Факултет педагошких наука
Универзитета у Крагујевцу, Јагодина

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STEPAM APPROACH IN CONTEMPORARY EDUCATION – CHALLENGES AND PERSPECTIVES –



Conference Proceedings

International Conference organized by the Faculty of Education,
University of Kragujevac, Jagodina, Serbia






Jagodina, 11-12. 05. 2026.



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ISBN 978-86-7604-260-9

The Teaching and Scientific Council of the Faculty of Education, University of Kragujevac, Jagodina, approved this publication by Decision No. 01-3455/1. © Faculty of Education, University of Kragujevac, Jagodina

Co-funded by the European Union

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Publisher: Faculty of Education, University of Kragujevac, ilana Mijalkovića 14, Jagodina, Serbia

Publisher's Representative: Prof. Dr. Nenad Vulović

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Acknowledgment
This research was conducted within the framework of the STEPAM project, co-funded by the European Union under the Erasmus+ Programme, Cooperation Partnerships in Higher Education. Grant No. 2023-1-RS01-KA220-HED-000166894. Project title: Teacher Training in Physical Activities and Embodied Learning through STEAM Education – STE(PA)M.

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https://doi.org/10.46793/STEPAM26.009S
Udk: 37.091.3::5/6-057.87

STEM LEARNING ACTIVATION AMONG LOWER PRIMARY SCHOOL STUDENTS

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Abstract: STEM learning activation refers to the combination of dispositions, practices, and knowledge that enable success in proximal STEM learning experiences and encompasses fascination with STEM, values, beliefs about one's own competencies, and an innovative mindset. STEM learning activation is considered an important prerequisite for the development of long-term interest and engagement in scientific domains. The aim of this study was to examine the level of STEM learning activation among lower primary school students, as well as to identify differences with respect to gender and place of residence, and its relationship with academic achievement. The study was conducted on a sample of 282 third-grade primary school students. A questionnaire was administered, including socio-demographic data and students' academic achievement, as well as a single-factor scale for assessing STEM learning activation. The results indicate that students demonstrate a relatively high level of STEM learning activation. The highest values were observed in dimensions related to valuing science, while the lowest values were found in aspirations toward STEM careers. No statistically significant gender differences were identified, whereas students from urban areas showed higher levels of activation in certain dimensions, indicating the influence of context and access to resources. A weak but statistically significant positive correlation was found between academic achievement and STEM learning activation, suggesting that students with higher achievement demonstrate greater engagement in the STEM domain. Overall, STEM learning activation is confirmed as a dynamic and developmentally sensitive construct, influenced by environmental factors. Accordingly, the findings highlight the need to develop inquiry- and problem-based teaching, integrate creative and engineering activities into instruction, strengthen early STEM career aspirations, and reduce disparities in access to STEM resources.

Keywords: STEM Learning Activation; Lower Primary School Students; STEM Careers

Introduction

Contemporary educational systems increasingly emphasize the development of competencies that enable students to actively engage in solving complex problems, think critically, collaborate effectively, and act creatively (OECD, 2019a). Within this context, STEM education (Science, Technology, Engineering, and Mathematics) has emerged as one of the most significant educational approaches, as it integrates multiple disciplines while fostering the development of functional, transferable, and applicable competencies (Bybee, 2013).

STEM education encompasses more than the simultaneous teaching of science, technology, engineering, and mathematics. Its essence lies in interdisciplinary integration, authentic problem solving, and the creation of opportunities for active learning through inquiry, experimentation, and collaboration (Honey et al., 2014; Kelley & Knowles, 2016). An integrated STEM approach enables students to develop scientific literacy, creativity, innovativeness, and the competencies required for successful participation in

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contemporary society. Consequently, STEM education has become an increasingly important component of national educational policies and curricula worldwide (Bybee, 2013; OECD, 2019).

Despite the widely acknowledged importance of STEM education, numerous studies indicate that it is still frequently implemented through separate school subjects, with limited integration across disciplines (Honey et al., 2014). Under such circumstances, students have fewer opportunities to apply their knowledge in authentic contexts and to develop positive attitudes toward STEM fields. At the same time, research has shown that interest in science and technology begins to develop during early childhood and that early experiences substantially influence later educational and career choices (Archer et al., 2015; Maltese & Tai, 2010). Moreover, children aged 7 to 10 acquire a considerable proportion of their interest, engagement, and positive experiences related to STEM not only through formal schooling but also through various forms of informal learning, including play, family activities, media, and extracurricular experiences (Dabney et al., 2012).

Understanding how students perceive STEM learning and the extent to which they are prepared to engage actively in STEM activities represents an important research challenge. In this regard, Dorph, Cannady, and Schunn (2016) introduced the concept of STEM learning activation, referring to a combination of dispositions, practices, and knowledge that enables success in immediate STEM learning experiences. Success is defined not solely in terms of academic achievement but also by students' willingness to choose STEM-related activities, participate actively in them, and persist in accomplishing their goals.

According to this framework, STEM learning activation comprises four interconnected dimensions: fascination with STEM, the value students attribute to STEM, beliefs about their own STEM competence, and an innovative mindset. Although these dimensions can be distinguished analytically, the authors conceptualize them as a unified construct reflecting students' overall readiness to engage actively and meaningfully in STEM learning (Dorph et al., 2016). This understanding of STEM learning activation closely aligns with the Expectancy–Value Theory (Eccles & Wigfield, 2002), according to which beliefs about one's own competence and the value attributed to a particular activity jointly shape motivation and engagement.

Furthermore, from the perspective of the concepts of science identity and science capital (Archer et al., 2015), STEM learning activation in primary school can be viewed as an early disposition that precedes the development of a more stable scientific identity. Initially, students develop interest, positive attitudes, and a sense of competence, whereas professional aspirations and identification with scientific careers gradually emerge under the influence of family, school, and the broader sociocultural context. Therefore, the early years of primary education represent a particularly important period for creating positive STEM experiences that may shape students' future educational pathways.

Although the significance of STEM education has been increasingly emphasized in the literature,

research focusing specifically on STEM learning activation among primary school students remains limited, particularly within the Serbian educational context. Accordingly, the aim of the present study was to examine the level of STEM learning activation among third-grade primary school students, to identify differences according to gender and place of residence, and to investigate the relationship between STEM learning activation and academic achievement in Mathematics and Science.

Research Methodology

The aim of this study was to examine the level of STEM learning activation among third-grade primary school students. The study addressed the following research questions:What is the level of STEM learning activation among third-grade primary school students? Are there differences in STEM learning activation according to students' gender and place of residence? Is STEM learning activation associated with students' academic achievement in Mathematics and Science?

The study included 282 third-grade primary school students from the Republic of Serbia. The characteristics of the sample are presented in Tables 1 and 2.

Table 1. Distribution of Students by Gender and Place of Residence

Sample Characteristics		Frequency |	Percentage
Gender	Male	148	52.5
	Female	134	47.5
Place of Residence	Urban	244	86.5
	Rural	38	13.5

Table 2. Students' Final Grades in Mathematics and Science at the End of the First Semester of the Third Grade

Grades		Frequency |	Percentage
Mathematics	2	9	3.2
	3	23	8.2
	4	90	31.9
	5	160	56.7
Science	2	6	2.1
	3	15	5.3
	4	68	24.1
	5	193	68.5

Note. Grades range from 2 (sufficient) to 5 (excellent).

The study employed survey and scaling techniques. Data were collected using a questionnaire that included students' sociodemographic characteristics, academic achievement, and a one-factor scale assessing STEM learning activation.

Students' STEM learning activation was assessed using the Emerging STEM Learning Activation Survey Version 1.1 (Learning Activation Lab, 2018), an instrument specifically designed to measure emerging STEM learning activation among children aged 7–9 years. The instrument consists of 14 items and assesses four dimensions—fascination, values, competence beliefs, and an innovative mindset—conceptualized as a unidimensional construct. The scale was designed to minimize reading demands by

allowing children to indicate their level of agreement using smiley-face response options, making it appropriate for young learners who are still developing their reading skills. The instrument demonstrated satisfactory internal consistency, with a Cronbach's alpha coefficient of .780.

Results

The findings are presented according to the research questions. First, the level of STEM learning activation among third-grade primary school students was examined (Table 3).

Table 3. Level of STEM Learning Activation Among Students

Item	N	Min	Max	M	SD
I would like to be a scientist.	282	1	5	2.97	1.383
I am really good at science.	282	1	5	3.26	1.231
I find new ways to solve problems.	282	1	5	4.22	1.051
I want to make other people like my ideas.	282	1	5	4.30	1.018
I figure out new ways to do things.	282	1	5	4.20	1.011
I like to hear other people's ideas.	282	1	5	3.98	1.245
I want to be an inventor.	282	1	5	3.27	1.454
I'm really good at inventing things.	282	1	5	4.11	1.068
I wish I could build things more often.	282	1	5	4.15	1.089
Science is important.	282	1	5	4.41	1.020
Inventing things is important.	282	1	5	4.28	.986
People who design things we use are important.	282	1	5	4.41	.898
I like to know how things work.	282	1	5	4.36	1.035
Inventing things makes me feel excited.	282	1	5	4.18	1.125

The lowest mean score was obtained for the item *I would like to be a scientist*, whereas the highest mean scores were obtained for the items *Science is important* and *People who design things we use are important.*

Differences in the level of STEM learning activation according to students' gender were subsequently examined (Table 4).

Table 4. Gender Differences in STEM Learning Activation

Item	Gender	N	M	SD	t	df	p
I would like to be a scientist.	Male	148	2.86	1.353	-1.364	280	0.174
	Female	134	3.09	1.411			
I am very good at science.	Male	148	3.16	1.345	-1.338	280	0.182
	Female	134	3.36	1.086			
I find new ways to solve problems.	Male	148	4.18	1.099	-0.741	280	0.459
	Female	134	4.27	.997			
I want to make other people like my ideas.	Male	148	4.27	.994	-0.539	280	0.590
	Female	134	4.34	1.047			
I figure out new ways to do things.	Male	148	4.22	.966	0.245	280	0.806
	Female	134	4.19	1.063			
I like to hear other people's ideas.	Male	148	3.95	1.271	-0.464	280	0.643
	Female	134	4.01	1.220			
I want to be an inventor.	Male	148	3.10	1.511	-2.097	280	0.037
	Female	134	3.46	1.369			
I'm really good at inventing things.	Male	148	4.11	1.047	0.140	280	0.889
	Female	134	4.10	1.096			
I wish I could build things more often.	Male	148	4.05	1.151	-1.595	280	0.112
	Female	134	4.25	1.009			
Science is important.	Male	148	4.39	1.021	-0.397	280	0.691
	Female	134	4.44	1.022			
	Male	148	4.23	.997	-0.965	280	0.335

Inventing things is important.	Female	134	4.34	.974			
People who design things we use are important.	Male	148	4.39	.938	-0.452	280	0.652
	Female	134	4.44	.854			
I like to know how things work.	Male	148	4.26	1.101	-1.736	280	0.084
	Female	134	4.47	.947			
Inventing things makes me feel excited.	Male	148	4.16	1.035	-0.399	280	0.691
	Female	134	4.21	1.221			

The results showed a statistically significant gender difference for only one item, *I want to be an inventor*, with female students obtaining a higher mean score than male students. No statistically significant gender differences were found for any of the remaining items.

Differences in the level of STEM learning activation according to students' place of residence were subsequently examined (Table 5).

