, use of language in the texts and textual tasks found in

Mathematics and Nature and Science handbooks, we can improve the reading comprehension skills of our students.

CONCLUSION

The main novelty of the approach proposed in this paper is two-fold. First, the lesson models presented here aim to teach science by integrating the topics relevant to The Serbian Language with the content relevant to natural sciences. Second, by integrating the material from two subjects (mother tongue and mathematics), teachers can support the advancements in language competencies and skills that are, inter alia, vital for solving open-ended science questions and comprehending the textual tasks in mathematics. Moreover, the reading comprehension of non-literary texts enhances students' abilities to formulate explanations and understand professional texts and instructions. All these skills are essential for further academic success and are indispensable for any occupation.

The teachers' roles in the STEMS approach are very important, as with STEM and any other derivate of the concept. One of the definitions of the STEM concept points out "the extent of the ability teachers have to take charge of STEM education" (Sulaeman et al., 2022: 70). The examples of the preparations proposed in this paper can help teachers develop their competencies and empower them to implement STEM-based activities so that they can improve students' lexical-semantic abilities and literacy and expand their knowledge in mathematics and natural sciences.

We advocate for an experimental program based on the proposed lesson models. It will be conducted with the students attending the fourth grade of primary school. The subsequent experimental research would provide more insight into the effectiveness of this approach. The emphasis should be placed on preparing the teachers for the implementation of STEM activities in primary schools since this is a prerequisite for the successful realization of the experiment. The students will be tested twice in both fields. Namely, two tests would be used to evaluate students' lexical-semantic abilities and two tests would be used to test the knowledge in science and mathematics.

The proposed research is significant because it may offer a model for connecting the contents and concepts of the subjects: The Serbian language, mathematics, and science. It is expected to enhance the development of scientific literacy. It is also believed to improve lexical-semantic abilities through language games created with Web 2.0 technology and consequently, to improve language production, i.e. the ability to express one's thoughts clearly and precisely, and reading comprehension skills. Without a doubt, these skills are essential for flourishing in any academic and workplace setting.

The research can be extended to teaching mathematics and natural sciences in the older grades of primary school and to the analysis of spelling and grammatical errors made by students during mathematics and science classes.

The STEMS approach can improve teaching practice and students' verbal competencies and scientific literacy at younger school age. Hence, this should result in better academic achievements and should positively influence their ability for lifelong learning. The proposed research should improve education in the field of natural sciences, specifically science and mathematics, in the younger grades of primary school, which is an important strategic goal of every country that strives for competitiveness in the international context (Stanišić, Blagdanić, & Marušić Jablanović, 2021). Through integrated games, students' achievements in the field of natural sciences can be improved, bearing in mind the importance of the position of language as the most basic semiotic and symbolic cultural support, crucial for understanding and building thoughts (Antić & Pešikan, 2015: 106). The proposed integration model can be applied to the mother tongue, mathematics, and natural sciences both in Serbia and in foreign countries. The offered lesson suggestions, but also a research proposal, are significant for society in a wider context because they can contribute to the development of literacy and understanding in a broader sense, which is one of the key competencies for lifelong learning. Comprehension of non-literary texts, ability to formulate explanations, and comprehension of professional texts and instructions are important for a large number of occupations.

Based on everything we stated in the paper, we believe that the STEMS concept, which integrates science, technology, engineering, mathematics, and speech, can promote the reading comprehension of different text types present in Mathematics and Nature and Society, the establishment of connections between concepts taught in The Serbian Language and those present in Mathematics and Nature and Society, the proper usage of spelling and grammar rules in open-ended tasks in Mathematics and Nature and Society, and the understanding of the vocabulary used in textual tasks in Mathematics and Nature and Society.

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MEASUREMENTS AND ADVENTURES AT THE INTERFACE OF MATHEMATICS AND ENVIRONMENTAL EDUCATION[1]

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Abstract: STEAM subjects are becoming increasingly important in 21st-century education as they provide opportunities to develop problem-solving skills. Through experiential learning, students can learn science through play. Learning by doing at an early school age also makes math and science lessons fun. The current Hungarian National Curriculum (2020) strongly emphasizes the development of key competencies, but science competencies are not part of the current curriculum. Thus, teaching environmental studies in grades 1–2 has been discontinued, and students' scientific competence in grades 3–4 must be developed in other subjects. Mathematics and environmental education are linked in several areas, one of which is measurement, including the concepts of perimeter and area. In teaching the concept of perimeter, we aim to give children numerous ways of experiencing that perimeter is the length of a line that bounds a shape in the plane. When developing the concept of area, the first step in defining the area of a rectangle is always to start from the actual coverage, and then the measurement of the area of the rectangle can be the basis for further area definitions. These concepts should be explored not only on the plane but also on a finite spherical surface (e.g. a Lénárt sphere) through playful activities that help students navigate and measure the globe.

Keywords: STEAM-based problem-solving, measurement, mathematics, environmental education

INTRODUCTION

21st-century skills are essential in all areas of life, whether at work or in our personal lives. That is why it is so important for students to leave school with

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the right competencies. The development of competencies is not only a task for secondary school, as many people believe, since most of them are already present in primary school.

The key competencies are also included in the Hungarian National Curriculum, in line with the European Union's requirements. However, the key competencies of science are missing from the new basic curriculum, and as a result, the number of lessons in subjects that support the foundation and development of scientific thinking has been reduced. In this study, we will address the situation of the subject of environmental studies at the primary level, which has been discontinued in grades 1 and 2. This change has led to the integration of environmental content into other subjects, including mathematics. The only positive aspect of this situation is that it allows STEAM-based problem-solving with environmental content in mathematics lessons.

In this study we have collected good practices from Hungary that can help practicing teachers in teaching measurement, focusing on the environmental content and the importance of learning and understanding mathematics.

LITERATURE REVIEW

Competencies for the 21st Century

The terms transversal competencies, soft skills, and key competencies are often used instead of 21st-century competencies. Not only do we read about different terms in different literature or documents of international organizations, but also different definitions. Accordingly, there are different frameworks, which largely overlap, but with some minor differences. In the grouping of competencies and areas of competence into structural categories, such as cognitive, interpersonal, intrapersonal, and global citizenship, differences can be observed depending on the mission of the organizations developing each framework and their objectives in using the framework.

According to M. Binkley et al. (2012):

> Twenty-first-century skills are abilities and attributes that can be taught or learned in order to enhance ways of thinking, learning, working and living in the world. The skills include creativity and innovation, critical thinking / problem-solving / decision-making, learning to learn / metacognition, communication, collaboration (teamwork), information literacy, ICT literacy, citizenship (local and global), life and career skills, and personal and social responsibility (including cultural awareness and competence).

Based on Suto and Eccles (2014), the "inter-disciplinary skills most commonly regarded as essential for the 21st Century are problem-solving, ICT operations and concepts, communication, collaboration, and information literacy."

As stated by the OECD when it established the PISA framework, the "competency is more than just knowledge and skills. It involves the ability to meet complex demands, by drawing on and mobilizing psychosocial resources (including skills and attitudes) in a particular context" (OECD, 2005).

According to UNESCO (2016), transversal competencies can be grouped into six areas of competence: interpersonal skills, intrapersonal skills, media and information literacy, critical and innovative thinking, global citizenship, and other skills (*Figure 1*). Each area has several competencies.

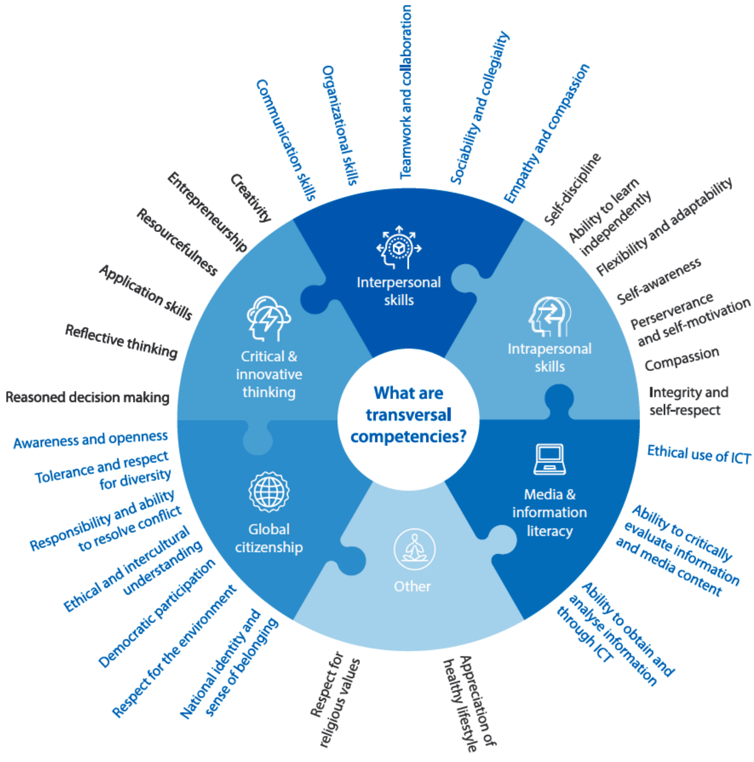

Figure 1: Transversal competences (UNESCO, 2016)

As defined by the European Commission (2019) "key competencies are a combination of knowledge, skills, and attitudes. The key competencies are developed throughout life, through formal, non-formal and informal learning in different environments, including family, school, workplace, neighborhood, and other communities."

Whichever framework we look at, they all have one thing in common: they all seek to respond to the challenges of the future of the world. Taking into account the current problems – including the incredibly rapid technological development, which is becoming even more important with the use of artificial intelligence, the effects and challenges of globalization, demographic changes, environmental sustainability, the uncertain political situation – the aim is to develop competencies that can be acquired to mitigate and solve them.

Problem-solving is the ability to identify a problem, determine its cause, and come up with all possible solutions to solve it. Problem-solving, along with other transversal competences, should be acquired at a young age (Bağçeci & Kinay, 2013). In preparing students for the future, relevant and innovative problems that are challenging, yet solvable and manageable, should be built into the learning process, thus fostering the development of problem-solving skills (McKenna, 2014). Developing problem-solving skills is, by its very nature, a core task of STEAM subjects, of which mathematics is considered the foundation of other sciences yet is often overlooked in STEAM activities (Maass et al., 2019; Mayes, 2019; Roberts et al, 2022). However, this may have negative consequences if students do not see meaningful connections between learning mathematics and other STEAM subjects, as they may then lose interest not only in mathematics but also in other subjects (Kelley & Knowles, 2016). In the real world, STEAM-based problems are increasingly covering broader areas than just disciplinary content and practice, meaning that non-STEAM dimensions of the problems need to be addressed and prepared for.

Key Competencies and the Hungarian National Curriculum (NAT)

The European Parliament and Council Recommendation on Key Competencies for Lifelong Learning was adopted in 2006. As a result of this document, the key competencies – combinations of knowledge, skills and attitudes – were introduced in the National Curriculum of Hungary in 2007, and special emphasis was placed on competence-based teaching and learning. The development of key competencies has been an ongoing process in public education since then, as confirmed by the subsequent National Curricula (*Table 1*).

In *Table 1*, it can be observed that the 2020 National Curriculum lacks scientific and technical competencies, which are the knowledge and skills that describe processes in the environment and predict their expected outcomes. This poses a problem for the teaching of science subjects, as the change has resulted in a reduction in the number of hours taught in these subjects.

Table 1: Key competencies (NAT 2007; NAT 2012; NAT 2020)

NAT 2007	NAT 2012	NAT 2020
Native language communication	Native language communication	Communication competencies (native and foreign language)
Foreign language communication	Foreign language communication	
Mathematical competences	Mathematical competences	Mathematical, thinking competencies
Nature scientific competence	Nature, scientific and technical competence	-
Digital competence	Digital competence	Digital competences
Social and civic competence	Social and civic competence	Personal and interpersonal relationship competencies
Initiative and entrepreneurial competence	Initiative and entrepreneurial competence	Employability, innovation, and entrepreneurship competences
Aesthetic-artistic awareness and expression	Aesthetic-artistic awareness and expression	Competences for creativity, creative work, self-expression and cultural awareness
Effective, independent learning	Effective, independent learning	Competences of learning

In Hungarian primary schools, environmental studies is one of the natural science subjects in the lower grades, which builds on students' curiosity to learn about phenomena and processes in the wider environment. Environmental studies provide the basis for a scientific way of thinking. The already low number of lessons in the subject has been further reduced following the introduction of the National Curriculum 2020, so there are no environmental lessons in grades 1 and 2 (*Table 2*), and the previous environmental content is only integrated into other subjects such as Hungarian language and literature, mathematics, ethics/faith and morals, technology and design, visual culture (Nat, 2020). The positive side of this change is that STEAM activities can integrate mathematics into the environmental content by working on real problems that are age-appropriate for children.