Table 5. Differences in STEM Learning Activation by Place of Residence

Item	Place of Residence	N	M	SD	t	df	p
I would like to be a scientist.	Urban	244	2.94	1.379	-1.018	280	0.309
	Rural	38	3.18	1.411			
I am very good at science.	Urban	244	3.30	1.229	1.520	280	0.130
	Rural	38	2.97	1.219			
I find new ways to solve problems.	Urban	244	4.25	1.041	1.055	280	0.292
	Rural	38	4.05	1.114			
I want to make other people like my ideas.	Urban	244	4.32	1.033	0.934	280	0.351
	Rural	38	4.16	.916			
I figure out new ways to do things.	Urban	244	4.20	1.022	0.117	280	0.907
	Rural	38	4.18	.955			
I like to hear other people's ideas.	Urban	244	4.02	1.227	1.571	280	0.117
	Rural	38	3.68	1.338			
I want to be an inventor.	Urban	244	3.32	1.456	1.367	280	0.173
	Rural	38	2.97	1.423			
I'm really good at inventing things.	Urban	244	4.18	1.061	2.816	280	0.005
	Rural	38	3.66	1.021			
I wish I could build things more often.	Urban	244	4.13	1.103	-0.556	280	0.579
	Rural	38	4.24	.998			
Science is important.	Urban	244	4.49	.983	3.263	280	0.001
	Rural	38	3.92	1.124			
Inventing things is important.	Urban	244	4.34	.982	2.277	280	0.024
	Rural	38	3.95	.957			
People who design things we use are important.	Urban	244	4.48	.891	3.110	280	0.002
	Rural	38	4.00	.838			
I like to know how things work.	Urban	244	4.40	1.012	1.795	280	0.074
	Rural	38	4.08	1.148			
Inventing things makes me feel excited.	Urban	244	4.22	1.095	1.377	280	0.170
	Rural	38	3.95	1.293			

The results showed statistically significant differences according to students' place of residence for the following items: *I'm really good at inventing things*, *Science is important*, *Inventing things is important* and *People who design things we use are important*. In all four cases, students living in urban areas obtained higher mean scores than those living in rural areas. No statistically significant differences according to place of residence were found for the remaining items.

Pearson's correlation analysis revealed a weak but statistically significant positive relationship between students' Mathematics grades and their level of STEM learning activation ($r = .171$, $p = .004$), as

well as between their Science grades and STEM learning activation ($r = .179$, $p = .003$). These findings indicate that higher academic achievement in both subjects was associated with slightly higher levels of STEM learning activation. However, the relatively low correlation coefficients ($r \approx .17$) suggest that academic achievement represents only one of several factors associated with students' attitudes toward STEM learning and is not the predominant determinant.

Discussion

The findings of this study indicate that primary school students generally demonstrate a relatively high level of STEM learning activation. From a theoretical perspective, these findings suggest that STEM learning activation at this age should be understood as a general disposition toward STEM learning experiences, providing a foundation for the subsequent development of STEM identity and career aspirations. This finding is consistent with the original study by Dorph et al. (2016), who conceptualized STEM learning activation as a unified construct and demonstrated that interest, competence beliefs, and readiness to engage are interrelated dimensions that collectively facilitate successful participation in STEM learning experiences. Similar findings were reported by Maltese and Tai (2010), who showed that positive early experiences with science are significant predictors of later interest in STEM fields.

The high scores obtained on most items indicate that students recognize the importance of science, value innovation, and demonstrate an interest in understanding the world around them. These findings are consistent with those of Ainley and Ainley (2011), who reported that students' interest in science is closely associated with positive emotional experiences and the meanings they attribute to scientific content. Likewise, DeJarnette (2012) argued that early exposure to STEM activities promotes curiosity and positive attitudes toward science, thereby providing an important foundation for subsequent engagement in STEM fields. These findings can also be interpreted through the lens of the Expectancy–Value Theory (Eccles & Wigfield, 2002), according to which learning motivation depends on individuals' beliefs about their own competence and the value they attribute to a particular activity. Similar conclusions were reached by Lyons (2006) who found that students recognize the importance of scientific knowledge and value its practical applications even when they do not intend to pursue science-related careers.

However, the somewhat lower scores on items related to perceived success in science and the desire to become a scientist suggest that, at this age, students have not yet developed a fully established STEM identity but rather exhibit an initial predisposition toward its development. Similar findings were reported by Archer et al. (2010) who found that children aged 10–11 years expressed positive attitudes toward science and enjoyed science-related activities but did not perceive themselves as future scientists. Likewise, findings from the ASPIRES project (Archer et al., 2013) indicate that children's science aspirations emerge through a long-term developmental process shaped by family influences, school experiences, and broader societal perceptions of science. From the perspective of the concept of science identity (Carlone & Johnson,

2007), the findings indicate that the components of scientific identity are not yet firmly established among primary school students. This interpretation is further supported by Hazari et al. (2010), who argue that science identity develops gradually through experiences of success, recognition by significant others, and opportunities to participate actively in scientific activities. Similarly, Martin-Hansen (2018) emphasizes that STEM identity is not an innate characteristic but rather the outcome of continuous educational and life experiences. Therefore, positive attitudes toward STEM should be regarded as a prerequisite for, rather than an indicator of, a well-developed STEM identity.

The findings can also be interpreted from the perspective of the concept of science capital (Archer et al., 2015). Science capital encompasses the resources, experiences, knowledge, attitudes, and social influences that shape an individual's relationship with science. Accordingly, students' positive attitudes toward STEM are not solely a consequence of academic achievement but develop through interactions among the family, school, peer group, and the broader social environment. The differences observed with respect to place of residence can also be understood within this framework. DeWitt et al. (2016) demonstrated that higher levels of science capital are associated with stronger science aspirations and a greater likelihood that students perceive science as "something for people like me." Likewise, Godec et al. (2024) reported that science capital and STEM identity are significant predictors of subsequent enrollment in STEM degree programs. Similar evidence has been provided by the PISA 2018 studies (OECD, 2019b), which indicate that students from urban areas have greater opportunities to participate in both formal and informal STEM learning experiences.

The absence of significant gender differences across most items is consistent with the findings of Wang and Degol (2017), who argued that gender differences in STEM interests develop gradually throughout schooling under the influence of social expectations and gender stereotypes. Similar conclusions were reached by Master, Cheryan, and Meltzoff (2016) who found that boys and girls in primary school exhibit relatively similar levels of interest in STEM, whereas these differences become more pronounced during adolescence.

The weak but statistically significant association between STEM learning activation and students' achievement in Mathematics and Science suggests that academic achievement represents only one of several factors related to students' orientation toward STEM learning. Similar findings were reported by Dorph et al. (2016) who argued that students' interest and engagement are not direct consequences of academic achievement but are mediated by the quality of instruction and a range of contextual factors. These results are also consistent with the findings of Osborne, Simon, and Collins (2003), who emphasized that positive attitudes toward science are not necessarily a direct outcome of school achievement. The National Research Council (2009) further argued that interest in science develops through a combination of school-based and out-of-school experiences, while Tai et al. (2006) demonstrated that early interest in science is an important predictor of subsequent educational and career choices.

Overall, the findings of the present study are consistent with contemporary research indicating that the early years of primary education constitute a critical period for developing positive attitudes toward STEM fields (Maltese & Tai, 2010; Archer et al., 2015). Students demonstrate curiosity, positive attitudes, and a willingness to explore; however, their career aspirations and self-perceptions in science have not yet fully developed. These findings are consistent with previous research (Archer et al., 2013; DeWitt, Archer, & Mau, 2016), showing that enjoyment of science-related activities is not necessarily accompanied by clearly defined career aspirations but nevertheless provides an important foundation for their later development. According to Archer et al. (2015), the development of science aspirations depends on the accumulation of science capital and the gradual formation of a sense that science is "for people like me." In this respect, STEM learning activation may be regarded as an early developmental prerequisite for the formation of STEM identity and long-term engagement in STEM fields.

Conclusion

The findings of the present study indicate that primary school students generally demonstrate a relatively high level of STEM learning activation, confirming that interest in understanding the world around them; positive attitudes toward science and innovation, and a willingness to engage actively in STEM activities are already evident during the early years of schooling. Viewed as a unified construct, STEM learning activation represents an early disposition toward STEM learning that integrates motivational, affective, and cognitive aspects of students' orientations toward science, providing a foundation for the subsequent development of STEM identity and career aspirations.

The findings further indicate that students largely recognize the importance of science and innovation and display positive attitudes toward STEM-related content. However, their beliefs about their own competencies and their identification with science-related careers are not yet fully developed. This suggests that positive attitudes toward STEM precede the development of a more stable STEM identity and confirms that career aspirations evolve gradually under the influence of educational experiences and the broader sociocultural context.

The absence of significant gender differences across most survey items suggests that boys and girls in the early years of primary education have similar potential for developing interest in STEM. In contrast, the differences observed according to place of residence highlight the importance of educational and sociocultural contexts in shaping students' orientations toward STEM fields. At the same time, the weak but statistically significant association between STEM learning activation and academic achievement indicates that positive attitudes toward STEM learning are not simply a consequence of school success but rather emerge through the complex interaction of individual, school, and family-related factors.

The practical implications of this study point to the need for creating supportive learning environments that enable students to explore, solve problems, collaborate, and gain positive experiences in STEM-related

activities. Particular attention should be given to strengthening students' beliefs in their own competencies and ensuring equitable access to STEM learning opportunities, especially in communities with limited educational resources.

Although the findings provide valuable insights into STEM learning activation among primary school students, it should be acknowledged that the data were based on students' self-reports and were collected within a specific educational context. Future research should include larger and more diverse samples and adopt mixed-methods approaches to gain a deeper understanding of the developmental processes underlying STEM learning activation and its relationship with the formation of STEM identity throughout students' educational trajectories. In particular, longitudinal studies are needed to examine changes in STEM learning activation over time and to investigate how different instructional approaches and educational experiences contribute to the development of sustained interest in STEM fields.

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https://doi.org/10.46793/STEPAM26.018B
Udk: 37.091.3::5/6-027.22
37.091.3::5/6-057.87

OUTDOOR STEAM EDUCATION: OPPORTUNITIES AND CHALLENGES

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Abstract: In contemporary educational conditions, marked by rapid technological, social, and cultural changes, there is an increasing need for teaching approaches that contribute to the development of competencies relevant to the 21st century. The STEAM approach represents an integrative model that connects different disciplines, while outdoor learning provides an authentic context for its implementation through experiential and inquiry-based learning. The research is based on a theoretical analysis of relevant scientific and professional literature dealing with the application of the STEAM approach and outdoor learning in the first cycle of primary education. The findings indicate that outdoor learning represents a stimulating framework for the implementation of STEAM education, as it enables the development of scientific thinking, problem-solving skills, creativity, collaboration, and active student participation. At the same time, certain challenges were identified, such as limited time for lesson implementation, lack of material resources, and insufficient teacher competence for interdisciplinary work in outdoor learning environments. The obtained results suggest that outdoor learning has significant potential for improving STEAM education; however, its successful implementation requires systematic planning, institutional and professional support, as well as continuous professional development for teachers. Overcoming the identified limitations is a prerequisite for the full realization of the potential of this approach in contemporary education.

Keywords: *STEAM education; outdoor teaching; first cycle of primary education.*

Introduction

Contemporary education is increasingly moving away from a model focused on the reproduction of knowledge and turning toward the development of competencies that enable individuals to function in the complex and dynamic conditions of modern society. Critical thinking, creativity, collaboration, and problem-solving skills are recognized as key competencies of the 21st century (Yim et al., 2025; Supianti et al., 2025; Soomro et al., 2026). In this context, there is a growing need for teaching approaches that enable the integration of knowledge and its application in real-life situations.