Table 2: Proposed number of lessons for mathematics and environmental studies based on NAT 2012 and NAT 2020

	Grade 1	Grade 2	Grade 3	Grade 4
Mathematics NAT 2012	4	4	4	4
Mathematics NAT 2020	4	4	4	4
Environmental Education NAT 2012	1	1	1	1
Environmental Education NAT 2020			1	1

In the 2020 National Curriculum for Mathematics for grades 1–2, several topics combine mathematical and environmental content:

- Sorts, creating and investigating sets,
- System design, system building,
- Assertions,
- *Use of measuring instruments, methods of measurement,*
- Spatial and Plane Orientation,
- Recognising relationships, connections, regularities, and
- Observing data.

Based on the development tasks and the knowledge listed, the topic Use of measuring instruments and methods of measurement is one of the most suitable topics to teach students about measurement, the use of measuring instruments and measurement methods and to implement STEAM-based problem-solving.

Teaching Measurement in Primary School

Measurement also plays a variety of roles within mathematics in lower school work. In other subjects (e.g. environmental studies, technology, drawing), measurement is used primarily as a method and tool for learning. In mathematics, it is not only used as a tool but also to build two important concepts. Measurement is the empirical basis of the number concept, and operations are also linked to this number concept. The development of quantity concepts also relies on practical measurements. It is not enough to name a quantity; the content of the concept is closely linked to the measuring instrument and the measurement procedure. It is also part of the work at the primary level to develop elementary skills in practical measurement and to develop an awareness of standard units.

We follow the usual steps in the development of geometric concepts of quantity (e.g. length, perimeter, area):

1. sensory experience of quantity, comparisons by size through direct experience: grasping and expressing the difference;
2. measuring quantities together; learning the tools and procedures to be used for this purpose; thus, detecting small differences, grasping and expressing equality; deciding how much larger or smaller is a question of how much larger or smaller; and
3. measuring by units; (measuring by multiples of a unit); increasing the accuracy of measurement by measuring by fractions of a unit, (lower and upper approximation). (C. Neményi, 2007)

Working out the concept of length means, first of all, experiencing and then linking the different quantities of length: height, length, width, thickness, depth, and circumference (including perimeter) separately in school activities. By school age, children have already had sensory experiences of each of these contents and have also had the opportunity to experience direct or indirect measurement.

We emphasize that the perimeter is not an independent quantity, but a length: the length of the line bounding the plane shapes. This length can be measured just like any other length dimension. At most, it is sometimes more convenient to measure the sides separately and add the resulting measurements; at other times, if there are equal sides, the addition can be further simplified by substituting multiplication. We do not learn a "formula" for "calculating" the circumference of a rectangle or square, for example, not only because it would not be the correct way of learning at the right age. Nor is it because it would obscure the point: the concept of perimeter (C. Neményi, 2007).

The concept of area is more difficult than that of length. Young children can have a wide range of sensory experiences of what it means to walk a very long way, to climb a high couch, to jump down a high staircase, or to hug a thick tree. But they have less experience of the volume of the area. As with length, it's useful to gain experience of the area through some kind of movement. *Do not tie the concept of area to a shape!* In real measurements, it is important to make children aware that the unit of measurement does not depend on the shape of the unit, but only on its size, and that they should therefore measure units of the same size but different shapes. When determining the area of a rectangle, start by working out the simplifying procedure, always starting from the actual puzzle first. Measuring the area of a rectangle can be the basis for further area definitions (C. Neményi, 2007).

It is also worth introducing the Lénárt sphere to children. Research has shown (Gambini, 2021) that if children are introduced to plane geometry and spherical geometry at the same time, it becomes natural for them to accept and compare the concepts of plane geometry and spherical geometry. Spherical geometry is a mathematical and pedagogical counterpart to plane geometry. In fact, it surpasses plane geometry in one very important respect: it is not based on infinite but on finite surfaces. Moreover, the understanding of the concepts involved is greatly facilitated by the fact that pupils can experiment on a real sphere (an orange, a paper ball or a Lénárt sphere). At the same time, the comparison of the plane and the sphere also encourages pupils to ask questions of each other and their teachers, to explore and experiment independently, and to compare their ideas with those of others. Another advantage of spherical geometry is that many of its basic concepts are also covered in another subject, geography. Learning spherical geometry can contribute to an easier orientation on the globe and a better understanding of basic geographic concepts (Lénárt, 2009).

GOOD PRACTICES FROM HUNGARIAN EDUCATION

Game to Experience the Concept of Length

The online logic puzzle game Shingoki (Semaphores) is also a great way to experience the concept of length, gain sensory experience, and use direct comparison. The rules are very simple. You have to draw lines between the dots to form a single loop without crossings or branches. The loop should pass through all black and white circles in such a way that:

- White circles must be passed through in a straight line;
- Black circles must be turned upon; and
- The numbers in the circles show the sum of the lengths of the 2 straight lines going out of that circle.

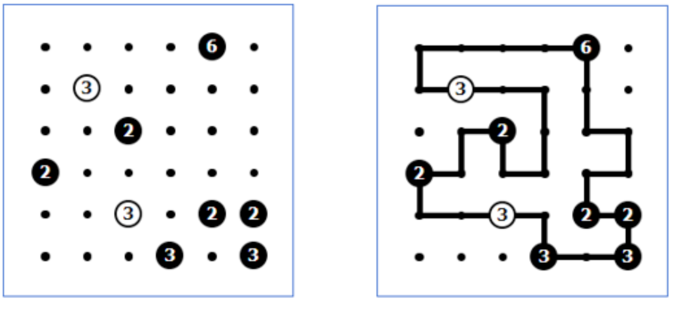

Figure 2: A Shingoki puzzle and its solution (Source:https://www.puzzle-shingoki.com/)

Games to experience the concept of area

The online logic game Shikaku (also known as Rectangles) is a great way to determine the area of a rectangle, to try out the actual puzzle, and to experience it. The rules are simple. You have to divide the grid into rectangular and square pieces such that each piece contains exactly one number, and that number represents the area of the rectangle.

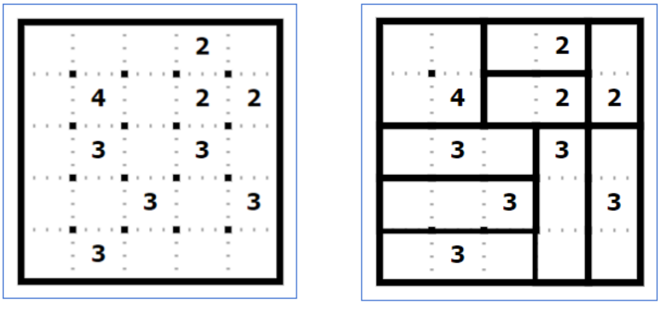

Figure 3: A Shikaku puzzle and its solution (Source: https://www.puzzle-shikaku.com/)

For trying out different polygon puzzles and covering a given area, the Geogebra-based online game Playing with Pentominoes (*Figure 4*) is a great way to do it. In the game, two players have to place 12 pentominoes on an 8 by 8 grid on the game board. The players can place one element at a time, and the elements can be rotated and mirrored, but the elements must not hang off the track and must not overlap. The game continues until the track is full or the set of elements is exhausted. The last person to place a pentomino on the playing field wins.

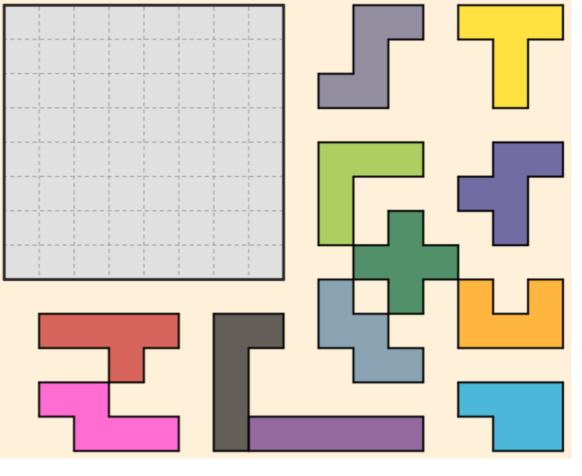

Figure 4: Playing with Pentominoes (Source: https://tananyag.mdoe.hu/mod/book/view.php?id=37&chapterid=594)

The GeoGebra-based Mosaic Puzzle game, of which there are several versions, helps to build the concept of area. There is one in which you can cover the plane with diamonds only, one in which you can cover the plane with two types of plane (diamond and regular triangle), one in which there is a "blank" area to cover, and one in which pre-drawn lines help you to cover the area. In the case of the exercise in *Figure 5*, the area of an empty hexagon is to be covered by congruent triangles and congruent quadrilaterals (diamonds). In the game, the plane objects can be dragged into position and rotated to the correct position. The hexagon can be covered by the 6 blue diamonds and 12 orange triangles given.

The students will experience the gap-free and overlap-free covering of a plane. Since the area of a diamond is equal to the area of two triangles, they can also think about how many pieces of the same shape would be needed if only diamonds or only triangles were used for the puzzle. They can also make the important deduction that triangles with half the area would need twice as much to complete a hexagon as diamonds. This proportional reasoning will be of great help to children later on when learning to convert units of measurement.

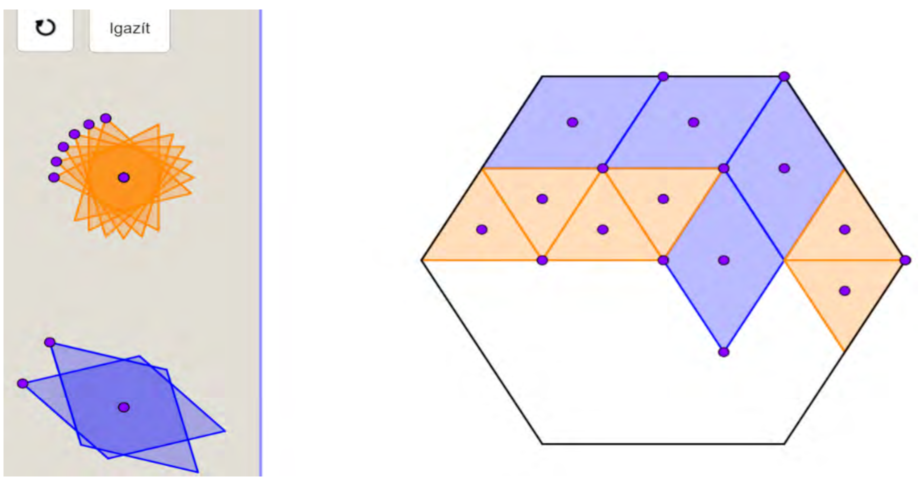

Figure 5: Mosaic puzzle (source: https://tananyag.mdoe.hu/mod/book/view.php?id=39&chapterid=562)

Playful Activities on the Sphere

To illustrate the sphere for primary school children, choose orange because it fits easily in a child's hand and can be drawn on with a marker pen. To experience the concept of length on the sphere, the children should first be asked to place a dot on the orange, this dot is called the North Pole. Tell the children that there is a penguin who wants to be the furthest away from the North Pole. Ask the children to place on the orange where the penguin might be located. Let's call this point the South Pole! Next, let's tell the children about another character, a turtle who hates the cold and wants to be as far away as possible from both the North and South Poles. Ask the children to draw on the orange where this turtle might be located (*Figure 6*). After completing this task, it is also worth discussing with children how many places they can draw the turtle on the orange.

Figure 6: Where does the turtle live?

Then ask the children to take the oranges in their hands and try to measure around them (*Figure 7*). After measuring, it is worthwhile to experience and discuss with the children that the distance on the sphere (orange) cannot be greater than the distance they measured on it.

Figure 7: Measurement of orange

The activities presented are an excellent way for children to experience the very important difference between the plane and the sphere, namely that the sphere, and therefore spherical geometry, is not infinite, unlike the plane, but is based on a finite surface.

RESULTS

In our research, we wanted to demonstrate that children's skills and knowledge levels can be improved using different geometric play activities and the good practices described above. Experience has also shown that when teaching geometry, it is worth starting with games about bodies and real objects, and by the principle of perceptual variety, it is worth showing children as many different shapes as possible of the geometric structure to be taught (C. Neményi, 2007). Through games, children can experience the connections within a given system and later, based on experience, they can also visualize the clarification of this structure (Dienes, 1999). Games and playful activities lead to the experience of geometric properties and geometric relations and relationships, as well as to the learning of geometric shapes. On this basis, we used different geometric games and activities during 6 lessons (Kéner, 2023). The class that participated in the research was a lower 3rd-grade class at a practical school in Budapest. The participating students are not representative of the population, so the results are not generalizable, but they do provide an opportunity to make observations that can be verified by increasing the sample size.