STEAM education represents one of the most significant contemporary responses to these demands. As an integrative approach, it connects science, technology, engineering, arts, and mathematics, enabling students to develop functional knowledge through solving complex problems (Chappell et al., 2025; Haas et al., 2023). At the same time, outdoor learning provides an authentic context in which such learning can be implemented, as it enables direct experience, inquiry, and the connection of educational content with the environment (Becker et al., 2017; Remmen & Iversen, 2023).

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The integration of these approaches is of particular importance in the first cycle of primary education, where learning is based on activity, play, and experience, and where students are still developing fundamental cognitive and inquiry competencies (Lindfors et al., 2021; Yeong et al., 2013).

STEAM Education: Concept and Pedagogical Foundations

STEAM education represents an approach that goes beyond the traditional subject-based organization of teaching and enables the integration of different disciplines into a unified learning process. Instead of the isolated acquisition of knowledge, the emphasis is placed on its application in solving real-life problems, which contributes to the development of students' functional literacy (Yim et al., 2025).

One of the key theoretical concepts supporting the STEAM approach is the work with so-called "wicked problems," that is, complex problems that do not have simple solutions and require interdisciplinary thinking (Chappell et al., 2025). Such problems encourage students to connect knowledge, analyze different aspects of a situation, and develop creative solutions.

Empirical research indicates that STEAM education has a significant impact on the development of cognitive abilities. A meta-analysis shows that inquiry-based approaches in science teaching significantly improve critical thinking and problem-solving skills (Soomro et al., 2026). In addition, STEAM activities foster creativity, collaboration, and student motivation (Supianti et al., 2025).

From a pedagogical perspective, this approach is based on constructivist learning theories, in which students actively participate in the learning process, ask questions, explore, and draw conclusions (Tuan Soh & Mohd Meerah, 2013). In this way, learning becomes non-linear and includes experimentation, errors, and adaptation of strategies (Colella & D'Arando, 2021). Mistakes and risk become an integral part of the learning process, contributing to deeper understanding (Cure et al., 2018).

However, despite its potential, research highlights significant challenges in the implementation of the STEAM approach. Teachers often lack sufficient competencies for interdisciplinary work, and clear pedagogical guidelines for its implementation are also missing (Yim et al., 2025; Mehdi et al., 2025).

Outdoor Teaching as a Framework for Experiential Learning

Outdoor teaching represents a pedagogical approach based on learning in authentic environments outside the traditional classroom, enabling direct experience as the basis for knowledge acquisition. The environment becomes an active learning resource, and students learn through interaction with natural and social phenomena (Mitic et al., 2022; Mladenović et al., 2015).

Outdoor teaching has multiple educational effects. It contributes to better understanding of learning content, increased student motivation, and the development of social skills (Becker et al., 2017; Remmen

& Iversen, 2023). In addition to cognitive effects, it also has a significant impact on students' physical and mental health, as well as their overall well-being (O'Brien et al., 2011).

The importance of this approach is also reflected in its holistic character. Learning in a natural environment enables the integration of cognitive, emotional, and social aspects of learning, contributing to the development of the student as a whole person (Clarke & Mcphie, 2014). In this way, outdoor teaching goes beyond traditional instructional frameworks and approaches the concept of sustainable education.

Research in science education indicates that outdoor activities promote the development of scientific thinking, as they enable students to observe, ask questions, and draw conclusions based on direct experience (Skalstad & Munkebye, 2022; Arntzen, 2023), which contributes to a deeper understanding of scientific concepts and the development of inquiry skills.

However, although the benefits of outdoor teaching are numerous, its implementation in practice is not uniform. In Nordic countries, this approach is systematically integrated into the teaching process and represents an integral part of the educational system (Lauterbach et al., 2024; Korsager & Gabrielsen, 2024). In contrast, in Serbia, outdoor teaching is often implemented occasionally and without a clear methodological structure (Dubljanin et al., 2019).

Additionally, research shows a gap between teachers' intentions and actual practice, reflected in insufficient integration of theoretical and practical aspects of teaching (Winje & Løndal, 2021). This clearly indicates the need for a systematic approach and support for teachers in planning and implementing outdoor teaching.

Integration of the STEAM Approach and Outdoor Teaching: Potentials and Educational Outcomes

The integration of the STEAM approach and outdoor teaching represents significant pedagogical potential, as it enables the connection of interdisciplinary learning with an authentic context. While STEAM education provides a conceptual framework for knowledge integration, outdoor teaching enables its application through direct experience and inquiry (Haas et al., 2023; Chappell et al., 2025).

In such an environment, students are not passive recipients of knowledge but active participants who achieve understanding through observation, experimentation, and collaboration. Outdoor activities significantly contribute to the development of scientific thinking, as they enable students to recognize patterns, ask questions, and test assumptions in real-life conditions (Wijayanti & Munandar, 2017; Killengreen et al., 2023).

In addition to cognitive effects, the integration of these approaches also has a significant impact on the development of non-cognitive skills. Learning in outdoor environments encourages collaboration, self-confidence, and responsibility, as well as students' willingness to take initiative in the learning process (Richmond, 2016; Richmond et al., 2017).

An important aspect of this integration relates to connecting learning with the local environment. Activities carried out in students' immediate surroundings contribute to greater relevance of teaching and better understanding of content (Remington & Legge, 2016; Torkos & Roman, 2019). In this way, learning becomes meaningful and connected to students' everyday experiences.

Additionally, contemporary approaches emphasize the importance of integrating digital technologies into outdoor learning, which enables the combination of traditional and modern learning, in line with the goals of STEAM education. The use of mobile applications and digital tools enables students to collect, analyze, and present data, further enriching the learning process (Schilhab & Esbensen, 2021).

Research findings show that the integration of the STEAM approach in outdoor teaching contributes to the development of mathematical and scientific literacy, as well as students' character traits such as perseverance and responsibility (Supianti et al., 2025). Overall, this approach has the potential to influence academic achievement as well as the holistic development of students.

Despite numerous advantages, the integration of these approaches requires careful planning and adequate pedagogical support. The lack of structured models and methodological guidelines may lead to superficial implementation that does not produce expected outcomes (Yim et al., 2025). Therefore, it is necessary to develop teaching models that enable effective integration of the STEAM approach and outdoor learning.

Challenges in the Implementation of the STEAM Approach in Outdoor Teaching

Although the integration of the STEAM approach and outdoor teaching has significant potential, its implementation in practice is accompanied by numerous challenges. One of the most significant relates to insufficient teacher preparation for interdisciplinary work and the application of inquiry-based teaching methods. Teachers often lack sufficient competencies for integrating different disciplines, as well as for organizing teaching in outdoor environments (Mehdi et al., 2025; Winje & Løndal, 2021; Nikolić et al., 2025).

In addition, limited material resources and organizational conditions represent a significant difficulty. Lack of time, adequate equipment, and school support often hinders the implementation of outdoor activities (Munawar et al., 2024; Rojo-Ramos et al., 2021), which may lead teachers to avoid such forms of teaching or apply them only to a limited extent.

Another important challenge relates to risk management in outdoor environments. Teachers face dilemmas regarding how to ensure student safety while at the same time allowing sufficient freedom for exploration and experiential learning (Ramey et al., 2024). The balance between risk and safety is one of the key aspects of successful outdoor teaching implementation (Cure et al., 2018).

There is also a problem of insufficient integration of theoretical and practical aspects of teaching

which highlights the need for systematic planning and clear pedagogical models that enable the integration of different forms of learning. Even when there is an intention to implement outdoor teaching, it often remains isolated from the curriculum and does not lead to deeper understanding of content (Winje & Løndal, 2021).

Discussion

The results of the theoretical analysis indicate that outdoor teaching represents an exceptionally stimulating framework for the implementation of STEAM education, as it enables the connection of knowledge with real-life experience and the development of key student competencies. Accordingly, it can be concluded that the authenticity of the environment is one of the most important factors contributing to the effectiveness of this approach (Becker et al., 2017; Remmen & Iversen, 2023).

At the same time, the analysis shows that successful implementation depends on several interconnected factors. First, continuous professional development for teachers is necessary in order to plan and implement interdisciplinary activities (Mehdi et al., 2025). In addition, institutional support plays a significant role, including provision of resources, time, and organizational conditions.

Particular importance is also given to the development of pedagogical models that enable effective integration of the STEAM approach and outdoor teaching. Research indicates that without a clear structure and methodological framework, there is a risk that the full potential of this approach will not be achieved (Yim et al., 2025; Tekakpinar & Tezer, 2019).

It should be emphasized that this approach is particularly important in the first cycle of primary education, as it enables the development of the foundations of scientific literacy and the formation of positive attitudes toward learning. In this sense, outdoor STEAM learning represents an important step toward functional and sustainable education (Lindfors et al., 2021; Yeong et al., 2013; Skalstad & Munkebye, 2022).

Conclusion

STEAM education and outdoor teaching represent complementary approaches with significant potential for improving contemporary education. Their integration enables learning that is simultaneously interdisciplinary, experiential, and problem-oriented.

Especially in the first cycle of primary education, this combination enables the development of scientific thinking, creativity, collaboration, and active student participation in the learning process. Outdoor teaching provides an authentic context for applying the STEAM approach, thereby increasing the relevance and effectiveness of teaching.

However, to fully realize the potential of this approach, it is necessary to overcome the identified challenges. This includes systematic lesson planning, institutional support, and continuous teacher professional development. Only in this way is it possible to fully realize the potential of STEAM education in outdoor learning environments and contribute to the development of competencies relevant to contemporary society.

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https://doi.org/10.46793/STEPAM26.025S
Udk: 373.2::78
373.2::796

MUSIC-MOVEMENT INTEGRATION IN EARLY CHILDHOOD

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Abstract: Contemporary approaches to early childhood education increasingly affirm an integrative approach as a starting point in designing educational practice, with musical and motor activities occupying an important place within a developmentally supportive environment. Although relevant literature indicates a relationship between musical experience and motor development, this relationship has not yet been sufficiently theoretically systematized or methodologically operationalized within the field of preschool education. The paper examines the possibilities of integrating music and movement in early childhood education, based on the content, aims, and tasks of music and physical education, and offers a conceptual framework for their application. In this context, rhythm is emphasized as a structural element that enables the functional integration of musical and motor expression. The "Rhythm–Movement–Development" model is conceived as a conceptual framework that connects musical and motor activities through different levels of complexity. Its contribution is reflected in the systematization of activities, clearer definition of their structure, and the formulation of proposals for their application in work with preschool children. The integration of music and movement is considered in light of existing professional literature, highlighting its significance in the context of improving practice in the fields of music and physical education. The proposed model represents a theoretically grounded and methodologically applicable framework that may serve as a basis for further professional considerations and the advancement of early childhood education practice.

Keywords: *motor development, music, rhythm, early childhood education, integration, physical education*

Introduction

In contemporary scientific literature, early childhood is recognized as a period of critical importance for the formation of neurophysiological, motor, and cognitive foundations of development, with experiences from this period having long-term effects on functional abilities and health later in life (Bala, 2010; Adolph & Hoch, 2019). In particular, motor development at this age is closely linked to the development of cognitive and socio-emotional functions, highlighting the need for integrated approaches in early childhood education and care. At the same time, modern lifestyles are characterized by a significant reduction in children's physical activity, accompanied by increased time spent in sedentary behaviors. This trend has led to increasingly frequent motor development problems, such as reduced coordination, poor postural control, and delays in the acquisition of fundamental motor skills (World Health Organization, 2019; Gallahue, Ozmun & Goodway, 2019; Haywood & Getchell, 2020; Payne & Isaacs, 2017).

In this context, preschool institutions play a key role in creating a stimulating environment that supports adequate motor development and prevents potential developmental delays. Parallel to these findings, research in neuroscience and developmental psychology indicates a strong connection between

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music and motor functions. Musical stimuli, particularly rhythm, activate not only auditory but also motor brain regions, including the premotor cortex, basal ganglia, and cerebellum (Chen, Penhune & Zatorre, 2008; Patel, 2014). This neurofunctional connectivity enables the phenomenon of sensorimotor synchronization, which underlies the coordination of movement with rhythmic stimuli and plays a significant role in the development of coordination and temporal organization of movement.

Despite clear scientific evidence of the connection between music and movement, in preschool practice these domains are most often treated as separate pedagogical units. Music activities are mainly oriented toward listening and reproduction, while physical activities are implemented independently of the musical context (Barrett, 2006). Such segmentation limits opportunities for the integrated development of children and highlights the lack of systematically designed approaches that would connect these two domains.

Although an increasing number of studies point to the positive effects of musical activities on various aspects of development, the integration of music and motor development in preschool education is still insufficiently theoretically elaborated and practically systematized. In particular, there is a noticeable lack of conceptual models that would enable a clear understanding of the mechanisms of music–movement interaction and their application in educational practice.

Based on the above, this paper aims to critically examine, through the analysis of contemporary scientific knowledge, the role of music in the motor development of preschool children, and to propose an integrative model that may contribute to the improvement of educational practice. Special emphasis is placed on rhythm as a key mediating factor between auditory and motor processes. This factor may significantly contribute to the development of coordination, movement control, and cognitive functions.

Theoretical Frameworks of Music–Movement Relations

The relationship between music and movement is one of the central topics in contemporary interdisciplinary research spanning neuroscience, developmental psychology, and kinesiology. Unlike traditional approaches that considered music exclusively as an auditory phenomenon, contemporary research points to the existence of a complex auditory–motor network in which musical stimuli are processed through the interaction of multiple functional brain systems (Chen et al., 2008). Neurophysiological findings consistently show that even passive listening to rhythmically structured music leads to the activation of motor areas, including the premotor cortex, supplementary motor area (SMA), basal ganglia, and cerebellum. This activation is not incidental but reflects internal mechanisms of temporal prediction that enable the organism to recognize rhythmic patterns and prepare motor responses (Chen et al., 2008; Grahn & Brett, 2007). The ability of prediction represents a foundation for movement coordination and the temporal organization of motor activity. In this context, the concept of sensorimotor

synchronization represents a central theoretical framework for understanding music–movement relationships. It refers to the ability to align movements with external rhythmic stimuli, resulting in precise temporal coupling between auditory input and motor output (Repp & Su, 2013). Research shows that this ability develops early in life and is present already in the first years, indicating its biological basis. Developmental neuroscience further indicates that rhythm plays a specific role in organizing motor behavior by structuring movement in time. Contemporary studies emphasize that rhythm is one of the key elements enabling the coupling of musical experience and movement (Grahn, 2012; Repp & Su, 2013), which is particularly important for the development of coordination and motor control. These findings suggest that music, and especially its rhythmic structure, can function as an external "timing mechanism" that facilitates movement organization.

From a developmental perspective, research shows that children spontaneously respond to rhythmic stimuli through movement, representing one of the earliest forms of integration between sensory and motor systems. This early connection suggests that music may function as a natural modulator of motor development, particularly in the domain of coordination and movement control.

In addition, numerous studies emphasize that movement-based musical activities represent a significant stimulus for the motor development of preschool children. Through rhythm games, movement to music, and various forms of musical expression, children develop coordination, spatial orientation, and movement control, while musical experience and motor activity are realized as a unified process of learning and development (Jaques-Dalcroze, 2000; Zachopoulou et al., 2004; Hallam, 2010). However, despite strong theoretical and empirical evidence of the connection between music and movement, this relationship is still insufficiently conceptually articulated in pedagogical practice. There is a lack of integrative models that connect neurophysiological mechanisms with pedagogical application, representing a significant research and practical challenge.

It may be concluded that the connection between music and movement is not only functional but represents a deeply rooted biological and cognitive mechanism with significant potential for enhancing motor and overall child development. On this basis, contemporary pedagogical approaches can be developed that integrate music and movement to improve developmental outcomes.

Pedagogical Aspects and Challenges in Preschool Practice

Despite the growing body of scientific evidence highlighting the importance of integrating music and motor activities, traditional, segmented approaches to organizing educational work still dominate preschool practice. Music and physical education are most often implemented as separate domains with different goals, methods, and scheduling, which limits their synergistic effects on child development. Such practice is not aligned with contemporary pedagogical concepts emphasizing a holistic approach to

development and learning. Modern preschool curricula are increasingly based on the integration of different developmental domains, emphasizing experiential learning, activity, and play as fundamental forms of children's engagement. In this context, music–movement activities represent a natural form of integrated learning, as they simultaneously engage multiple developmental domains. One of the major challenges in practice relates to insufficient teacher training for the implementation of integrated approaches. Research shows that in pre-service teacher education, musical and physical competencies are often developed separately, which is later reflected in practice. As a result, musical activities are frequently reduced to reproductive forms (singing, playing instruments) and listening, while motor activities are conducted without using music as a supportive contextual factor.

Furthermore, there is a lack of structured and scientifically grounded programs that would enable systematic implementation of music and movement activities. In most cases, activities are carried out spontaneously, without clearly defined objectives or monitoring of developmental outcomes, which reduces their effectiveness.

In this sense, the contemporary challenge of preschool education lies in the need to redefine the role of music and movement within the educational process and to develop integrated models that enable their systematic and purposeful application. In response to these shortcomings, this paper proposes the conceptual model "rhythm–movement–development," aimed at a more systematic understanding and enhancement of the relationship between music and motor development in early childhood, where rhythm, as the basic and most accessible element of musical expression, acts as a stimulus for movement and its temporal organization.

The "Rhythm–Movement–Development" Model

The "rhythm–movement–development" model represents a dynamic and multilayered system in which musical rhythm is used as a temporal and organizational framework for shaping, guiding, and coordinating movement. The model is based on the understanding that music, particularly its rhythmic component, plays a significant role in structuring motor expression and linking musical experience with movement in order to support motor development (Robinson et al., 2015; Barnett et al., 2016). At the same time, in accordance with approaches in music pedagogy, rhythm is viewed as a fundamental element of musical expression that is most naturally acquired through movement and bodily activity (Jaques-Dalcroze, 2000; Orff & Keetman, 2000; Kodály, 1974). In this sense, rhythm is not treated solely as a musical parameter but as an integrative factor enabling functional connections between musical and motor domains in educational practice.

The program is designed as a system of interconnected levels encompassing perceptual, sensorimotor, motor, and musical aspects of activity, with integration achieved through practical

implementation in music–movement content and gradual progression from simple to more complex forms.

The perceptual level refers to auditory perception and discrimination of basic rhythmic characteristics of music (tempo, pulse, accent), which forms the basis for understanding and experiencing musical flow (Repp & Su, 2013; Kodály, 1974). Activities include listening, imitation, and simple rhythmic responses.

The sensorimotor level involves the synchronization of movement with the rhythmic structure of music through basic forms of locomotion (walking, hopping, clapping), thereby establishing a functional connection between musical impulse and bodily response (Morillon & Baillet, 2017; Jaques-Dalcroze, 2000).

The motor level includes the execution of organized movement structures in accordance with rhythm, with gradual complexity and integration into meaningful sequences with clear temporal and spatial organization, in line with the concept of motor competence (Barnett et al., 2016).

The musical level refers to the development of basic musical elements through movement, including rhythm perception, memory, and reproduction of simple rhythmic patterns, as well as understanding the relationship between music and movement. These activities foster musical sensitivity, expressiveness, and understanding of musical flow, as well as the gradual formation of musical competencies appropriate to children's age (Orff & Keetman, 2000; Kodály, 1974; Repp & Su, 2013).

Rhythmic musical content, due to its structure and clarity, naturally initiates and guides movement, enabling children to experience and understand musical flow through bodily action. In this process, movement is not merely a response to musical stimulus but becomes a means of expression, organization, and acquisition of musical content. When pedagogically structured and methodically guided, such movement contributes both to the improvement of motor functioning and to the development of fundamental elements of musical culture. Thus, rhythm in the proposed model is established as a key mediator between musical experience and motor development.

The main goal of the program is to promote holistic child development through the functional integration of music and movement, with particular emphasis on linking rhythmic musical expression and motor functioning. The program aims to:

- develop motor expression through rhythmically organized movement,
- improve coordination between movement and musical flow,
- develop a sense of rhythm as a fundamental element of musical culture,
- develop music–movement expression appropriate to children's age.

In line with these goals, the program includes the following operational objectives:

- enabling children to recognize and differentiate basic rhythmic structures,
- developing the ability to synchronize movement with music,
- improving control and organization of movement under different rhythmic conditions,

- encouraging music–movement expression through various activities,
- developing basic elements of musical education through movement.

The program is implemented through structured activities lasting 15 to 25 minutes depending on age and includes:

- Introductory phase (musical activation): focusing attention on rhythm and musical flow through listening and simple movement.
- Main phase (music–movement realization): performing activities that connect music and movement through various forms of locomotion.
- Final phase (music–movement integration): activities that encourage independent expression and musical experience through movement.

The program includes different levels of complexity:

- basic level – movement in simple rhythm,
- intermediate level – adaptation to different tempos,
- advanced level – combining movements into rhythmic units,
- higher level – execution of complex music–movement structures,
- creative level – independent movement creation in response to music.

Formulated in this way, the model enables a clearer understanding of the integration of music and movement, with emphasis placed on their mutual interconnectedness in the function of development, drawing on relevant scientific and methodological knowledge, without entering domains that go beyond the scope of music and physical education methodology. Table 1 presents an example of a program unit.

Table 1. *Example of a Program Unit*

<table>
<tr><td colspan="2">Activity title: Rhythm and Movement</td></tr>
<tr><td colspan="2">Age group: 5–6 years</td></tr>
<tr><td colspan="2">Duration: 20 minutes</td></tr>
<tr><td colspan="2">Objectives:
- development of a sense of rhythm and rhythmic movement,
- development of motor expression through rhythmic movement,
- improvement of coordination between movement and music.</td></tr>
<tr><td colspan="2">Activity structure:</td></tr>
<tr><td>Introductory part</td><td>Children move in accordance with a simple rhythm (walking, hopping, light movements) accompanied by music.</td></tr>
<tr><td>Main part</td><td>Different musical elements are introduced:
- change of tempo → change in movement patterns
- different rhythms → different movements
- combining movements into short sequences</td></tr>
<tr><td>Final part</td><td>Children independently create movements in response to music, with an emphasis on expressiveness.</td></tr>
<tr><td colspan="2">Expected outcomes:
- improved sense of rhythm,
- development of music–movement expression,
- increased engagement and motivation of children.</td></tr>
</table>

The practical value of the proposed program is reflected in the fact that it enables a clearly structured application within the domains of music and physical education, it also enables a systematic integration of

musical and motor content through various forms of activities (rhythmic games, movement to music, and elements of dance expression), as well as the gradual introduction of increasingly complex music–movement demands. In this way, a foundation is created for integrated and meaningful learning in early childhood education.