To test the effectiveness of the teaching-development process, a test was set up. The eDia online diagnostic assessment system developed by the Educational Theory Research Group of the University of Szeged was chosen as the test platform (Molnár & Csapó, 2019; Molnár, et al., 2021). Students were able to access the series of tasks for the test on any device (desktop, laptop, tablet, or smartphone). For the tasks for grades 1 – 3, the instructions are not only readable but also listenable, so students' reading performance does not affect their math performance. For the substantive part of the test, 8 tasks were selected, containing a total of 31 items. 19 plane geometry items and 12 solid geometry items were included in the test.

We administered this test to 25 third-grade students in a school in Budapest, Hungary, to see if the test could be used to measure children's plane geometry and spatial geometry skills. The reliability of the test was good (Cronbach's $\alpha=0.85$), so we used this test as a first step in the implementation of our development program. Thus, students in the class from which the children participated in the program took a pre-test as a first step. The purpose of the pre-test was not only to assess the children's current level of skills and knowledge but also to select the students in the control group and the experimental group.

Based on the pre-test, pairs of students were formed in the research class, i.e. students with the same or nearly the same score were paired, one in the experimental group and one in the control group. Occasionally, two children were assigned to the control group in addition to one child, so that there would be enough comparable performance in case of dropouts or absenteeism. At the end of development, all the children took the post-test, but only the data of the originally selected children were included in the analysis. Thus, 7 young children from the experimental group and 9 young children from the control group.

To measure the changes in the performance of the children in the study, we included two spatial geometry and three plane geometry tasks from the pre-test in the post-test. These included both easier and harder items. The other tasks, whose results did not allow us to detect a possible developmental effect, were replaced by more challenging tasks. Which items were harder, and which were easier in the pre-test was determined based on the children's performance on each task by averaging the scores on each item. Thus, the post-test consisted of 9 tasks, with a total of 32 items. 15 items were around plane geometry, while 17 items were around solid geometry.

To examine progress, only the twenty items included in both tests were analyzed. There was no measurable difference between the performance of the two groups on the pre-test, so it can be said that the children were in the same place in terms of their knowledge and ability levels in both groups. However, the results of the post-test show that the experimental group performed significantly better than the control group because of the development (*Table 3*).

Although the performance in the post-test was also examined for the full test (*Table 3*), this result is not comparable with other results, as it does not only include the same items as in the pre-test. However, this test also included more challenging items than the pre-test. When comparing the results of the two groups on the full post-test, it can be seen that the experimental group maintains a significantly better performance than the control group on the full test. The results show that the experimental group achieved significantly better results than the control group because of the program we designed and implemented.

Table 3: Comparison of the performance of the experimental and control groups on each test

Test	Group	Headcount (N)	Average (percent.+point)	Scatter	Significance level (p)
Pre-test	Experimental	7	77.00	5.78	0.201
	Control	9	79.40	5.05	
Items common to the pre-test and post-test	Experimental	7	70,71	9.32	0.216
	Control	9	74.44	8.82	
Items common to the post-test and pre-test	Experimental	7	87.14	9.51	0.008*
	Control	9	73.89	9.61	
Post-test	Experimental	7	82.49	9.83	0.028*
	Control	9	71.33	11.57	

$p<0.05$

If we look at the results not by comparing the two groups, but by comparing the pre-test and post-test scores of both the experimental and control groups, we see that the control group did not improve relative to itself, while the experimental group performed significantly better relative to itself on the post-test than on the pre-test (*Table 4*).

Table 4: Change in each group's performance relative to itself between the two surveys

Group	Test	Headcount (N)	Average (percentage point)	Scatter	Significance level (p)
Experimental group	Items common to the pre-test and post-test	7	70.71	9.32	<0.001*
	Items common to the post-test and pre-test	7	87.14	9.51	
Control group	Items common to the pre-test and post-test	9	74.44	8.82	0.455
	Items common to the post-test and pre-test	9	73.88	9.61	

$p<0.05$

The results of the study show that the 3rd-grade students who were involved in activities involving geometric play and good practice during the study period improved their knowledge and skills. Considering the results obtained, we intend to present further good practices in geometry to practicing teachers in the framework of professional days, and to put more emphasis on playful activities and their practical usefulness for our teaching students by restructuring the geometry pedagogy course structure in our department.

CONCLUSION

The development of 21st-century competencies is now an important task for teachers, even in primary schools. These competencies are not subject-specific and are becoming indispensable for students in all walks of life. This paper focuses on problem-solving competencies and how they can be developed.

The Hungarian National Curriculum, which will be in force from 2020, will no longer provide the opportunity to teach the former environmental studies subject in the 1st and 2nd grades of primary school due to the reduction in the number of lessons. Therefore, environmental content will have to be taught to pupils in mathematics lessons, among others. The positive side of this situation is that by using STEAM-based problem-solving in teaching lower secondary school pupils, environmental and mathematical content can be presented together, thus increasing the importance of mathematics – a necessary subject, as it is the basis of all science subjects – in the eyes of the pupils. In this study, we have focused on measurement, which is an integral part of both subjects. To develop problem-solving competencies and take into account the situation in Hungary regarding the teaching of environmental content, in this study we have presented Euclidean and non-Euclidean geometric good practices that can help to teach the topic of measurement.

In our research, using STEAM-based problem solving, we found that the use of geometric play activities has a developmental impact on students' knowledge and skills. Using the results obtained, we would like to incorporate more hands-on activities in the geometry teaching course of our department, hoping that the colorful methodological repertoire of future lower secondary teachers will help the development of their students.

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VI

PROFESSIONAL DEVELOPMENT AND COMPETENCIES OF EDUCATORS FOR THE STEM/STEAM/STREAM APPROACH

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PROFESSIONAL DEVELOPMENT OF PRESCHOOL TEACHERS IN THE FUNCTION OF IMPLEMENTATION OF STEAM APPROACH[1]

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Abstract: The professional development of preschool teachers and readiness for innovative action is challenging for educational policy-makers and teachers. The starting basis of the work is the analysis of normative acts, legal regulations, and guidelines that document the importance, expediency, and effectiveness of teachers' professional development. The paper discusses the relevant scientific sources, which shed light on the basics of the STEAM approach. The challenges and perspectives faced by preschool teachers when implementing the STEAM approach are determined through the analysis of research findings, as well as the importance of professional development for the improvement of knowledge, skills, and values necessary for the implementation of the STEAM approach. The literature analysis identifies the challenges that can be a dysfunctional factor in the STEAM implementation in educational practices and which primarily originate during the professional development of preschool teachers. By reviewing relevant sources, the specific implications of using the STEAM approach are determined.

Keywords: professional development, STEAM approach, preschool teacher, normative regulation

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INTRODUCTION

Through a critical review of the literature, as the goal of the paper, we highlight the analysis of the concept of the STEAM approach in preschool education by focusing on the benefits it provides and the challenges that arise, putting in mutual connection the peculiarity of the importance of the professional development of teachers for the effective implementation of the STEAM approach in direct work with children.

Due to the large, continuous transformations of educational goals, outcomes, and the need to form a new type of teacher with personal and professional competencies for lifelong learning, the Ministry of Education, as the initiator of reforms in education, approaches the process of teachers' professional development with great care. Within legal regulations, the Ministry of Education has regulated this area through laws and regulations. From the perspective of the best interest of a child and the improvement of the educational process, as well as the affirmation of work efficiency, it is vital to provide comprehensive support to teachers. A competent teacher is a part of the paradigm that has been set. To ensure the thorough and complete professional development of teachers, it is necessary to satisfy their professional needs.

Early childhood, as the period of the most turbulent development and the period of creating the foundation for the further development of the individual, requires the creation of a stimulating environment within which the child will develop his full potential through experiential situations. As a response to the presence of ongoing global changes, and in an effort to create professionals who will be able to actively and effectively operate in the field of the labor market using the acquired knowledge, the trend of STEAM education is gaining popularity in many countries. The teachers' need for professional development in the function of realizing STEAM activities has been proven by a significant amount of research (Jamil, et al. 2017).

NORMATIVE REGULATION OF THE PROFESSIONAL DEVELOPMENT OF PRESCHOOL TEACHERS

Professional development of teachers is a right, but also an obligation of teachers. The changes that are taking place in all areas of society have not bypassed preschool education. Due to the need to harmonize with the demands of society, that is, the needs of children, it is necessary that both the normative regulation and its application follow the demands of children, that is, contribute to the achievement of high-quality preschool education and enable and oblige teachers to work on their professional development. The competences of teachers as an important segment of achieving the quality of services in early childhood are acquired both during basic education and through training and lifelong learning. These three segments of teacher competence acquisition are interrelated. Normative acts, study programs, and continuing professional development programs are aligned with the needs of children, that is, the need to provide quality services for children of preschool age.

In the Republic of Serbia, regarding the required qualifications of employees in preschool institutions, there is a model where the qualifications of employees differ and where children aged six months to three years work with nurses who have completed a four-year school, while children aged two years work with teachers who have completed primary or master's vocational studies or academic studies, as well as teachers with higher education who completed their studies according to the previously valid plan and program for teacher education (Law on Preschool Education, 2010, Article 39). In Europe, there are two models regarding the qualifications of employees in preschool institutions. In the first model, which also exists in our country, the qualifications of employees who are in charge of the youngest children and teachers who work with children older than 3 years are different. This model is also represented in Belgium, France, Italy, Luxembourg, Portugal, the Netherlands, Greece, and Ireland. In the second model, there is a unified system regarding the requirements for the necessary qualifications (Denmark, Finland, Sweden, New Zealand, Spain, England, and Scotland). In England and Scotland there used to be a distinction in terms of the required qualifications, but the system has now been equalized. According to the official position of the European Union, it is considered unjustified that employees with lower qualifications, that is completed four-year high school, work with children at a younger age (up to 3 years) (Urban, et al., 2011).

According to the Law on Preschool Education and Training (2010, Article 38), it is the teacher's task "to ensure respect for the principles and the realization of the goals of preschool education with his competencies." It is the obligation and right of teachers to continuously review and develop competencies through various types of professional development (Regulation on Continuous Professional Development and Advancement in the Professions of Teachers, Preschool Teachers, and Professional Associates, 2017, Article 2). It is for this reason that we are aware of the fact that the knowledge acquired in basic studies is not enough to respond to the demands and changes that happen daily and quickly. The professional development of teachers begins with the introduction of trainees into the work of teachers, in order to acquire knowledge and develop skills for independent work. (Guide for the Introduction of Preschool Teachers to their Position in Preschool Institutions, 2010). After completing the internship and taking the license exam, the teacher's professional development continues through various trainings, as well as through "constant review and reflection on conceptual settings and personal beliefs and practices, by participating in the development of reflective practice in their kindergarten through cooperation with professional associates and teachers" (Fundamentals of Preschool Education Program, 2018, 34). The professional development of teachers as an essential prerequisite for achieving high-quality preschool education implies the acquisition and development of competencies necessary for: direct work with children, possession, and improvement of knowledge about cooperation and exchange of experiences with colleagues, work with family and improvement of professional practice (Regulation on Standards of Teachers' Competences and their Professional Development, 2018).

Activities aimed at training preschool teachers to deal with their professional development are also regulated by the Rulebook on Work Permits for Teachers, Preschool teachers, and Professional Associates, according to which the teacher, after being introduced to the work of a trainee teacher by the assigned mentor, takes an exam for a license to work as a teacher. The Rulebook regulates the knowledge, skills, and abilities of a teacher who has undergone the process of introduction to the work of a teacher and which refers to the possibility of working on his professional development. First of all, after passing the license exam, the teacher must: know the importance of continuous professional development; be familiar with different forms and methods of professional development; understand the ways and techniques of planning professional development; know the structure of professional bodies at the institution level; know the elements for planning one's own professional development; participate in various forms of professional development; follow the development of modern literature and educational technology (Regulations on the Permit for the Work of Teachers, Preschool Teachers, and Professional Associates, 9/22).

The adopted regulations regarding the professional development of preschool teachers will not achieve their purpose if they are not accompanied by concrete political measures in the form of providing teachers with the necessary conditions for work, both spatial and material, and the conditions related to the recognition of the need for sufficient time to analyze and document practice. "The quality of the workforce cannot be reduced to the sum of competencies. [...] In fact, the quality of the workforce is determined by the interaction between competent individuals in what we call a competence system" (Urban, et al., 2011: 27). Numerous countries perceive the implementation of the STEAM approach as the main attribute of future economic, political and educational development, although this approach still cannot offer all the answers to certain educational problems (Razi & Zhou, 2022). Every successful transformation of educational systems must have effective professional development of teachers as a basic resource (Trilling & Fadel, 2009).