The proposed model may indicate the significant role of music in promoting children's motor development, which is consistent with findings from numerous studies (Gerry et al., 2012; Tierney & Kraus, 2013) supporting the concept of sensorimotor integration. However, despite the existence of a considerable number of studies highlighting the positive effects of music, there is still a lack of research that systematically examines the integration of music and movement in the context of preschool education. Existing research tends to focus on isolated effects, without a clear conceptual framework linking different aspects of development. In this sense, the proposed "rhythm–movement–development" model represents an attempt to bridge this research gap through the integration of existing scientific knowledge and its application in pedagogical practice. A particular value of the model lies in its structured design and its applicability across different levels of activity complexity.

Accordingly, the implementation of music–motor integration in preschool education requires a systemic approach involving changes at multiple levels. First, it is necessary to integrate musical and motor activities into daily practice, rather than planning them in isolation. It is also important to enhance educators' competencies through professional training, enabling them to apply contemporary approaches in working with children. The development of new programs and materials that combine music and movement represents another important step in this process. Finally, it is essential to encourage further research in this field in order to ensure a solid scientific foundation for the continued development of practice.

Concluding Remarks

The integration of music and movement represents an important but still insufficiently systematized and methodologically developed component of preschool education. The analysis of relevant theoretical and methodological foundations indicates that rhythm, as a fundamental element of musical expression, has particular potential in organizing and guiding movement, thereby establishing a functional link between musical experience and motor development.

In this context, the proposed "rhythm–movement–development" model represents an attempt to conceptualize and operationalize this relationship within educational practice. Its value lies in enabling systematic integration of music and physical education content through clearly defined activity levels and gradual progression of complexity.

The model is particularly significant due to its practical applicability in preschool settings, where it

may contribute to enriching existing practices and improving the quality of the educational process. At the same time, it opens possibilities for further professional and scientific exploration of music–movement integration and for the development of methodological approaches that more effectively connect music and physical education in early childhood.

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https://doi.org/10.46793/STEPAM26.034S
Udk: 37.091.39:004.8

WILL ROBOTS REPLACE TEACHERS? TEACHERS' OPINIONS ON THE IMPACT OF ARTIFICIAL INTELLIGENCE ON THE TEACHING PROFESSION WITHIN THE STE(P)AM APPROACH

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Abstract: This paper analyzes the impact of the application of artificial intelligence (AI) in education, particularly from the perspective of the teachers who follow STEPAM approach in teaching with particular attention to professional status, well-being, instructional efficiency and effectiveness, and expectations for future development. With the development of AI in recent years, the debate in both professional circles and the broader public about the possibilities and risks of its use in education has been revived. Hence, the title alludes to the decades-long concern that one day robots might replace teachers. The first part of the paper provides an overview of recent relevant research on the effects of AI in education. The findings of these studies are critically analyzed in order to arrive at more objective insights into the real effects of AI in education. The second part analyzes the results of an empirical pilot study examining teachers' opinions on the effects of AI on education and on their own profession. Preliminary results indicate that teachers are aware of the inevitability of AI in education and the changes it brings, but they generally believe that AI will not replace teachers. They also point to potential risks and misuse of AI in education.

Keywords: *Effects of AI in education, technology and education, teaching profession, STEPAM approach in teaching*

Introduction

The rapid expansion of artificial intelligence (AI) has reached one of society's most important and consequential professions - teaching and education in general. Since the release of widely accessible generative AI systems in late 2022, educational institutions have moved from experimentation to routine in using AI. Many national survey data illustrate the pace of this shift. In USA, RAND Corporation research found that the share of English language arts, math, and science teachers using AI tools for instructional planning or teaching roughly doubled between the 2023–2024 and 2024–2025 school years, with comparable increases among students, school leaders, and district administrators (Doss et al., 2025; Kaufman et al., 2025). Gallup and the Walton Family Foundation similarly reported that six in ten U.S. public school teachers used an AI tool for their work during the 2024–2025 school year (Gallup, 2025). What began as a peripheral curiosity, has within roughly three years, become an important part and infrastructural feature of the profession.

This normalization raises questions beyond classroom teaching methodologies including approaches like STEM/STEAM/STREAM and most recently STEPAM approaches in education. It should be noted that STEPAM (Science, Technology, Engineering, Physical Activities, Arts & Mathematics) is an expanded and recently developed concept of integrative education in Serbia that goes beyond traditional

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disciplinary frameworks. This approach is based on connecting scientific, technological, artistic fields with physical education, with the aim of comprehensive personality development of preschool teachers, which includes cognitive, creative, physical, social and emotional dimensions.

Because teaching is simultaneously a craft, a labor-market position, and an important socially recognized and revered profession, AI touches several loosely connected dimensions of teachers' working lives at once. For example, it changes what tasks teachers perform and how long they take, reshapes how teachers feel about their work, unsettles assumptions about what only a human educator can do, with consequences for professional status and labor market, and it generates divided opinions among teachers about whether these changes are, on balance, beneficial. This introduction reviews findings across four interrelated areas: status and labor market, efficiency and effectiveness, satisfaction and well-being, and teacher opinion on how often, and for what purposes, they use AI.

Theoretical background

AI and the Status of the Teaching Profession

Teaching has long been characterized in the social science as an occupation with only partial or contested professional status, lacking some of the exclusive expertise claims and market controls enjoyed by professions such as medicine or law (Mehta, 2013, as cited in Parker, 2024). Parker (2024) argues that the growing presence of AI in schools intensifies this vulnerability rather than resolving it. In a perspective essay published in The Clearing House, Parker (2024) contends that public discourse about AI in education has focused heavily on efficiency and workload relief, on the promise that AI will make teachers' jobs easier. He warns this framing risks devaluation: if the public comes to see much of what teachers do as automatable, it becomes harder to argue for higher pay, smaller classes, or greater professional autonomy. In this reading, the central threat AI poses to teaching is not wholesale replacement, but a slower erosion of perceived indispensability and professional standing.

Some analysts suggest that AI disruption in other white-collar sectors could, paradoxically make teaching relatively more attractive to new entrants, particularly if AI closes off entry-level positions in fields such as consulting or software development (Fordham Institute, 2025). Under this view, a surge in prospective teachers could improve the eventual quality of the teaching workforce, provided schools can absorb this larger applicant pool. Cross-sectoral evidence on AI and skilled labor indicates that an occupation's exposure to AI depends on the composition of its underlying tasks (Kaufman et al., 2025). Because teaching combines tasks that resist automation, such as relationship building, with tasks highly amenable to AI assistance, such as drafting materials, its labor market trajectory is likely to differ from more routinized occupations.

AI and Teaching Efficiency and Effectiveness

The strongest and most consistent empirical claims about AI's impact on teaching concern time savings and instructional efficiency. In the 2025 Gallup–Walton Family Foundation survey of 2,232 U.S. public school teachers, those who used AI tools at least weekly reported saving an average of 5.9 hours per week, equivalent to roughly six weeks of working time over a school year (Gallup, 2025). A systematic review of 28 empirical studies on generative AI in pedagogical practice, published between 2022 and 2024, reached a broadly consistent conclusion: generative AI tools improved instructional efficiency by supplying rapid feedback and personalized learning materials, while supporting learner engagement, motivation, and idea generation (Leng, 2025).

Evidence on instructional effectiveness, as distinct from efficiency, is more qualified. The same review identified persistent concerns about the accuracy of AI-generated content, algorithmic bias, threats to academic integrity, and unresolved questions about whether AI-assisted instruction reliably improves learning outcomes (Leng, 2025). This distinction, between efficiency gains, which appear well documented, and effectiveness gains, which remain contested, is a recurring theme that cautions against treating faster task completion as equivalent to better teaching or learning.

AI and Teacher Job Satisfaction and Well-Being

Findings on job satisfaction and well-being are notably mixed, suggesting that AI's psychological impact depends heavily on how it is implemented rather than on its mere presence. Several studies report positive associations. Huang and Zhao (2025), surveying 511 university faculty members through the lens of self-determination theory, found that AI literacy was positively associated with faculty members' sense of autonomy, competence, and relatedness, which in turn supported better work and life balance and, through perceived autonomy specifically, higher job satisfaction. Related research cited within that study similarly links higher AI literacy to improved teaching effectiveness and reduced burnout (Hashem et al., 2024, as cited in Huang & Zhao, 2025).

Other studies point toward the opposite pattern. Research on middle school teachers in China found that AI integration introduced measurable stress, driven largely by role conflict, as teachers were expected to remain subject experts and classroom managers while also learning to operate, supervise, and troubleshoot new AI systems (Wu et al., 2025). This so-called technostress was associated with burnout, reduced job satisfaction, and resistance to further AI adoption. Taken together, this research suggests satisfaction hinges less on AI's mere presence than on institutional support, workload manageability, and whether AI genuinely offloads low-value tasks rather than adding new technical responsibilities.

Teacher Opinions on the Use of AI in Education

Survey research on teacher attitudes toward AI reveals a profession that remains largely unconvinced of AI's net benefit, even as adoption continues to rise. A Pew Research Center survey of 2,531

U.S. public school teachers, conducted in fall 2023, found that a quarter of respondents believed AI tools did more harm than good, compared with only 6% who believed AI did more good than harm; another third saw a roughly even mix of benefit and harm, and over a third said they were unsure (Lin, 2024). Skepticism was not evenly distributed: high school teachers were considerably more likely than elementary teachers to view AI negatively (35% versus 19%), while elementary teachers were most likely to report genuine uncertainty (Lin, 2024), suggesting that concern may intensify with the stakes of subject-matter instruction.

Notably, this skepticism coexists with substantial personal use of AI tools by the same population, and with broad support for AI-related instruction; national surveys find that most teachers favor teaching students about the ethical use of AI even while ambivalent about AI's classroom benefits overall (Kaufman et al., 2025). This tension, between guarded evaluative judgments and steadily rising personal adoption, is a striking and underexplored feature of the evidence base, underscoring the need to distinguish teachers' opinions about AI in education from their behavioral engagement with it.

Frequency and Patterns of AI Use Among Teachers

Quantitative evidence on the frequency and character of teacher AI use has accumulated rapidly since 2023, primarily through large-scale panel surveys by RAND, Gallup, and Pew. RAND's American Teacher Panel data show that the share of English language arts, math, and science teachers using AI for instructional planning or teaching rose from about a quarter in 2023–2024 to 53% in 2025, with progressively higher adoption from elementary to middle to high school (Doss et al., 2025; Kaufman et al., 2025). Gallup and the Walton Family Foundation similarly found that 60% of K–12 teachers used an AI tool for their work in 2024–2025, with 32% using it at least weekly and 28% monthly or less (Gallup, 2025).

Regarding specific use cases, the evidence converges on a consistent hierarchy of tasks. Instructional preparation, such as drafting lesson plans, generating worksheets, and adapting materials to meet individual student needs, is consistently reported as the most common application, followed by administrative work such as communication and record-keeping (Gallup, 2025). Despite this rapid growth in usage, professional development and policy guidance have not kept pace: as of spring 2025, fewer than half of school principals reported having district policies on AI use, and roughly two-thirds of surveyed teachers reported receiving no formal training, with many describing themselves as self-taught (Doss et al., 2025).

Taken together, the reviewed literature indicates that AI's influence on the teaching profession is neither uniformly positive nor negative, but is instead unevenly distributed across the dimensions of status, efficiency, well-being, and opinion, and is moderated by factors such as school level, institutional support, and the specific tasks to which AI is applied. Rapid adoption has outpaced both the governance structures meant to guide it and the profession's own settled judgment about its long-term implications

Research Design and Methodology

This study was designed as small-scale descriptive pilot research aimed at exploring primary school teachers' perceptions of the role and impact of artificial intelligence (AI) on their professional status, personal well-being, and the efficiency and effectiveness of the teaching process. The study was not intended to provide a definitive or comprehensive assessment of the influence of AI on the teaching profession. Such an objective would be unrealistic given the complexity and rapidly evolving nature of AI technologies, as well as the multitude of interrelated variables that cannot be adequately examined within a single descriptive study. Consequently, the scope of the research was deliberately limited to the perceptions of a specific population of primary school teachers in Serbia who implement STEM, STEAM, STREAM, or STE(P)AM approaches in their teaching practice.