THE STEAM APPROACH IN PRESCHOOL EDUCATION

The concepts that promote and encourage the processes of curiosity, creativity, collaboration, and critical thinking should be represented in early childhood because these processes are innate in children (Chesloff, 2013). It is shown that the above-mentioned skills, which are used to get out of the template frameworks of action, are of vital importance for the development of an individual's future career. International research concludes that it is necessary to create a pedagogical environment and new approaches to the educational process in which creativity, critical thinking, imagination, innovation, flexibility, and interaction will be encouraged (Harris & Bruin, 2017). In research, we also come across the sources that prove that an interdisciplinary approach to work that includes visual arts, mathematics, and literacy contributes to cognitive development and the development of meaningful thinking (Cunnington, et al., 2014).

The STEAM approach has its origins in the STEM approach that was launched in the 1990s in the United States of America. The addition of art to the STEM approach aimed at increasing children's motivation, sense of interest, and attraction to participate in STEAM activities, and increased socio-emotional development. The STEAM approach in its name is an acronym that includes science, technology, engineering, art, and mathematics (Dua, 2022). The importance of interdisciplinary and multidisciplinary cooperation is reflected in the fact that it represents a dynamic influence on the process of children's adaptation to the world around them (Yakman, 2008). In support of the implementation of the STEAM approach in educational work, there are opinions that the most important skills needed in the 21st century are critical thinking skills, problem-solving abilities, and creativity (Trilling & Fadel, 2009). Adding art to the STEM approach provides a key component that contributes to the development of creativity and innovation (Beaman & Sears, 2013).

The STEAM approach to learning represents an experiential form of learning and it contributes to the response of educational institutions to contemporary development trends and the need for the formation of an individual who will have the skills needed to effectively build his or her future, which are primarily the skills of creativity and innovation, collaboration, communication, critical thinking, and problem-solving (Dua, 2022).

Highly trained teachers, the teachers who are builders of their practices, are the key in the implementation of the STEAM approach. In the sources, we can find results that confirm that using this approach contributes to improving children's achievements (Brouillette & Graham, 2016). The goal of this approach is to create a transdisciplinary learning environment that allows children to connect their activities with the real world around them and acquire skills to demonstrate ways to solve real-world problems (Liao, 2016). With this particular approach to learning, preschool children become more self-confident, more active, and able to take initiative based on the knowledge and skills they acquire (Wahyuningsih, et al., 2020).

The positive contribution of STEAM activities to the development of creativity in early-age children was determined through the analysis and existence of flexible thinking, innovative thinking, thinking about details, and fluid thinking (Atikah & Biru, 2024).

Through their work, preschool teachers have the task of preparing children to face real-life situations and actively act in them. The STEAM concept contributes to these outcomes because skills such as observation, research, critical thinking, which are acquired within this approach, are transferable, and they can be used in different spheres of life (Spyropoulou, et al., 2020).

PROFESSIONAL DEVELOPMENT OF PRESCHOOL TEACHERS AND THE STEAM APPROACH TO PRESCHOOL EDUCATION

Professional development is a “continuous process that begins with the choice of profession, through basic education (faculty and higher school for teachers), introduction of teachers to work (traineeship), as well as constant development, professional development, and further education during work” (Stamatović, 2006: 475). In the Rulebook on Continuous Professional Development and Advancement in the Professions of Teachers, Preschool Teachers, and Professional Associates, professional development is defined as “a complex process that implies the constant development of the competencies of teachers, preschool teachers and professional associates in order to perform their work better and improve the development of children and students that is the level of their achievements” (The Rulebook on Continuous Professional Development and Advancement in the Professions of Teachers, Preschool Teachers, and Professional Associates). The same rulebook points out that an integral and mandatory part of professional development is vocational training, which implies the acquisition of new and improvement of existing competencies important for the improvement of education, professional work, and child care.

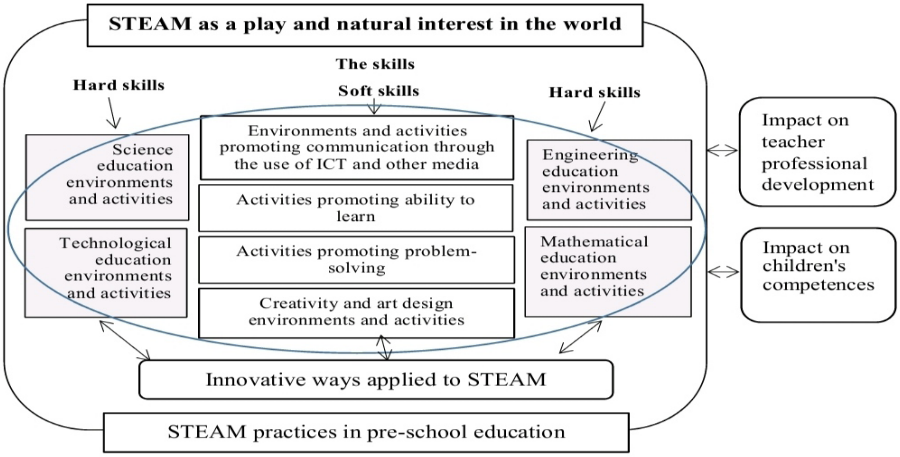
The three most important effects of the teacher’s professional development (Mizell, 2010) refer to the fact that: the teacher acquires new knowledge and skills, improves the management of educational work, and the most significant effect is the greater achievement of children during the educational process.

Teachers, in the process of their professional development, represent adult students. The importance of the inextricable connection between the professional development of teachers and the learning of adults is recognized in the Guide for Professional Development in Preschool Institutions through Horizontal Learning, which highlights the principles whose observance conditions the quality of learning of teachers during professional development. According to the stated principles, teachers' learning is more successful: when during that process they notice the problem and the purposefulness of learning; when teachers can participate in shaping opportunities for learning and creating conditions for learning, when within the collective they feel that they are competent and when their autonomy is respected while fostering a sense of trust, respect and appreciation, and when success is achieved in that learning process (Guide for Professional Training in a Preschool Institution through Horizontal Learning, 2022).

The concept of STEAM education is a relatively new trend and has not been incorporated to a significant extent in the initial education programs of teachers in Serbia. Also, analyzing the offer of formal training for the professional development of teachers, we do not find a sufficient number of potential training in which teachers can be trained for the needs of the implementation of the STEAM approach in the educational process. Bearing in mind the efficiency of the STEAM approach and the above data, it can be expected that the need for the training of teachers in this area will be actualized.

In current research (De Jarnette, 2018) of preschool practice, we come across sources that show that teachers' engagement in professional development increases their self-efficacy, contributes to a sense of comfort, and increases the base of strategies and the ability to incorporate STEAM activities in their immediate work with children. However, the implementation of the STEAM approach, despite positive information on the outcomes of professional development, was not at a high level, which indicates that teachers had reservations regarding the level of their capacity to implement STEAM activities, requiring additional support in preparing activities. Here, there is a gap between the effect of professional development and the support that is necessary to put what has been learned into practice. An important fact is that children in STEAM activities showed a high degree of enthusiasm, engagement, experimentation, and communication.

Through their research, some authors indicate that preschool teachers have less developed skills in terms of mathematical, engineering, and technical education, as well as that the professional development of teachers within the STEAM approach to learning leads to the self-directed improvement of professional competencies of teachers and is an essential factor for the development of the implementation of STEAM approach by which they are improved (Monkeviciene, et al., 2020). The same authors provide a graphic representation of the components of STEAM practices and their impact on the development of children's competencies and professional development, pic. 1.



Source: (Monkeviciene, et al., 2020, 11).

Picture 1. STEAM as a play and natural interest in the world

Bearing in mind the multidisciplinarity of the STEAM approach, the child's age should be taken into account and children should not be overloaded with different contents at the same time.

Teachers' views on the effectiveness of the STEAM approach show that they can be different depending on their age, work experience, and professional qualifications they possess (Jamil, et al., 2017). The research worth mentioning (Jamil, et al., 2017) is also the one examining the attitudes of 60 preschool teachers after professional development in the field of the STEAM approach, which indicates that teachers view the STEAM approach as a separate content to be realized and not as a part that can be integrated into the existing educational practice, and the implementation of the STEAM approach has a positive effect on the motivation of children and the development of their motor skills, creating positive excitement and satisfaction for them while performing these activities. The research that examined the impact of the STEAM approach is not fully focused on the learning outcomes of children, although it is determined that it contributes to the development of creativity, solving new problems, and developing new perspectives, the results of the research on the outcomes of children and to what extent those outcomes have been improved which may lead to doubts regarding the implementation of STEAM programs (Perignat & Katz-Buonincontro, 2018).

When implementing the STEAM approach, teachers state the difficulties they faced: it is debatable how capable children can be of STEAM tasks and safety issues, and difficulties when implementing the STEAM approach in working with children with special needs. Furthermore, the challenge with the implementation of the STEAM approach is the lack of time for planning as well as the material aspect, that is, difficulties in providing materials (Jamil, et al., 2017).

A surprising fact is that less experienced and younger teachers had beliefs that do not contribute to the effectiveness of using the STEAM approach and that this data is the result of professional training attended by older teachers (Jamil, et al., 2017).

We can conclude that for the STEAM approach, as part of the innovative concepts, teachers are faced with the requirement for continuous professional development, bearing in mind that it is an interdisciplinary and multidisciplinary approach. The fulfillment of such a requirement leads to the empowerment of the teacher, who must be sufficiently motivated to reflexively review their practice, and develop cooperation and learning.

CONCLUSION

Although we can find elements of the STEAM approach in integrated programs of preschool education, it is up to the teachers to identify, combine, and use them, putting children in a position to learn based on research activities and meaningful experiences. The lack of sufficient opportunities for acquiring competencies for STEAM implementation in educational work is a signal and a space where the process of professional development of teachers could be improved.

The specific implications of using the STEAM approach in preschool are multidirectional. First of all, the focus is on the possibility of influencing the intellectual sphere of children's development, on a holistic approach to children' development, contributing to the development of creativity, critical thinking, self-confidence, initiative, as well as preparation for successful dealing with future everyday life situations. For such specificities to be realized, successfully implemented, and supported, the role of the teacher is transformed into the role of a facilitator who will upgrade the competencies necessary for the successful implementation of the STEAM approach in direct work with children through additional training.

The review of the mentioned literature found that the STEAM approach contributes to the development of children's skills. The effective implementation of this approach is conditioned by the professional development of preschool teachers through the acquisition of competencies through formal, informal, and accidental forms of training. Challenges that teachers may face when implementing the STEAM approach are related to the existence of adequate space and environment, lack of materials and resources, lack of sufficient time for planning and insufficient expertise of teachers in the implementation of the STEAM approach. In addition to identified challenges in the implementation of STEAM activities in a preschool institution, the realization of a professional development program and support for the implementation of acquired knowledge and skills from the implementation of the STEAM curriculum is a necessity for the formation of a stimulating environment for children within the STEAM approach.

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THE ROLE OF THE STEM/STEAM/STREAM APPROACH IN THE PROFESSIONAL DEVELOPMENT OF TEACHERS WORKING IN PRESCHOOL TEACHER TRAINING COLLEGES

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Abstract: This paper aims to point out the importance of the STEM/STEAM/STREAM approach in the professional development and training of teachers in preschool teacher training colleges. Within the theoretical framework of the paper, the essential concepts related to the process of improvement of higher education teachers are discussed and the topicality of the problem of professional training is indicated. The methodological framework of the research is based on a research goal oriented to the examination of the opinions of teachers and associates of the Unit for Preschool and Nursery Teachers of the Academy of Applied Studies Šabac on the role of STEM/STEAM/STREAM approaches in the professional development of teachers. The general goal of the research is specified through two research tasks: 1) to examine how teachers perceive the impact of the STEM/STEAM/STREAM approach in their professional development process; and 2) to determine to what extent the research of examples of good practice and perspective in the field of STEAM through the establishment of partnerships with other institutions and organizations dealing with STEAM contributes to the improvement of knowledge and skills in the application of STEAM approaches in teaching. Using the descriptive method, by the Likert scale of judgments, the attitudes of teachers and associates of the Unit for Preschool and Nursery Teachers were examined and analyzed. The research results indicate that the system of professional development and training, which is based on important programs and legal document contributes to the improvement of the knowledge and skills of teachers in the application of the STEAM approach

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in teaching and the need for permanent training in different areas, to achieve a higher level of quality work with students.

Keywords: teachers, education, professional development, student, preschool teachers

INTRODUCTION

As a consequence of the emergence of complex social, technological, economic, and cultural challenges of modern society at the global level, there is a need for a significant change in the approach to learning and teaching at all levels of upbringing and education. The English term STEAM appears as an acronym, which refers to several academic disciplines: science, technology, engineering, arts, and mathematics. This term refers primarily to schools, that within the offered educational programs and modules, favor education as the key to the development of the scientific and technological sphere.

The importance of STEM and the investment of significant resources in the development of STEM competence is related to the needs of the labor market for experts in areas that are in expansion, which are related to the development of new technologies, such as currently robotics or artificial intelligence. A STEM education develops a range of transversal skills that are applicable in all fields, including critical thinking, problem-solving, innovation and creativity, scientific curiosity, collaboration, and teamwork, as well as communication and metacognitive skills.

Kelley and Knowles (2016) state that STEM has evolved into a meta-discipline and that it is an integrated approach that removes traditional barriers between subjects and focuses on applied processes of designing solutions to complex contextual problems using modern tools and technologies. In addition, the STEM approach in higher education encourages going beyond the framework of the traditional teaching paradigm and using student-centered teaching techniques, such as project teaching, problem teaching, collaborative learning, experiential learning, etc. This interdisciplinary approach contributes to the personal development of students during initial education and at the same time prepares them for continuous education, making them more employable, even if they do not decide on a career in the STEM field. Thinking about the ways in which national higher education systems can encourage students to develop the necessary skills will help them in their personal and professional development, which is important for a quality life.

Apart from the acronym STEM, the acronym STEAM appears more and more often, which in addition to the areas included in STEM also denotes "Arts," i.e. humanities, languages, dance, acting, music, visual arts, design, and new media. STEAM deals with the same concepts, but through the prism of the creative process and with the development of skills for the 21st century, it also develops the so-called 22nd-century skills that include connectivity, community, and culture.

The acronym STEM was introduced in 2001 by the American organization National Science Foundation (NSF), and it replaced the acronym SMET, which had been in use until then. Since research at that time showed that students in American schools had lower achievements in the STEM field compared to their peers from other parts of the world, various initiatives were launched to introduce STEM curricula in schools, so that students would acquire competencies in accordance with the needs of the labor market. On the other hand, the need for teacher education was also noted so that they could lead students on an interdisciplinary STEM journey. Those initiatives outlined the direction of STEM curriculum development, which spread from the United States of America to the world, following the needs and peculiarities of the educational systems of individual countries.

Thus, Wells (2019) emphasizes that the emergence of the STEM movement in its current form is the result of long-term attempts to integrate STEM content into the American K-12 education system, which includes education from kindergarten to high school, and to improve and adapt the system to social and the US economic context. Hence, in his opinion, we find the first initiatives for the popularization of STEM during the 1970s and 1980s; since then, there was continuity until the early 2000s, when systematic dealing with the topic began, and it has been developing ever since.

In the European Union, the interest in developing STEM skills can be seen through the European strategic framework for developing skills. The 2020 Communication from the Commission to the European Parliament, the Council, the European Social Committee, and the Committee of the Regions, entitled *Skills Agenda for Europe for Sustainable Competitiveness, Social Justice and Resilience* (EC, 2020), states the urgency of a paradigm shift in skills in the context of green and digital transitions.

Therefore, [Skills Agenda for Europe (EC, 2020)] sets goals for a five-year period, which are respectively aimed at increasing the number of adults involved in lifelong learning and raising the level of digital skills. To achieve these goals, 12 measures were determined, and measure number 7 refers to increasing the number of people with a diploma in the field of STEM and encouraging entrepreneurial and transversal skills. The description of the measure states that "[…] young people, especially women, are encouraged to be educated in the field of science, technology, engineering, and mathematics. Also, […] strengthen support for entrepreneurs and the acquisition of transversal skills such as collaboration and critical thinking" (EC, 2020).

From the above, it can be clearly concluded that the European Union recognized the importance of the STEM field, as well as the importance of encouraging the implementation of education to popularize the STEM field among young people. The progress report from 2021, which refers to the implementation of the aforementioned Program, states that, as one of the activities to encourage the participation of women in the STEM field, through the Erasmus+ program, partnerships on the design and implementation of higher education programs in the field of engineering and advanced of ICT based on the STEAM approach, as well as mentoring programs for female students, encourage them to choose STEM studies and a career in STEM occupations. On the other hand, there are numerous initiatives in practices, among which we highlight the STEM Alliance, an initiative coordinated by the European Schoolnet (a network of 33 European ministries in charge of education), which brings together participants from the economy and education to implement activities aimed at promoting STEM education and careers among young Europeans.

Figure 1. Transformation of a classroom into a small research center

Modern and high-quality teaching must enable students to take knowledge and skills that are applicable in the real world from the classroom, which can be achieved by transforming the classroom into a small research center, removing the barrier between the classroom and the workplace, teaching and real tasks, education, real life, and work environment. An efficient and modern classroom fosters a positive culture that enables students to solve problems, collaborate, create, test ideas, share knowledge, and encourage the use of technology.[1]

[1] https://sportedukalis.com/2023/07/01/stem-sistem-u-obrazovanju/

STEAM PROJECT TEACHING – TEACHING MODEL AND SUCCESS IN AN ONLINE ENVIRONMENT

In modern society, the educational system is rapidly changing, as many educational institutions have started to use the STEAM approach to learning, which does not focus only on additional teaching in the disciplines of science, technology, engineering, and mathematics, but applies a holistic approach to this teaching model, breaking artificial academic boundaries between scientific fields.

The integrated approach and STEAM connection in higher education is designed not only to improve student achievement but also to ensure more permanent retention of knowledge and ways of thinking that are needed for successful problem-solving and following modern innovations in all areas, especially in education.

The transition to online teaching and project-based learning with a STEAM approach has strengthened the STEAM project-based teaching model, in which students do not only learn content, which they would then apply in a project but the traditional approach to content learning is completely changed. In the STEAM project-based learning approach, students are first presented with a real problem and then tasked with learning the content necessary to answer questions that are the answers to the assigned project problem. During the process of testing, researching and developing solutions, students build problem-solving, project management, and collaboration skills, as well as leadership skills, necessary for success in the world outside the higher education institution, which is the basis of the educational system as a whole.

1. It helps students to apply knowledge from various STEAM disciplines in practice

The best success for online teaching is with project assignments that are based on real-world problems, providing an opportunity to make a clear connection between what is learned in the course of study and what is relevant outside the classroom. The authentic nature of STEAM project problems is that they require students to draw on knowledge and expertise in many areas, which gives them the chance to structure solutions in many different ways. Practically, with this approach, students are given the chance to feel that there was a right and a wrong direction, i.e. the right and wrong application of what they learned, by reaching the final outcome of the project.

2. It promotes deeper and more permanent knowledge

The goal of learning based on STEAM projects is to awaken the students' desire to come up with the correct solution, to find out what the correct answer is, and then to understand in more detail the purpose and goal of the project and establish connections between the problems they face, and based on this, to think about what they already know and discover what they still need to learn in order to finish the project. This specific context helps them not only to identify and avoid misconceptions but to connect facts and information as they apply knowledge to solve, evaluate, and think about different project solutions.

3. Cultivates the inquiry and research skills necessary for the success of STEAM and project-based teaching

The open nature of the STEAM project approach, which does not seek a single correct answer but directly encourages both analytical and creative thinking, is necessary for introducing innovations and preparing students for the challenges of the modern world. If a teacher prepares a STEAM project that is focused on the development of research skills, he/she offers students learning questions that practically do not give correct answers, but lead to even more questions, deepening knowledge, but most importantly – to understanding the learning path, as well as what has been learned.

4. Learning based on the STEAM project approach fosters reflection and metacognition

As teachers have the challenge of presenting teaching material to students in a changed environment during online classes, it is necessary to teach them to learn to think and learn independently by applying the STEAM project model. Practically, in this way, students develop a sense of self-reflection for the adopted material and the successful implementation of the project. This would mean that the teacher has the task of teaching students about independence during educational activities, learning, and working on project tasks, through continuous questioning: What do we know? What do we need to know? What do we think will happen? What succeeded in the implementation of the project? What didn't work? What can we improve? How can we achieve a better outcome of STEAM project teaching?

The reflective nature of the STEAM project-based process helps students connect content and subject matter to the way they think and solve project challenges. The better they can find and use the learned knowledge, mastered skills, and abilities, the better they can understand not only the task that is set before them but also how to solve it.

The main advantages of applying the STEAM project approach in teaching include:

- mastering the material based on solving the problems needed for the realization of the project,
- encouraging the dynamic development of the student's personality through project-based, problem-based, and STEAM education,

– creation of a rich experience for students based on thinking about potential possibilities for the realization of the project,
– development of communication and social interaction skills, as well as teamwork,
– motivating students for scientific research work,
– encouraging students to independently create and come up with solutions,
– directing the student to apply educational technology and interdisciplinary approach with artistic expression in practice.

Research about STEAM and Education Institutions in Serbia

By reviewing the research of numerous foreign and domestic authors, it can be seen that the STEAM concept of education is recognized as suitable for the interdisciplinary connection of content from different spheres of science but also as a modern model of work organization that develops social skills, self-confidence, and motivation for learning, as being important factors for further progress of pupils and students.

Research results (Ingersoll & Merrill, 2012) point out that 18.2 percent of natural science teachers leave their teaching positions after the first year of working in education – 14.5 percent of mathematics teachers, and 12.3 percent of teachers of other STEM fields. A high percentage of teachers' lack of motivation to contribute to STEM fields through their own creative expression also led to a decrease in student interest in science subjects. Significant changes followed when the field of arts was added to the STEM educational concept, thus creating the acronym STEAM as a link between science, technology, engineering, art, and mathematics.

Some of the research findings (Jaipal-Yamani & Angeli, 2016) indicate that the use of educational robots encourages the development of STEAM skills, but also develops students' self-confidence and interest in the STEAM field in general. The authors Noh and Lee (2020) point out that the use of robots in educational work has a positive effect on the development of IT thinking skills, encourages the development of creativity and critical thinking, and develops problem-solving skills. In connection with the above, it can be concluded that the introduction of educational robots into teaching results in the effective inclusion of children in STEAM education activities and the encouragement of children to learn the basics of programming and develop IT thinking, i.e. the knowledge and skills they will need in the future.

Mora, et al. (2017) analyzed a literature review on gamification at the higher education level. The main focus of the review paper is on the review of the framework for the development of gamification, taking into account the appropriateness of the age of students and the type of elements of gamification in higher education environments. The conclusion of the research showed the dominance of gamification elements in the business environment, while available tools for gamification were much less present in general activities such as education and healthcare. The authors state that most publications in higher education do not follow the formal design of the gamification process. Also, most of the paper focuses on the description of the experience, that is, on the so-called “ad hoc way” and thus does not contribute to the conduct of research by other researchers and teachers.

Recently, the idea of adding art to STEM programs has become popular, as a result of research into the positive effects of engaging in various types of art on children’s development (Popović, 2017).

Contemporary trends in the STEM field emphasize teaching in which students make models, mini-robots, rockets, circuits, etc. and at the same time, they learn new content often by the method of insight and trial and error. To carry out such classes, modern STEM classrooms equipped with numerous equipment are needed, in which students have 3D printers, programmable robots, various measuring sensors, and electronic sets (e.g. LittleBits), (Glasnović et al., 2018).

Some previous research attempts in the STEM in Croatia have resulted in the findings that speak of the low interest of students in STEM professions, and the very poor and unfavorable educational structure of parents, which represents a threat to the achievement of many goals in the STEM area.

Also, the role of students’ socioeconomic status in aspirations towards STEM professions is significant and in some parts of the educational system, there is a particularly low participation in extracurricular STEM activities. In addition, previous studies have shown that mathematics as a subject is among the least-liked subjects among students (Glasnović, et al., 2018).

Authors Nieto-Escamez and Roldan-Tapia explore experiences in the application of gamification at universities during the COVID-19 pandemic. The paper does not use the SLR methodology, and the authors narratively described 11 case studies on the application of gamification grouped by subjects or areas (chemistry, biology, medicine, computing, and economics). They analyzed the impact of gamification on increasing student motivation and the adoption of learning outcomes and found that it was positive, but also concluded that additional research is needed to confirm this, especially since there was no comparison with the adoption of learning outcomes in a traditional environment without gamification.

STEM has been a reality in the world for some time in the best educational institutions. However, there are also schools in Serbia where the highest quality and most modern world educational practices are nurtured, and students are truly prepared for life and work in the 21st century. In such schools, STEM education is an integral part of age-appropriate teaching.

Through the innovative concept of STEAM education, students of *Modern Elementary School and Gymnasium, International School, and ITHS secondary school for IT* acquire knowledge in science, technology, engineering, art, and mathematics in a creative way through project teaching, problem-solving approach, team work, and research spirit.

Also, in these schools, IT is an integral part of teaching from a young age, and regardless of age, students acquire important IT skills such as programming, design, and robotics, and with the use of educational technology, they master digital literacy, and *ITHS* students become qualified IT experts.