The decision to focus on this particular group of teachers was motivated by the growing adoption of integrated STEM-related pedagogical approaches in Serbian primary schools. In recent years, an increasing number of teachers have incorporated one or more of these approaches into their instructional practice, frequently through collaborative school-based initiatives and the extensive integration of information and communication technologies (ICT). Given that these teachers are generally more engaged with educational innovation and digital technologies, they constitute an appropriate population for examining perceptions of the current and prospective impact of AI on the teaching profession and educational practice.

In accordance with the defined research problem, the general objective of this study was to examine the perceptions of primary school teachers in Serbia regarding the impact of artificial intelligence on the teaching profession and on the implementation of STE(P)AM and related educational approaches. To achieve this objective, the study addressed the following research tasks:

* To examine the extent to which primary school teachers use artificial intelligence in their professional practice.
* To investigate teachers' perceptions of the impact of AI on their professional status and position within the labor market.
* To examine teachers' perceptions of the effects of AI on their well-being, job satisfaction, and work motivation.
* To investigate teachers' opinions regarding the influence of AI on the efficiency and effectiveness of teaching within STE(P)AM and related educational approaches.
* To explore teachers' expectations concerning future trends in the adoption of AI and its potential implications for the teaching profession and education more broadly.

A purpose-designed questionnaire consisting of 14 items was developed for the purposes of this study. The first three items collected demographic and professional information, including respondents' gender, years of teaching experience, and place of employment. An additional item explicitly asked

respondents whether they use AI in their professional practice. The remaining ten items were formulated as statements assessed using a five-point Likert scale, ranging from 1 ("strongly disagree") to 5 ("strongly agree"). The internal consistency of the instrument was evaluated using Cronbach's alpha coefficient. The obtained reliability coefficient ($\alpha = 0.7893$) indicates satisfactory internal consistency, suggesting that the instrument is sufficiently reliable for the purposes of this pilot study.

Data were collected between April and June 2026. The questionnaire was distributed electronically via e-mail and social media groups dedicated to teachers and educators. The final sample comprised 188 primary school teachers from seven schools located in five Serbian cities (Kragujevac, Jagodina, Paraćin, Ćuprija, and Svilajnac). All participants identified themselves as teachers who regularly implement STE(P)AM or conceptually related instructional approaches in their teaching practice.

More than three-quarters of the respondents were female, reflecting the well-established gender distribution within the Serbian primary education workforce and indicating that the sample closely corresponds to the demographic structure of the target population.

Data analysis and interpretation

This section presents the results of the descriptive empirical study outlined in the methodology section, conducted on a sample of 188 primary school teachers in Serbia.

At the outset, it is important to note that the data analysis revealed no statistically significant differences in the responses of teachers with respect to gender, years of teaching experience, or place of residence. Consequently, these results are not presented, as they do not provide meaningful insights relevant to the aims and research questions of the study.

In contrast, the statistical analysis identified a significant difference between the opinions of teachers who use artificial intelligence in their professional practice and those who do not. Figure 1 illustrates the distribution of teachers according to this variable.

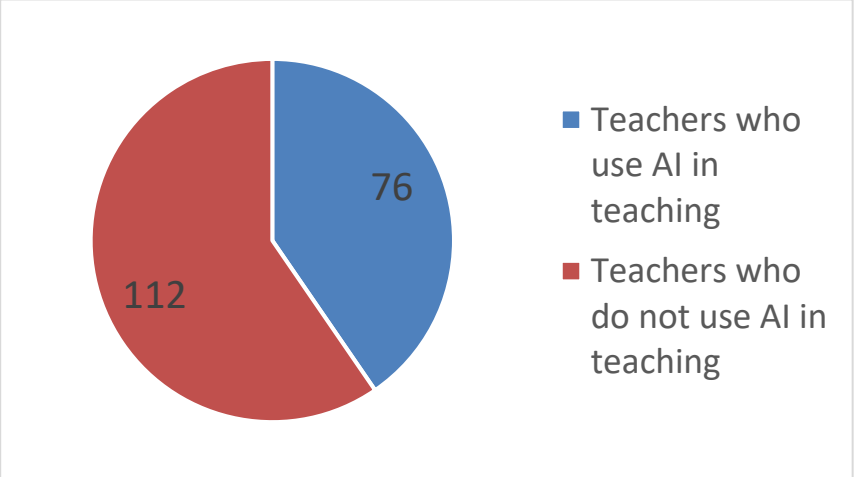

Figure 1. Distribution of teachers according to are the they use AI in the teaching practice

Given that the perceptions of teachers who use AI may differ substantially from those of teachers who do not, the present analysis focuses specifically on these two groups. Each survey statement is analyzed separately to facilitate a direct comparison between teachers with and without firsthand experience of using AI in their professional practice.

The group of teachers who do not use AI (N = 112) is slightly larger than the group of teachers who do use AI (N = 76). This finding suggests that AI has not yet become a dominant tool in educational practice. Nevertheless, the proportion of teachers who already use AI is far from negligible, particularly considering that AI is a relatively recent phenomenon whose adoption is expanding rapidly.

The following table presents the mean scores for each statement measured on a Likert-type scale, together with the corresponding statistical significance parameters. It should be noted that each statement was deliberately designed to correspond to a specific research objective, thereby enabling more precise analysis, interpretation, and conclusion drawing.

Furthermore, some statements were intentionally phrased in a positive manner, while others were framed negatively. This approach was adopted to encourage teachers to respond based on their underlying sentiments, as the emotional dimension of teachers' attitudes toward AI constitutes an important aspect of the present study.

Table 1. Teachers' opinions on the impact of artificial intelligence on the teaching profession separated between teachers who use, and teachers who do not use AI.

No.	Statements	Teachers who use AI in teaching (N=76)		Teachers who do not use AI in teaching (N=112)		t-test (df)	p-value	Sig. diff. (p<.05)
		M	SD	M	SD			
1.	AI will affect teachers' position in the labor market.	4.21	0.67	4.34	0.57	t(143)=-1.39	.168	No
2.	AI will lead to greater layoffs of teachers and educational staff.	2.87	0.71	4.26	1.01	**t(186)=-11.08**	**<.001**	**Yes**
3.	AI will completely replace teachers in the traditional sense.	2.23	0.87	3.78	0.96	**t(171)=-11.49**	**<.001**	**Yes**
4.	AI will negatively affect teachers' well-being.	3.05	0.76	3.67	0.85	**t(172)=-5.23**	**<.001**	**Yes**
5.	AI will negatively affect job satisfaction.	2.67	0.54	3.77	0.69	**t(182)=-12.23**	**<.001**	**Yes**
6.	AI will negatively affect teachers' motivation for pedagogical work.	2.76	0.74	3.46	0.87	**t(177)=-5.92**	**<.001**	**Yes**
7.	AI will positively affect the efficiency of teachers' work (saving time and resources).	4.07	1.12	3.88	0.95	t(143)=1.21	.227	No
8.	AI will positively affect the effectiveness of teachers' work (actual pedagogical outcomes).	3.56	0.78	2.76	0.56	**t(126)=7.70**	**<.001**	**Yes**
9.	AI will compel teachers to engage in continuous professional development in the field of ICT.	4.46	0.55	4.32	0.55	t(161)=1.71	.089	No

No.	Statements	Teachers who use AI in teaching (N=76)		Teachers who do not use AI in teaching (N=112)		t-test (df)	p-value	Sig. diff. (p<.05)
		M	SD	M	SD			
10.	AI will lead to a decline in the quality of education across society.	2.87	0.76	3.88	0.65	**t(144)=-9.47**	**<.001**	**Yes**

Welch's independent-samples t-test is calculated (unequal variances, since the two groups' SDs differ noticeably) for all 10 statements, using M, SD, and N for each group (N=76 AI users vs. N=112 non-users). Statistically significant differences (p<.05) were found for 7 of the 10 statements (highlighted in the table). No significant difference was found for 3 statements (not highlighted). In all significant cases, teachers who don't use AI reported higher agreement with the negatively-framed statements (layoffs, replacement, well-being, satisfaction, motivation, quality decline), while AI users rated the effectiveness statement (#8) higher, suggesting AI users hold more optimistic and less fearful views overall.

To gain a more precise understanding of the views held by both groups of teachers regarding the role of AI in the teaching profession and in education more broadly, it is necessary to examine the results for each statement in greater detail:

Statement 1. AI's effect on labor market position. Both groups sit around 4.2–4.3 (agree). Both AI users and non-users similarly believe AI will affect their position in the job market. No significant difference (p = .168), this is a shared concern regardless of AI use.

Statement 2. AI will lead to layoffs. AI users are near neutral (2.87), non-users lean toward agreement (4.26). This is one of the largest gaps in the whole table. Teachers who don't use AI are considerably more worried about job losses; hands-on users are far less alarmed, possibly because they see AI as a tool rather than a replacement threat.

Statement 3. AI will completely replace teachers. AI users disagree (2.23), non-users are near agreement (3.78). Non-users are notably more fearful of full replacement, while users — likely because they have seen AI's actual limitations, reject this idea more strongly.

Statement 4. Negative effect on well-being. AI users are near neutral (3.05), non-users lean agree (3.67). Non-users anticipate more personal strain from AI; users report less concern, again consistent with firsthand familiarity reducing perceived threat.

Statement 5. Negative effect on job satisfaction. Similar pattern: users lean disagree (2.67), non-users lean agree (3.77). Non-use is associated with more pessimism about how AI would affect satisfaction at work.

Statement 6. Negative effect on motivation. Users near neutral-low (2.76), non-users neutral-agree (3.46). Same direction as above: non-users expect more of a motivational hit from AI than users do.

Statement 7. Positive effect on efficiency (time/resources). Both groups agree fairly strongly (4.07 vs 3.88). No significant difference (p = .227), everyone, regardless of usage, sees AI as a time-saver. This

is common ground.

Statement 8. Positive effect on effectiveness (actual pedagogical outcomes). Users agree (3.56), non-users are more neutral-low (2.76). This is the one case where AI users are more positive than non-users, and it's significant. Actually, using AI seems to translate into believing it improves real teaching outcomes, not just saves time, non-users are less convinced of that deeper value.

Statement 9. AI will compel continuous ICT professional development. Both groups agree strongly (4.46 vs 4.32), and there's no significant difference (p = .089). Nearly everyone, user or not, accepts that AI will require ongoing upskilling.

Statement 10. AI will lead to decline in education quality. Users disagree (2.87), non-users lean agree (3.88). Another strongly significant gap: non-users are notably more pessimistic about AI's broader impact on educational quality; users are more skeptical of that narrative.

On negatively formulated statements (layoffs, replacement, well-being, satisfaction, motivation, quality decline), non-users consistently score higher, i.e., more worried/pessimistic, while users score lower. On shared, non-threatening statements (labor market awareness, efficiency gains, need for ICT development), both groups agree similarly and differences are not significant. And on the one item capturing actual effectiveness of AI in teaching (#8), users are the more convinced group. Taken together, direct experience with AI appears to be associated with less fear and more (cautious) confidence in its practical value, while those without hands-on use hold more apprehensive views.

Data in table 2 shows aggregated values across the 10 attitude statements. Highlighted gray rows indicate a notable or statistically meaningful difference between the two groups.