What particularly distinguishes the STE(A)M concept in these schools is the unique 4C principle: Creativity, Collaboration, Critical Thinking, and Communication. Thanks to them, students, instead of passively, acquire STEM knowledge actively, through real examples and multidisciplinary projects, working in research teams. Also, these principles belong to the so-called transversal skills and are indispensable for working in any field of the 21st century. In this way, the students of these schools not only acquire STEM knowledge but also prepare for professional life in the real world after schooling.

When talking about trends, it can be concluded that the effectiveness of the STEM approach depends on teachers who are trained and able to transfer knowledge in the right way. This is precisely why the *Modern Elementary School and Gymnasium, International School, and ITHS* place a lot of emphasis on the professional development of teachers so that they are always up to date with the latest knowledge and trends in education. In this way, they and their students are making progress.

What makes these schools stand out in this part of Europe is the fact that they connect STEM teaching with ecology in line with the latest world approaches and needs. We are talking about schools where students' environmental awareness is continuously developed – known as "green schools" – which organize numerous environmental actions. This is precisely why many STEM projects at the *Modern Elementary School and Gymnasium, International School, and ITHS* are designed to be directly related to environmental issues, which is why students acquire important knowledge but also learn how to use it positively and constructively to provide the benefits for the entire planet.

Serbia also has its exclusive representative for the promotion and implementation of STEM education. Namely, the Institute for Modern Education is the representative of the *Science on Stage Europe* network in Serbia. It is the largest network of STEM teachers in Europe with more than 100,000 representatives from over 30 European countries, as well as Canada, Egypt, Kazakhstan, and Georgia. Through this network, teachers have at their disposal numerous resources for improvement, as well as various workshops where they work together with colleagues from all over the world on the implementation and improvement of STEM teaching. The Institute for Modern Education will also organize the first *Science on Stage* festival, where students from Serbia will have the opportunity to present their works from the STEM field and compete to go to the European *Science on Stage* festival.

In Serbia, there is also an interactive studio *Link STEAM Lab*, where students acquire knowledge in science, technology, engineering, art, and mathematics through practical examples, research work, and real projects. STEM education is one of the most important areas of today's education and it is extremely important to keep up with its trends if pupils and students were to be competitive at the world level in the 21st century.

Priorities in the Field of Higher Education

1. Promoting interconnected systems of higher education

The program will aim to strengthen strategic and structured cooperation between higher education institutions by:

a) supporting the development and testing of different types of cooperation models, including cooperation in virtual and combined formats and the use of various digital tools and online platforms;

b) promoting mobility through the application of automatic mutual recognition of qualifications and learning outcomes and incorporating mobility into curricula;

c) supporting higher education institutions to apply the Bologna principles including promoting core academic values and quality assurance standards and guidelines, as well as tools to improve mobility for all;

d) supporting higher education institutions in strong cooperation with representatives of EU member states, for piloting innovative cooperation and action; and

e) supporting the implementation of the Erasmus without papers initiative, the application of the European student identifier and the European student card.

2. Stimulating innovative learning and teaching practices, i.e. addressing social challenges and promoting innovation and entrepreneurship by supporting:

a) the development of learning outcomes and student-oriented curricula that better meet students' learning needs and reduce skill mismatches, and the promotion of entrepreneurship while at the same time being relevant to the labor market and wider society, for example by inviting employees from companies and the business world or by developing curricula with industry, including small and medium-sized enterprises;

b) development, testing, and implementation of flexible learning paths and modular course design (part-time, online, or combined) and appropriate forms of assessment, including the development of online assessment;

c) the promotion of lifelong learning in higher education, including facilitating the initiation, validation, and recognition of short blocks of training leading to micro-credentials; and

d) the application of transdisciplinary approaches and innovative pedagogies such as flipped learning, international collaborative online learning, research-based learning and combined intensive programs, which support the acquisition of future-oriented transferable skills and entrepreneurship through a challenge-based approach.

Developing STEM/STEAM Methods in Higher Education

Developing STEM/STEAM methods in higher education, especially the participation of women in STEM fields: this priority supports the development and implementation of STEM programs in higher education, following the STEAM approach; promoting the participation of women in STEM fields of study, especially in engineering, ICT and advanced digital skills; developing guidance and mentoring programs for students, especially girls and women, to pursue STEM and ICT fields of study and careers; fostering gender-sensitive practices of education and training in STEM education; and eliminating gender stereotypes in STEM**.**

Rewarding Excellence in Learning, Teaching, and Skills Development

a) by developing and implementing strategies and a quality culture to reward and encourage excellence in teaching, including online teaching and student teaching, improving the learning, and teaching experience of students with reduced opportunities, student-centered learning and teaching in higher education, as well as support for flexible and attractive academic careers, teaching evaluation activities, research, entrepreneurship, management, and leadership;

b) training academic staff in new and innovative pedagogical approaches, including teaching in online or blended environments, transdisciplinary approaches, new curriculum designs, delivery methods, and assessments that link education with research and innovation, where appropriate; and

c) developing new practices in teaching design, based on educational research and creativity.

Support for Digital and Green Opportunities in the Higher Education Sector through the support for:

a) digital transformation of higher education institutions (including interoperability) and digitalization of student mobility in accordance with the European Student Card initiative,

b) development of digital skills of students and employees, and

c) monitoring database graduate students.

In accordance with the green initiative, the program will support: a) institutional approaches, b) transdisciplinary approaches that have a clearly defined disciplinary background with lifelong learning, including support through micro-credentials, c) curriculum development in accordance with the necessary green skills, and d) supporting transnational partnerships between students, academic staff, universities, employers, the community and other stakeholders on climate challenges to create climate change leaders in higher education.

Building inclusive systems of higher education

The program will encourage inclusive approaches to mobility and cooperation activities, such as: a) supporting the education of refugee students and staff, and supporting institutions and staff from host countries to engage in this endeavor; b) increased access, participation, and completion rates for people with reduced opportunities including underrepresented groups, also through the development of voluntary quantitative targets; c) active support to incoming mobility participants during the process of finding accommodation, including cooperation with relevant stakeholders in providing appropriate and affordable accommodation; d) support for the mental health of students and academic staff; e) fostering gender balance in higher education institutions, in various fields of study and in management positions; and f) encouraging civic engagement by promoting informal learning and extracurricular activities and recognizing volunteer work and community work in students' academic results.

Support for innovation and entrepreneurial skills of students

The program will provide support for innovation and entrepreneurship in higher education, including for example a) support for the establishment and operation of living laboratories and incubators within higher education institutions, in close cooperation with the entrepreneurial sector and other relevant agents, in order to support innovative learning and teaching and help students entrepreneurs to develop their ideas into businesses, and b) supporting learning and teaching partnerships with commercial and non-commercial organizations in the private sector that support students' encounter with innovation and entrepreneurship.

RESEARCH METHODOLOGY

In the research, a scaling procedure was applied, within which the opinions of respondents were examined about the role of STEM/STEAM/STREAM approaches in working with students and the impact on the professional development of teachers. The goal of our research refers to the examination of the attitudes of teachers and associates of preschool teacher training colleges towards the possibilities of professional development and training by applying the STEAM concept of education. From the general goal thus conceived, we derived the following research tasks:

1. to examine the attitudes of teachers and associates of preschool teacher training colleges towards the contribution of the STEAM approach to professional qualification and advancement;
2. to examine the attitudes of teachers and associates of preschool teacher training colleges regarding the importance of the STEAM approach for developing interpersonal relationships;
3. to examine the attitudes of teachers and associates of preschool teacher training colleges regarding the importance of the STEAM approach for encouraging responsibility and creativity; and
4. to identify the proposals of teachers and associates of preschool teacher training colleges on what should be changed in teaching practice so that the STEAM approach is more prevalent.

By the STEM/STEAM/STREAM approach, we mean an integrated approach and STEM connection in higher education, which is designed not only to improve student achievement but also to ensure a more permanent retention of knowledge and ways of thinking that are needed for successful problem solving and following modern innovations in all areas, especially in education. We used descriptive analysis for data analysis.

The respondents' opinion on the role of the STEM/STEAM/STREAM approach in working with students and the impact on the professional development of teachers were examined through 24 statements where the respondents on a five-point Likert-type scale assessed the extent to which they agreed with them.

A suitable research sample was selected, which consisted of teachers and associates at the Unit for Preschool and Nursery Teachers of the Academy of Applied Studies Sabac (N=24). It is important to point out that the analysis and interpretation of the obtained results of this research can be viewed and related only to the given sample, but we believe that they represent a significant starting point for possible future research on the STEAM approach in higher education.

Table No. 1. Attitudes of teachers and associates about the STEAM approach on working with students and the impact on professional development

Areas of STEAM approach contribution	Attitudes	f
PROFESSIONAL QUALIFICATION AND ADVANCEMENT	STEAM is a philosophy, an approach in education that involves organizing teaching activities oriented toward learning outcomes.	5
	The emphasis of the STEAM approach is on developing certain competencies in students and teachers in order to cope with challenges, and life situations as easily and successfully as possible, and to be as successful as possible in future careers.	16
	Through science, students gain an understanding of the world around us, research and think critically, and easily find their way in an environment full of technological innovations.	6
	The effectiveness of the STEAM approach depends on teachers who are trained and able to transfer knowledge to students in the right way,	12
	The STEAM approach is important for the education of the future, as well as the present.	7
	Establishing partnerships with other institutions and organizations dealing with STEAM contributes to improving the knowledge and skills of teachers and associates in the application of the STEAM approach in higher education	11

Areas of STEAM approach contribution	Attitudes	f
DEVELOPMENT OF INTERPERSONAL RELATIONS	For the successful implementation of STEAM in higher education, cooperation between teachers at the Unit of Academy level is necessary.	19
	Through STEAM, teachers have the opportunity to collaborate more, plan lessons together, and exchange ideas with each other.	21
	The STEAM approach promotes and seeks cooperation among students, but also teachers.	18
	The STEAM approach actively involves all students, encouraging them to discuss, establish cause-and-effect relationships, connect materials, and perceive situations from multiple aspects, and all this in the context of everyday, problem situations that are real.	17
	STEAM is a dynamic, interactive, and very interesting and fun approach for students.	15
Areas of STEAM approach contribution	Attitudes	f
ENCOURAGEMENT OF RESPONSIBILITY AND CREATIVITY	STEAM encourages students to independently create and come up with solutions.	19
	Through STEAM, teachers motivate students for scientific research work.	14
	The STEAM approach contributes to the creation of a rich experience for students created by thinking about potential opportunities for project implementation.	20
	STEAM education directs students to apply educational technology and an interdisciplinary approach with artistic expression in practice.	17

Based on the expressed views of teachers and associates about the role of the STEM/STEAM/STREAM approach in working with students and the impact on professional development and advancement, that they support such work, we can conclude that their views confirm the expertise and readiness of teachers and associates for the transition to the STEAM concept of education that is recognized as suitable for interdisciplinary connection of content from different spheres of science. Also, teachers and associates recognize the STEAM approach as a modern model of work organization that develops social skills, self-confidence, and motivation to learn, as important factors for the further progress of students.

We also analyzed the obtained responses of teachers and associates about the mentioned areas of contribution of the STEAM approach: a) professional competence and advancement; b) developing interpersonal relationships; and c) encouraging responsibility and creativity (*Table 1*). The results based on the views of teachers and associates point to several important facts, which can serve in establishing conclusions and proposing possible measures to improve the work of teachers and associates in the STEAM approach in working with students.

RESEARCH SAMPLE

In the research process, a wider set of elements that make up the content of the opinions of teachers and associates of the Unit for Preschool and Nursery Teachers was measured with the aim of studying the structure and relationship of those elements.

For the sake of better visibility and concretization of the research results, we analyzed the collected responses and attitudes of teachers and associates in the following areas of contribution of the STEAM approach: a) professional training and advancement, b) developing interpersonal relationships, and c) encouraging responsibility and creativity. Also, we considered it important to present the views of teachers and associates and their proposals for changes in teaching practice so that the STEAM approach would be more prevalent in teaching practice with future preschool teachers. In this way, we classified the attitudes of students into four categories, when it comes to the STEAM approach, which they support in working with students.

The results refer to the opinions of teachers and associates about the importance of applying the STEM/STEAM/STREAM approach in professional development and professional training (*Table 1*).

When it comes to individual claims, teachers, and associates in general, express a positive attitude in relation to the claims. They mostly agree that:

- The STEAM approach prepares professionals who can transform society with innovation and sustainable solutions.
- For the successful implementation of STEAM in higher education, cooperation between teachers at the Unit level is necessary.
- Through STEAM, teachers and associates have the opportunity to collaborate more, plan lessons together, and exchange ideas with each other.
- STEAM is a philosophy, an approach in education that involves organizing teaching activities oriented towards learning outcomes.

CONCLUSIONS

An integrated approach and STEAM connection in higher education not only improves student achievement but also contributes to a more permanent retention of knowledge and ways of thinking that are needed for successful problem-solving and following modern innovations in all areas, especially in education. The results confirm the good professional competence of teachers; there are also results that indicate the need to improve the work of teachers in the STEM/STEAM/STREAM environment.

Based on the opinions of teachers and associates about the role of STEM/STEAM/STREAM approaches in working with students and the impact on professional development, the basic conclusions of this research are determined:

- The opinions of teachers and associates are divided in relation to their views on the impact of the STEAM approach on professional competence and advancement. The largest number of surveyed teachers and associates confirm that the emphasis of the STEAM approach is on developing certain competencies in students so that they can more easily and successfully cope with challenges and life situations, and be as successful as possible in their future careers.
- It is possible to concretize the stated views of teachers and associates about the STEAM approach through the areas of contribution of the STEAM approach in relation to professional training and advancement, developing interpersonal relationships, and encouraging responsibility and creativity.
- In a positive context, when teachers and associates support the STEAM approach in teaching, they point out that the STEAM approach is dynamic, interactive, and very interesting and fun for students.
- Certain attitudes of teachers and associates point to the need and possibilities of improving the STEAM approach in teaching, primarily in relation to: a) encouraging the development of STEAM skills, students' self-confidence and interest in the STEAM field in general b) a more flexible and adequate choice of digital platforms; and c) better assessment of students; competencies.

We present these results as possible measures for improving the work:

- It is important that teachers and associates who educate future preschool teachers continuously work on improving their competencies in the field of developing STEM/STEAM methods in higher education.
- Work systematically to improve and develop quality strategies and culture to reward and encourage excellence in teaching, including digital opportunities and building inclusive higher education systems.

- An important aspect of improving the work of teachers and associates refers to the planning and organization of students' activities (the organization of their professional and integrated practice), for the purpose of practical training for their future profession.
- The system of professional development and training which is based on important programs and legal documents, contributes to the improvement of the knowledge and skills of teachers in the application of the STEAM approach in teaching.
- The need for permanent training in various fields, in order to achieve a higher level of quality of work with students.

We believe, based on the results presented in this paper, that in future research it would be important to compare students' attitudes about the contribution of the STEAM approach and the work of teachers with students' success in exams and the exam passing rate in the system of vocational education at the basic and master level. We thereby indicate the importance of this paper – on the one hand, for the improvement of pedagogical practice, and on the other hand, in relation to possible new research issues.

Based on the above-presented conclusions, a general conclusion can be drawn: teachers and associates have positive attitudes regarding the possibility of professional development by applying the STEAM approach in vocational schools for the education of preschool teachers. They are aware of the effects achieved by the STEAM approach and the implementation of the STEAM concept of education, but in order to apply this way of working with students, it is necessary to provide them with different working conditions and additional education.

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SELF-ASSESSMENT OF THE COMPETENCIES OF EMPLOYEES IN EDUCATIONAL INSTITUTIONS FOR THE STEAM CONCEPT OF EDUCATION

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Abstract: Unlike the conventional one, the STEAM concept integrates knowledge from several fields to solve problems and "big questions," respecting the individuality of children and the collaborative way of working. In addition to acquiring knowledge, this approach also plays an important role in developing key competencies for lifelong learning, which recommends its integration into educational work from the earliest age. Given that the research shows insufficient representation of the STEAM concept in educational systems, despite its advantages, the question arises of the competence of employees in educational institutions for the STEAM approach. In this sense, the aim of the work is to determine the competencies for the STEAM approach of the employees in preschool institutions and elementary schools. The research was carried out in the preschool institution Veselo detinjstvo and the elementary schools Raška and Sutjeska in Raška, among nursery school teachers, teachers from the first to the fourth grade, and specialized teachers from the fifth to the eighth grade, within the framework of focus groups, and based on an interview protocol that contains key determinants of the STEAM approaches and key competence for lifelong learning. The self-assessment of competences and the researchers' direct insight into their answers revealed a lack of competencies, with an evident difference between the mentioned groups. Namely, it is concluded that nursery-school teachers are the most competent group, followed by specialized teachers, while teachers from the first to the fourth grade have the least competence. The aforementioned finding can be interpreted through the prism of initial education and the (un)representation of these contents in study programs, as well as professional development, judging by the fact that the largest number of nursery-school teachers attended trainings for a project-based approach to learning, that the training in the function of STEAM learning was organized for subject teaching, in contrast to class teaching, in which subject fragmentation is the most dominant.

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Pedagogical implications are contained in the recommendations for professional development, which are reviewed through the results of the research.

Keywords: STEAM concept, self-assessment of the competencies, project approach to learning.

INTRODUCTION

The determinants of social changes are more and more numerous and visible. At the same time, they determinate the education system as well, especially when it comes to changing the learning paradigm that should meet the needs of the knowledge society (Bralić, 2016) and developing key competencies for lifelong learning (Eurydice, 2012). In the function of empowering individuals to face the demands of the knowledge society, the educational policy must meet the improvement of the quality of teaching programs and their implementation. In order to develop a holistic personality, in a personal and professional sense, reflections are imposed on which knowledge should be adopted to develop the practical abilities of individuals for successful functioning in the challenges of modern society. It is necessary to create a curriculum that goes beyond the framework of the traditional subject knowledge and insists to a greater extent on the greater participation of students and the integration of knowledge, skills, and attitudes that will be applicable in different life contexts. Furthermore, more importance should be given to the learning process than to the result itself in the form of knowledge that is checked via tests. This implies the need for a research approach in teaching and the strategy of its organization in the function of more effective development of children's competencies and social benefit. In order to achieve this, it was necessary to replace the traditional approach to education, which was dominated by the acquisition of ready-made knowledge, with an approach dominated by the co-construction of knowledge, by integrating content from different fields.

THEORETICAL APPROACH TO THE PROBLEM

An approach to teaching and learning that integrates science, technology, engineering, arts, and mathematics, and within which there are learning methods that include problem-solving, i.e. questions, discussion, critical thinking, and reasoning, is called STEAM education (Breiner, et al., 2012). Initially, this approach did not include arts as an integral part, so it was labeled as STEM. Over time, the benefits gained from arts have been spotted, so that this approach has been enriched with the art contents. Although the results of the research confirmed the benefits of the mentioned approach to learning, primarily because they encourage the "4Cs": communication, critical thinking, collaboration, and creativity (Scott, 2015), there are, however, significant difficulties contained in the question: How to create modern STEAM programs that support the development of skills for the 21st century and implement them in the class-subject-hour system? On the other hand, there is a question: how to create a curriculum that includes the mentioned areas and in what way to realize them, given that the subject content is studied at school in a time unit of 45 minutes? The difficulties can be overcome if there is a motivation of teachers for joint work, as well as the design and realization of project activities with integrated content from different sciences, technology, engineering, arts, and mathematics. A project approach to learning contributes more effectively to the development of key competencies for lifelong learning, which, in addition to subject-related competencies, also include cross-curricular competencies (Popović & Ristanović, 2020; Popović & Beara, 2022). Therefore, although the focus of the STEAM concept is the acquisition of knowledge from various fields and their practical application in the function of overall social development, a great contribution is also made in the development of some other life-practical competencies, such as: communication in the native and foreign languages, cooperation, teamwork, digital competence, entrepreneurship and entrepreneurial competence, proper attitude towards health and the environment, aesthetic competence, problem-solving, creativity, and responsible participation in a democratic society (General achievement standards for the end of general secondary education and upbringing and secondary professional education and upbringing in the part of general education subjects, 2013). In this way, children's curiosity for learning content from various sciences is developed from an early age through play-like activities, and it is understood that the aforementioned competencies also provide greater chances for employment (Soylu, 2016). Some researchers emphasize that STEAM education provides the opportunity for students from an early age to ask questions, observe, investigate, predict and search for solutions, like scientists and they are directed toward research work in the future (Ceylan & Akçay Malçok, 2020).

Due to the stated reasons and needs, the teacher's role becomes more complicated, especially the importance of their competence for cooperation with other teachers, parents, and children. Namely, changing the traditional approach to learning will depend on teacher's skill, but with preserving the coherence of the plan and program activities prescribed by the national curricula and achieving the set outcomes. By providing opportunities to discover and connect acquired knowledge from different subject areas, by solving "big questions" (Sugata, 2022), children develop skills for solving real-life and professional problems in extracurricular situations and the work environment. That is why some authors (Dart & Drake 1995) point out that the focus of teaching should be shifted from learning through the subject disciplines to the integration into the system of knowledge from the STEAM field, which will be more applicable in a real life context. Teacher effectiveness in changing the learning paradigm towards the STEAM concept is a process, not a construct or program. As such, it depends on a large number of factors, of which one of the most important is teachers, their competence, motivation, and the assessment of self-efficiency for STEAM learning. Bandura (1977) established the construct of self-efficiency and described it as a belief in one's ability to succeed in performing certain actions and behaviors. In this sense, the self-efficiency of teachers for the implementation of learning according to the STEAM concept can be observed, because it captures the motivation, cognitive resources, and directions of action that are necessary for this. The author further emphasizes the difference between outcome expectations and self-efficiency expectations. While the former refers to beliefs that determine behaviors, which further result in certain outcomes, self-efficiency expectations concern the self-assessment of behavioral competencies to perform specific actions, in this case, for STEAM teaching (Coleman & Karraker, 1997). According to some sources, the most powerful means of self-efficiency is auxiliary experience (Fleig et al., 2013), which in this case means support and cooperation with teachers who have direct or indirect experience with leading STEAM classes. Although self-efficiency is not based on real knowledge and abilities, but rather on a personal experience of competence, it greatly influences real efficiency. In this sense, and due to the impossibility of realistic assessment of the representation and effectiveness of the STEAM concept of education, a self-assessment survey of nursery-school teachers and teachers was conducted on the above-mentioned questions, with the aim of determining the direction of development of STEAM teaching/learning.

METHODOLOGICAL FRAMEWORK OF THE RESEARCH

To determine the competencies for the STEAM approach of employees in preschool institutions and primary schools, a micro-survey was carried out in May 2024, at the level of preschool and primary education in the municipality of Raška, through the self-assessment of the respondents. An appropriate sample consisted of 30 respondents, the same number of nursery-school teachers, class teachers and subject teachers, employed in the Preschool institution Veselo detinjstvo and in the primary schools Raška and Sutjeska. Within the focus groups, a conversation was conducted based on the protocol, which contained the key determinants of the STEAM approach and key competencies for lifelong learning. The guided interview protocol contained questions that were used in interviewing the respondents, divided according to research tasks. All three groups gave the common answer to the posed question; the answer was given by mutual thinking and defining. The first group of questions related to knowledge of the basic determinants of the STEAM approach in education, its importance, and the key disciplines that it is made of. The second segment of the questions examined the representation of the STEAM concept in pedagogical practice, its benefits and difficulties during its implementation, and overcoming them. The third group of questions was aimed at looking at the ways of developing competencies for the STEAM concept of education, that is the offer of the training and materials that support STEAM competencies.

THE RESULTS AND THE DISCUSSION

The first task of the research was related to understanding the STEAM concept.

By looking at the respondents' answers, it was determined that the respondents were familiar with this concept of education. Nursery school teachers believe that the STEAM concept is designed to prepare children for the professions that await them in the future through play, which can be realized through cooperation, improvement, developing skills, and connecting different topics using new technologies. The class teachers point out that the STEAM concept in students "develops creativity, critical thinking, and the ability to solve problems, which is very important as a preparation for lifelong learning." The subject teachers emphasize the importance of the intersubject correlation that the concept brings, as well as the importance of applying the acquired knowledge through practical examples and experience, that is, to develop functional knowledge.

The second task of the research was related to the examination of the representation of the STEAM concept in practice, benefits, difficulties, and possibilities of implementation in the educational system.