Table 2. Summary of Key Data: Teachers Who Use AI vs. Teachers Who Do Not Use AI

Summary Measure	**Teachers who use AI (N=76)**	**Teachers who do not use AI (N=112)**	**Difference (No AI − AI)**
Sample size (N)	76	112	/
Overall mean across all 10 statements (grand mean, scale 1–5)	3.27	3.81	**+0.54**
Average standard deviation across statements	0.75	0.77	+0.02
Mean. Negatively framed statements (job loss, replacement, well-being, satisfaction, motivation, quality decline; 6 items)	2.74	3.80	**+1.06**
Mean. Positively framed statements (efficiency, effectiveness; 2 items)	3.82	3.32	**−0.50**
Mean. Neutral/awareness statements (labor market impact, need for ICT development; 2 items)	4.33	4.33	0.00
Number of statements rated ≥3.5 (leaning agree/agree)	4 of 10	8 of 10	**+4**
Number of statements with statistically significant group difference (p<.05)	7 of 10	7 of 10	/

The core takeaway of summarized data is that non-users are more apprehensive overall, mainly because they score much higher on fear-based statements, while AI users are more confident specifically about AI's practical effectiveness — and both groups see eye-to-eye on the neutral, non-threatening items.

Discussion

The present findings, drawn from a survey of Serbian teachers comparing those who use AI in their teaching (N = 76) to those who do not (N = 112), reveal a consistent pattern. Teachers without direct AI experience report significantly stronger agreement with threat-oriented statements (job displacement, professional replacement, well-being erosion, declining motivation and satisfaction, and diminished educational quality), while AI-using teachers report significantly higher confidence in AI's practical effectiveness for pedagogical outcomes. Both groups converge on neutral, non-evaluative items, general awareness of AI's labor-market relevance and the anticipated need for continuous ICT development, suggesting that some perceptions of AI's reach are shared regardless of exposure, while affectively charged appraisals diverge sharply along the use/non-use divide.

This pattern aligns with the dual-appraisal framework proposed by Kong et al. (2026), who found that AI use among Chinese K–12 teachers simultaneously predicted both challenge appraisals (linked to greater innovative teaching) and threat appraisals (linked to reduced innovation). Direct engagement with AI tools may tip this balance toward the challenge pathway: users in the present sample were less likely to endorse threat-laden statements and more likely to affirm AI's tangible benefits, whereas non-users, lacking firsthand calibration, appear to default toward threat-dominant appraisal. This is consistent with Zhang and Cao (2025), who found that AI-induced educational anxiety undermines teacher well-being but is moderated by digital literacy, with more literate teachers experiencing less anxiety under equivalent AI integration. Familiarity thus appears to function as an active buffer against threat appraisal once grounded in practice, rather than mere reassurance in the abstract.

At the same time, the absence of a significant difference on labor-market impact and ICT-upskilling statements suggests experience selectively reduces anxiety tied to personal and professional threat while leaving system-level anticipations intact. This resonates with Kong et al.'s (2026) finding that stronger institutional support for innovation did not simply lower anxiety but also raised the perceived stakes of using AI well. Similarly, Molefi et al. (2024), applying UTAUT to Lesotho's in-service teachers, found school-level support and resources to be the primary mediators of technology acceptance, implying the tool itself is secondary to institutional scaffolding. The gap observed here between AI-using and non-using teachers may thus partly reflect differential access to such support; possibility future research should test directly.

The elevated threat appraisal among non-users also carries implications for teacher identity. Sumalinog's (2026) meta-synthesis describes identity reconstruction under AI unfolding through disruption, adaptation, and evolution toward a "co-creator" role, while Shao and Sun (2025) argue AI compels a renegotiation of identity from knowledge transmission toward facilitation. Non-users' disagreement with AI's positive effectiveness, against users' more favorable evaluation, may reflect this identity threshold: non-users may remain anchored in a transmission-based self-concept that AI destabilizes, while users may have begun the adaptive repositioning these authors describe. This repositioning is not risk-free, however: Ambady and Thomas (2026) caution that expanding AI dashboards and automated assessment can shift teachers from pedagogical authors toward "data custodians," a subtler erosion of autonomy that may compound over time. Özbilen et al. (2025) further found that psychological well-being mediates the link between digital habits and AI-related anxiety, suggesting AI-specific interventions require grounding in broader digital wellness practices.

These findings align with regional evidence, Polovina and Dinić (2025), surveying Serbian university teachers, similarly documented a split orientation toward AI, efficiency gains weighed against concerns about plagiarism, eroded student autonomy, and "dehumanization" of teaching, echoing the ambivalence found here and suggesting this bifurcated pattern may be a durable feature of Serbian educational discourse rather than a sample artifact. As AI-supported tools, including classroom robotics (Tasić et al., 2026), continue expanding into Serbian schools, these results point to a need for institutional interventions beyond mere exposure: structured, well-scaffolded opportunities for hands-on AI engagement, paired with digital literacy development and genuine school support, may be necessary to shift non-using teachers toward challenge-dominant appraisal without amplifying the pressure that institutional endorsement of innovation can itself generate.

Conclusion

This pilot study examined perceptions of Serbian primary school teachers implementing STE(P)AM approaches regarding AI's impact on their profession. Analysis of 188 teachers, split between AI users (N = 76) and non-users (N = 112), revealed a clear pattern: significant differences emerged on 7 of 10 statements, with non-users consistently more apprehensive about layoffs, replacement, declining well-being, satisfaction, motivation, and educational quality, while AI-using teachers showed greater confidence specifically in AI's pedagogical effectiveness. Both groups converged, without significant difference, on AI's expected labor-market impact, its efficiency benefits, and the need for continuous ICT development, suggesting these expectations are shared regardless of personal experience, while threat-versus-confidence appraisals diverge sharply along the use/non-use divide.

The five research tasks were largely fulfilled within the scope of a small-scale descriptive pilot.

Frequency of AI use, and perceptions of status, well-being, and instructional efficiency/effectiveness were addressed directly through the comparative statistical analysis, yielding consistent, interpretable results. The task concerning future expectations was addressed more indirectly and would benefit from more targeted items in future work. Overall, the general objective, examining teacher perceptions of AI's impact on the profession and on STE(P)AM practice, was achieved to a degree appropriate for pilot research, with findings congruent with the broader international literature reviewed.

Several limitations qualify these results: a geographically concentrated, self-selected sample of STEM/STEAM-oriented teachers limits generalizability; the cross-sectional design cannot establish causal direction between AI use and threat appraisal; and the purpose-built instrument, while showing satisfactory reliability ($\alpha = 0.79$), awaits validation against established scales. Future research should pursue longitudinal or mixed-methods designs, incorporate mediators such as institutional support and digital literacy, and extend sampling beyond STE(P)AM-oriented teachers.

Returning to the title's question, the data offer a reassuring answer. Even among the more apprehensive non-users, agreement that AI would completely replace teachers remained the lowest-rated item overall, and was rejected outright by AI users. Both groups instead anticipate that AI will reshape their labor-market position and require ongoing adaptation. Teachers, irrespective of personal experience, do not foresee literal replacement by robots, but a reconfigured profession in which AI alters tasks and competencies without displacing the human educator. The more pressing risk is not obsolescence, but an uneven transition, one in which unaddressed apprehension among inexperienced teachers could itself hinder the confident AI integration that even skeptics seem to accept as inevitable.

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ELECTRONIC TEXTBOOKS AS SUPPORT FOR STE(PA)M EDUCATION: CHALLENGES AND OPPORTUNITIES IN EMBODIED LEARNING

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Abstract: In modern education, digitization of teaching materials and innovative pedagogical approaches are becoming imperative for improving the quality of learning. Electronic textbooks, as one of the key components of digital teaching, enable not only access to contents in digital format, but also interactive multimedia and adaptive possibilities that support individual and group forms of work. Electronic textbooks enrich teaching through interactive tests, video and audio recordings, 3D models, virtual simulations, hyperlinks and much more, which increases the level of students engagement and enables differentiated monitoring of their progress. Along with digitization, theoretical and empirical studies point to the importance of embodied learning, an approach that starts from the fact that knowledge is not only a mental category, but is projected and built through the physical, sensorimotor and interactive activity of students and encourages them to create deeper meaning and concepts connected to real experience through movement, manipulation of objects and multisensory interactions with the environment, which contributes to a higher level of knowledge retention and motivation to learn. In the context of STE(PA)M education, which integrates science, technology, engineering, art, mathematics and physical activities, an electronic textbook can be designed to actively encourage embodied learning through digital elements that initiate physical tasks, simulations or gestural interactions of students. Such a design enables the transition from passive to active learning, where the digital platform is not only viewed as a source of information, but as an active tool for experiential learning and interaction. This paper investigates the theoretical foundations, pedagogical possibilities and challenges of implementing embodied principles in electronic textbooks within the STEPAM approach in classroom teaching.

Keywords: *Embodied learning, embodied cognition, electronic textbook, STEPAM education, digital learning environments*

Introduction

Technological innovation, together with the emergence of contemporary pedagogical approaches, is rapidly transforming educational practice. Current global trends increasingly emphasize the integration of digital technologies and innovative teaching methods, resulting in a gradual shift from traditional, teacher-centered instruction toward more dynamic, student-centered learning environments.

Drawing on classical theories of cognition and their subsequent revisions, Macedonia (2019) argues that, despite the abandonment of a strict dualistic distinction between mind and body, dualistic assumptions continue to shape contemporary educational practice. Consequently, learning is still predominantly viewed as a mental activity, whereas the body is often reduced to a passive carrier of cognitive processes. This perspective is reflected in traditional instructional models that rely on prolonged sitting, passive listening, and engagement with abstract cognitive tasks.

Advances in cognitive science and neuroscience have fundamentally challenged this view by demonstrating that cognition cannot be understood independently of the body. One of the central

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assumptions of embodied cognition is that cognitive processes are grounded in sensorimotor experiences and emerge through continuous interaction between the body and the environment (Macedonia, 2019). Thinking about objects, people, or events involves the reactivation of previously acquired perceptual and motor experiences, while neuroscientific research has shown that processing different concepts activates sensorimotor regions of the brain. These findings suggest that cognition is inherently embodied rather than detached from bodily experience.

This theoretical shift has important implications for educational practice. It places learners at the center of the learning process, positioning them as active constructors of knowledge while redefining the teacher's role from that of a transmitter of information to that of a facilitator and mentor. Within this educational paradigm, the electronic textbook acquires a fundamentally different pedagogical function. Its value no longer lies solely in the digital presentation of instructional content but in its capacity to become an interactive learning environment that supports active, experiential, and multisensory learning.

The principles of STEPAM education naturally align with this perspective. By integrating science, technology, engineering, physical activity, arts, and mathematics within a unified educational framework, STEPAM extends beyond disciplinary knowledge to foster critical thinking, creativity, collaboration, and problem solving through authentic learning experiences. Within such a framework, embodied learning occupies a central position. Rather than viewing learning as an exclusively mental process, embodied learning assumes that knowledge emerges through the interaction of the body, movement, perception, and the surrounding environment. This perspective is particularly relevant in primary education, where children learn most effectively through play, exploration, physical activity, and direct experience.

Against this background, an important pedagogical question arises: How can the principles of embodied learning be integrated into electronic textbooks, which are still frequently perceived as digital replicas of printed textbooks and therefore associated with relatively passive forms of learning? This question constitutes the starting point of the present study.

Although electronic textbooks are often regarded merely as digital alternatives to printed textbooks, their educational potential extends far beyond content digitization. When pedagogically designed to encourage movement, inquiry, experimentation, and interaction with the physical environment, they can become powerful tools for supporting both embodied learning and STEPAM education.