Based on the teacher's answers, it was determined that nursery school teachers apply the mentioned concept in accordance with their competencies and knowledge of new digital technologies during the development of a topic/project through an integrated approach to learning. There is no obligation to apply only this concept in the work. Preschool teachers believe that it is necessary to find ways to use new technologies for the benefit of children, as well as research and experimentation. They emphasize interdisciplinarity as a good side of the concept. The benefits for children are multiple, the child develops as a whole, full of potential, competent, active, creative, and dedicated to learning through play and research. For the nursery school teachers, it is an opportunity to create a space together with children, research topics that are close to children, use resources in the environment to deepen research, initiate cooperation, and develop partnerships with colleagues, parents and the local community. It is important for parents to get involved and participate in the upbringing and education of their children, to empower the child, to spend more useful time with their children, to follow modern trends in education, and to prepare children as best as possible for the life challenges that await them. What could improve the concept, as nursery school teachers point out, is equipment, materials, and space, and all of these require certain financial resources. They also point out that the implementation of this concept in educational work creates opportunities for connecting and deepening knowledge, developing skills, progress, and well-being for all who participate in it. Despite understanding the concept and realizing its importance, class teachers lack practical experience. The results of the research imply that the mentioned concept has not been represented in the younger grades until now. The class teachers estimate that they do not have the necessary competencies to be able to implement it. Recognizing the benefits that the educational concept brings, among which they highlight the connection of knowledge from different fields, the development of skills, and the application of what has been learned in practice, teachers show interest in the mentioned program, but see the possibilities of implementation in educational work only after appropriate training. According to the self-assessments of the subject teachers, it can be concluded that the STEAM concept was represented in practice for a certain period during the project in which the schools were involved, and it was implemented by a group of teachers who developed competencies during the trainings within the project for the implementation of STEAM classes. Teachers note that the good sides of applying this concept are in children's greater interest in work, the acquired knowledge is more permanent when applied in practice, children are active in work, and knowledge is interdisciplinary and connected to solving problems and learning through play. Teachers also see benefits in team work – children are more motivated for work. Thus subject teachers also introduce diversity in the set way of working. As difficulties or factors that make it difficult to implement this concept in teaching, they point out the insufficient education of teachers, as well as the necessary material and technical resources. The teachers also note that "greater involvement of artistic fields is needed, which would contribute to the development of aesthetic competence and the development of creativity." The above statement is the result of the observations of teachers who teach art and music in primary school.

The third task of the research was related to the examination of how the respondents developed STEAM competencies.

Based on the research in focus groups, it was determined through the statements of respondents that nursery school teachers had the most opportunities to develop STEAM competencies, by attending training in this area through professional development program or webinars that they attended. Namely, all of them attended the training for the application of project learning, which includes the postulates of the STEAM concept. There was no training that would be in the function of STEAM learning for class teaching, while only a certain number of subject teachers were included in the training, and then they participated in the project and practically applied the STEAM learning concept. The positive attitude of all respondents and their interest in improving the competencies and skills in order to meet the challenges in the future upbringing and education of preschool and school children was noted.

CONCLUSION

Considering the accelerated social development and the need to develop key competencies for lifelong learning in children, a change in the paradigm of education is also necessary, which would meet their development and social progress. Although there are various models that promise greater efficiency in the realization of that goal, the key difficulty is created by the class-subject-hour system. As the STEAM concept of education is one of the models that can contribute to the holistic development of the personality and readiness to function in the society of knowledge, and its realization depends on the competence of teachers who need social support in this sense. Given that the respondents showed in their statements that they understand the STEAM concept, its benefits and the possibilities of implementation in pedagogical practice, and that they implement it to the extent that is possible, they also expressed the difficulties they face in this regard. The support they expect is contained primarily in understanding their position and the effort they invest, but also in the training they need, as well as the provision of material and technical resources. Support, which would also be significant in motivating the introduction of innovations, is seen in the understanding of colleagues and parents. Children certainly prefer to learn within the STEAM concept of education and show a higher degree of prosocial forms of behavior, according to the estimates of the respondents.

Given that the research sample was small and included respondents from only one municipality, the obtained results cannot be generalized to the general population of respondents, although they may be very significant for the hypothetical framework of future research. It also seems important for future research to examine the role of art in the integrated curriculum, i.e. the contribution to the development of creativity, given that the intention of the STEM/STEAM concept is a critical reflection in the function of solving problems and coming up with new solutions.

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Правилник о општим стандардима постигнућа за крај општег средњег образовања и средњег стручног образовања у делу општеобразовних предмета (2013), *Службени гласник РС*, 117.

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Sandra Z. Tasić earned her degree (Master's Professor of Language and Literature) at the Faculty of Philology in Belgrade. She has taught in lower primary grades for seven years now. As a PhD candidate at the Faculty of Education in Jagodina, Sandra is interested in early English language learning. She is passionate about the impact of the Montessori Method on teaching-learning outcomes and other educational concepts that advocate for the promotion of early English language acquisition.

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Ana Z. Živković has a BA in English Language and Literature. She has been teaching at Čegar Primary School in Niš for 20 years. Her fields of interest are teaching with technology, utilizing video conferencing tools to connect students with their peers worldwide, and STE(A)M approach in teaching English as a foreign language. European Schoolnet Academy MOOCs *Airspace in Class* and *STEM out of the box* feature her examples of good practice. She is the recipient of the Saint Sava Award 2018 (awarded by the Serbian Ministry of Education), and she has more than 10 years of experience as a teacher trainer in professional development for teachers organized by the Institute for the Improvement of Education.

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Nataša Vukićević was born in 1971 in Jagodina. She completed her undergraduate academic studies at the Academy of Arts, University of Novi Sad. She defended her doctoral dissertation *Interactive Approach to Implementing Children's Musical Creativity in the Lower Grades of Primary School* at the Faculty of Philosophy in Novi Sad. She is employed at the Faculty of Education in Jagodina as an assistant professor in the scientific field of Methodology of Music Education. She is the Head of the Center for Support to Teachers Working with Gifted Students. Besides participating in bilateral projects, she has delivered invited lectures at Ilia State University in Georgia within the framework of the teacher mobility program. She has published about 40 professional and scientific papers in music pedagogy. Her fields of interest include children's musical creativity and creativity in teaching, with an emphasis on researching interaction in music education, integrated learning, and methodological aspects of acquiring musical concepts.

Emina Kopas-Vukašinović is now a retired professor in pedagogical sciences. She is dedicated to research in the field of preschool pedagogy. Her areas of interest in scientific and professional work include early childhood learning and development, the quality of university education, and pedagogical prevention of behavioural disorders. She has published more than 120 scientific papers in domestic and international scientific publications.

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Emilija J. Popović was born in 1975 in Niš. She graduated in General Music Pedagogy at the Faculty of Arts, Music Department. At the Faculty of Education in Vranje, University of Niš, she obtained the scientific title of Doctor of Didactic Methodical Sciences (2014). She is the founder and first director of the Dr. Dragutin Gostuški Music School in Pirot. Since 2008, she has been employed at the Higher School of Professional Studies for Pre-school Teachers in Pirot (where she has worked as a director since 2017). After the integration of higher schools in Serbia, when the Academy of Applied Technical and Preschool Studies Niš was formed, she was appointed Head of the Pirot Department (since 2020). She has extensive experience in the organization and management of various educational activities and the field of human resources. She participated in numerous professional meetings in the country and abroad.

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Dragana O. Dragutinović graduated from the Department of Painting at the Faculty of Fine Arts in Belgrade. In 2016, she received her PhD degree in art, at the Faculty of Fine Arts in Belgrade upon the completion of her project and dissertation *The Walled-up, Remake –Ambient Installation*, under the mentorship of Professor Mileta Prodanović. She works as a professor of vocational studies at the Academy of Applied Technical and Preschool Studies Niš, Pirot Departement. She is the author and co-author of research papers in arts education, art workshops, and projects in arts pedagogy and education of preschoolers. As a visual artist, she has held eighteen solo exhibitions and participated in numerous group exhibitions.

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Short Film, Gornji Milanovac (La Confrontation St Hippolyte, authors: M.Stanimirović & B.Nikolić). She has been a member of ULUS since 2006. She is the founder of the New Art Scene Association. She is an author and co-author of papers in the field of art education. She organized numerous art workshops for children. As a visual artist, she has held 34 solo exhibitions and participated in group exhibitions in the country and abroad.

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Bojan Miloradović was born in 1992 in Kragujevac. After completing his undergraduate and master's studies at the Faculty of Education in Jagodina, University of Kragujevac, he enrolled in PhD studies in the study program – Methodology of Teaching in 2017, and access to the research of his doctoral dissertation entitled *Effects of the Integrative Approach in Teaching Physical Education Using Logical-Mathematical Games* in 2020. During his studies and work as a teacher, he continuously improved his skills to be the best teacher possible for the children he teaches.

Anđela N. Milovanović graduated from the Faculty of Education in Jagodina in 2020. In 2021, she obtained the academic title of Master Teacher. In 2022, she enrolled in PhD studies in Teaching Methodology at the Faculty of Education in Jagodina, University in Kragujevac. Her interests include studying the effects of the application of modern teaching methods, with a focus on the educational approaches in natural sciences. In addition, she is dedicated to the development of innovative didactic materials that stimulate creativity and critical thinking in students of younger school age. Today, she works as a teacher in Elementary School 9th October in Prokuplje. She has published several scientific papers and review articles.

Irena B. Golubović-Ilić graduated from the Faculty of Teacher Education in 1998. In 2006, she received the academic title Magister of Methodology of Teaching Science. She completed her PhD in Teaching Methodology at the Faculty of Philosophy, University of Novi Sad in 2014. Her research interests include the study of didactics and methodical specificities, and the possibilities of innovating and intensifying the educational process of children of school and pre-school age, especially in natural (basic) sciences. She is the author of three monographs – *Individualization of Teaching of Science* (2008), *Research Activities in Teaching Nature and Science* (2017), and *Children's Play and Basic Science*. She has published more than 30 scientific and professional papers in journals of national importance and she has participated in numerous scientific conferences and professional meetings in the country and abroad. Today she is a full professor at the Faculty of Education in Jagodina, University in Kragujevac.

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Milan P. Milikić is an assistant professor at the Faculty of Education in Jagodina, Serbia. He is an expert in the field of the methodology of teaching mathematics. His research interests include examining mathematical knowledge for teaching and using technology to foster student learning of mathematical concepts. He has published more than 15 research papers and presented at many conferences in the country and abroad. He organized international conferences and was engaged in bilateral projects with foreign faculties. He has experience in Erasmus plus projects. Further, as a member of the Center for the Promotion and Popularization of Science, he associated award-winning projects of the Center for the Promotion of Science (Serbia). He was one of the realizers of the accredited program for the professional development of teachers of Mathematics conducted by the Institute for Improvement of Education of the Republic of Serbia (2016–2018).

Jelena S. Lukić is a teaching assistant on the course Teaching Methodology of Natural and Social Sciences at the Faculty of Education University of Belgrade. She graduated from the Teacher Education Faculty in Belgrade in 2019. In 2020, she completed her master's studies, defending her master's thesis entitled Methodological Effectiveness of the Flipped Classroom Model in Teaching Nature and Society. She is a Ph.D. student at Teacher Education Faculty in Belgrade. As a junior researcher and a Ph.D. student, she is conducting research funded by the Ministry of Education, Science, and Technological Development. She participated in the project *Development of Digital Content for Online and Distance Learning*, which is part of the European Union project – *Bridging the Digital Divide in Serbia for the Most Vulnerable Children*.

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Katalin Kulman is a teacher of mathematics and geography and an assistant professor at the Department of Mathematics, ELTE TÓK. Her main research areas are sustainability education and the possibilities of traditional and digitally supported mathematics education. She is working on several Erasmus+ projects to explore the potential of developing transversal skills in STEAM subjects for primary school students. She is a professional leader and trainer of teacher training courses to promote the use of digital tools in the classroom.

Časlav R. Stoiljković was born on June 28, 1985, in Kosovska Vitina. She finished the elementary school Vuk Stefanović Karadžić and the high school Bora Stanković in Vranje. She earned her degree after completing her studies in pedagogy at the Faculty of Philosophy in Kosovska Mitrovica. She is currently a third-year student of doctoral studies in pedagogy at the Faculty of Philosophy in Kosovska Mitrovica. She worked as a teacher of civic education in both primary and secondary schools, and after that, she started working at the Preschool Teacher Training Vocational School from Gnjilan with a temporary seat in Bujanovac. She is currently employed at the Academy of Southern Serbia – Department for Preschool Teachers in Bujanovac, as an assistant for a group of pedagogical subjects. Her fields of interest include: preschool pedagogy, andragogy, research methodology, and methodology. The research areas of interest include professional development of preschool teachers and contemporary methodological trends in preschool education.

Aleksandra V. Janković graduated from the Faculty of Law, University of Pristina in February 2004. Two years later, she passed the state professional exam at the Ministry of Public Administration and Local Self-Government, and in 2012, she passed the bar exam before the Commission in Belgrade. She completed her specialist studies in 2015. She defended her doctoral thesis entitled *Maintaining Personal Contacts of Parents and Relatives with a Child* at the Faculty of Law, Union University, before the Commission composed of: Prof. Dr. Nebojša Šarkić (mentor), Prof. Dr. Milan Počuča (member), and Prof. Dr. Jelena Arsić (member) in 2021. She works as a lecturer at the Academy of Professional Studies South Serbia, Department for Preschool Teachers in Bujanovac. Her field of interest is Children's Rights.

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