Building on these theoretical assumptions, this paper conceptualizes the electronic textbook not simply as a digital educational resource but as a learning environment capable of operationalizing the principles of embodied learning within the STEPAM framework. The central argument of the paper is that the greatest educational potential of electronic textbooks lies not in their digital format itself but in the transformation of their pedagogical role from repositories of information to environments that foster embodied, experiential, and interdisciplinary learning.

Theoretical Framework

Embodied Cognition and Embodied Learning: Theoretical Foundations

The concept of embodied learning has emerged as the pedagogical extension of the theory of embodied cognition. Wilson (2002) argues that embodied cognition should not be regarded as a single unified theory but rather as a family of approaches sharing the assumption that cognitive processes are fundamentally grounded in bodily interaction with the environment. While embodied cognition explains how the body participates in cognitive processes, embodied learning translates these theoretical principles into educational practice by proposing that knowledge is most effectively constructed through movement, experience, and active engagement with the physical and social environment.

Contemporary research in embodied cognition demonstrates that learning cannot be understood as an exclusively mental process. Instead, knowledge develops through the continuous interaction of perception, action, and sensorimotor experience. If the body constitutes an integral component of cognition, then learning environments should enable learners to observe, explore, manipulate objects, experiment, and move while constructing knowledge. Building upon these theoretical assumptions, Nathan (2021) conceptualizes embodied learning as a learning paradigm rather than a specific instructional method. In this perspective, learning emerges through action, manipulation, inquiry, and experience, fundamentally redefining the relationship between learners, their bodies, the environment, and the process of knowledge construction.

This understanding of embodied learning has important implications for educational practice. Rather than positioning students as passive recipients of information, it emphasizes learning environments that encourage exploration, object manipulation, problem solving, and the integration of new concepts with learners' previous sensorimotor experiences. Learning therefore occurs not only through abstract reasoning but also through bodily movement, gestures, physical interaction, and multisensory engagement.

Stolz (2015) highlights the educational significance of embodied learning by arguing that learners should be understood as integrated human beings whose thinking, feeling, and acting cannot be separated into independent physical and mental domains. From this perspective, learning becomes a holistic process in which cognitive, emotional, and bodily experiences jointly contribute to knowledge construction.

A growing body of empirical research supports these theoretical assumptions. Students demonstrate deeper conceptual understanding, longer knowledge retention, and higher motivation when new concepts are connected with meaningful bodily experiences, purposeful movement, and authentic interaction with the environment. Embodied learning has also been associated with the development of communication, collaboration, and social skills through active participation in learning activities.

Neuroscientific evidence further supports the embodied nature of mathematical cognition. Research has demonstrated close relationships between motor activity and numerical processing, particularly in relation to finger counting and the development of early mathematical concepts (Sato & Lalain, 2008). These findings are commonly explained through Hebbian learning mechanisms, according to which

repeated associations between finger movements and numerical operations strengthen neural connections linking motor and cognitive processes. Consequently, fundamental mathematical operations such as addition, subtraction, multiplication, and division are most effectively introduced through concrete manipulation of objects and physical actions, enabling abstract concepts to be grounded in learners' bodily experiences (Macedonia, 2019).

Building on these findings, Nathan and Walkington (2017) proposed the theory of Grounded and Embodied Mathematical Cognition (GEMC), which identifies action and gesture as essential cognitive resources for understanding concepts in science, technology, engineering, and mathematics. Rather than serving merely as communication tools, gestures function as cognitive mechanisms that facilitate conceptual understanding by connecting abstract reasoning with bodily experience.

Taken together, these theoretical and empirical findings suggest that successful implementation of embodied learning requires educational environments that actively support movement, exploration, experimentation, collaboration, and authentic interaction with the surrounding world. Such characteristics naturally position STEPAM education as an appropriate pedagogical framework for the implementation of embodied learning principles.

STEPAM Education as a Natural Environment for Embodied Learning

STEPAM represents an interdisciplinary educational approach that integrates Science, Technology, Engineering, Physical Activity, Arts, and Mathematics within a unified framework for teaching and learning. Unlike traditional instruction, where these disciplines are taught separately, STEPAM promotes their integration through authentic problem-solving, inquiry, collaboration, and the application of knowledge in real-world contexts (Milošević, 2024).

The inclusion of physical activity distinguishes STEPAM from conventional STEAM education by recognizing movement not as a break from learning but as an integral component of the learning process itself. Consequently, STEPAM provides an educational environment that naturally supports the principles of embodied learning. Within this framework, students acquire knowledge through purposeful movement, exploration, experimentation, collaboration, and the continuous interaction between cognition, perception, and action.

From this perspective, STEPAM should not be understood merely as the integration of several school subjects but as a pedagogical framework that enables meaningful learning experiences. Rather than emphasizing the acquisition of isolated disciplinary knowledge, it encourages students to develop conceptual understanding by engaging in authentic, interdisciplinary learning activities.

In primary education, the principles of STEPAM can be implemented through numerous embodied learning activities. Mathematical concepts may be introduced by jumping along a number line, estimating distances through physical movement, or measuring objects using body-based reference units. Scientific

phenomena can be explored through role-play, bodily simulations, and collaborative experiments, while astronomical concepts such as planetary motion or the relationship between the Earth and the Sun may be represented through spatial movement and embodied modeling. In each of these examples, movement is not an additional classroom activity but an essential cognitive resource through which students construct understanding.

The close alignment between STEPAM and embodied learning provides the pedagogical foundation for reconsidering the role of electronic textbooks. If meaningful learning emerges through movement, inquiry, experimentation, and interaction with authentic contexts, electronic textbooks should be designed to initiate and support precisely these forms of learning rather than merely presenting digital instructional content.

Discussion

The theoretical analysis presented in this paper suggests that electronic textbooks should no longer be viewed merely as digital sources of instructional content but as pedagogically designed learning environments that actively support knowledge construction. If learning is understood as a process grounded in movement, inquiry, experimentation, and active engagement with the environment, electronic textbooks should be designed to facilitate precisely these forms of learning.

From this perspective, electronic textbooks intended to support embodied learning within the STEPAM framework should be designed to promote:

- active inquiry and exploration;
- manipulation of physical and digital objects;
- authentic problem solving;
- multisensory learning experiences;
- reflection following action.

The literature consistently emphasizes that embodied learning should not be reduced to the simple inclusion of physical activity in the classroom. Rather, movement, gesture, manipulation, and interaction with the environment function as cognitive resources through which learners construct meaning (Barsalou, 2008; Macedonia, 2019; Nathan, 2021). Consequently, meaningful learning environments should integrate perception, action, and reflection into a coherent learning process instead of relying predominantly on passive reception of information.

This perspective fundamentally changes the pedagogical role of the electronic textbook. In traditional instruction, students typically read instructional content before completing a learning activity. Within the framework of embodied learning, this relationship is reversed: digital content becomes the starting point for action, while conceptual understanding develops through bodily experience, manipulation, exploration, and reflection.

A simple example illustrates this transformation. A QR code embedded in an electronic textbook has little educational value in itself. Its pedagogical value emerges only when it directs students to leave the classroom, collect empirical data, perform measurements, document observations, analyse their findings, and reflect upon the results. In other words, the digital element is not the learning objective but the catalyst that initiates embodied learning.

Although the theoretical foundations clearly demonstrate the educational potential of electronic textbooks for supporting embodied learning within STEPAM education, several challenges remain. These include the need for pedagogically redesigned electronic textbooks, the professional development of teachers capable of planning and implementing embodied learning activities, adequate technological infrastructure, and the development of reliable approaches for assessing learning outcomes achieved through experiential and interdisciplinary learning. These challenges do not diminish the educational value of electronic textbooks; rather, they highlight that their effectiveness depends primarily on thoughtful pedagogical design and meaningful classroom implementation.

Rather than functioning as digital repositories of information, electronic textbooks should be designed as learning environments that initiate movement, inquiry, interaction, and interdisciplinary problem solving. Accordingly, embodied electronic textbooks should support movement as a cognitive resource, multisensory learning, authentic learning contexts, interdisciplinary integration, and reflection following action. From this perspective, the educational value of an electronic textbook is determined not by its level of digitalization but by the extent to which it enables embodied, meaningful, and interdisciplinary learning experiences.

Viewed from this perspective, the principal challenge is no longer the digitalization of textbooks but the transformation of their pedagogical role. Future generations of electronic textbooks should therefore be evaluated not by their technological sophistication but by their capacity to create authentic learning environments in which knowledge is constructed through movement, experience, inquiry, and interdisciplinary interaction.

Conclusion

This paper examined the pedagogical potential of electronic textbooks from the perspective of embodied cognition, embodied learning, and STE(PA)M education. Building upon contemporary theoretical and empirical research, it explored how electronic textbooks can support learning environments in which knowledge is constructed through movement, inquiry, experimentation, and active interaction with the surrounding environment.

The analysis demonstrates that the educational value of electronic textbooks does not arise from their digital format or the inclusion of multimedia elements alone. Rather, their greatest potential lies in their capacity to initiate learning experiences that connect digital resources with bodily activity, authentic

contexts, and interdisciplinary problem solving. From this perspective, electronic textbooks should no longer be regarded as digital replicas of printed textbooks but as pedagogically designed environments that actively support embodied and experiential learning.

The main contribution of this paper lies in integrating the theoretical foundations of embodied learning, the pedagogical principles of STEPAM education, and the contemporary concept of electronic textbooks into a coherent conceptual framework. Within this framework, the electronic textbook is reconceptualized from a medium for delivering information into a learning environment that supports active knowledge construction through movement, exploration, collaboration, and reflection.

These findings have important implications for the future development of digital educational resources. Designing effective electronic textbooks requires a shift in focus from technological innovation alone toward pedagogical design that deliberately integrates movement, multisensory experiences, inquiry-based learning, and authentic educational contexts. Future research should therefore concentrate on developing and empirically validating models of embodied electronic textbooks, as well as establishing evidence-based guidelines for their pedagogical design and implementation across different educational settings.

Ultimately, the greatest educational potential of electronic textbooks lies not in their ability to digitalize instructional materials but in their capacity to transform learning itself. As learning environments grounded in embodied experiences, future embodied electronic textbooks have the potential to bridge digital technologies with authentic human experience, creating meaningful, interdisciplinary, and student-centered learning for the next generation of education.

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ANALYSIS OF TESTS FOR ASSESSING MOTOR ABILITIES

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Abstract: Teachers and physical education instructors have the task and responsibility to monitor the physical development and the development of motor abilities of their students within physical and health education classes. In order to collect data on physical development and motor abilities, test batteries have been designed according to age categories. All tests were selected based on scientific knowledge, practical experience, and a number of studies presented through published scientific papers in this field. The aim of this paper is to provide a comparative analysis of certain tests from the Eurofit battery and tests from other batteries used in Serbia, as well as to define the factors that influence results in the assessment of motor abilities. A comparative analysis of selected tests from the mentioned batteries indicates differences in test protocols used to assess the same motor ability. In the Eurofit battery, flexibility is assessed using the sit-and-reach test, while in Serbia the deep forward bend on a bench is used. Balance is assessed by the Flamingo test versus standing lengthwise on a balance bench. Speed is assessed by the 10 × 5 m shuttle run, while in Serbia the 4 × 10 m shuttle run is used. For assessing repetitive strength of hip flexors, the Eurofit battery uses sit-ups in 30 seconds, while in Serbia trunk lifts on a bench are used. Endurance is assessed by the 20 m shuttle run in the Eurofit battery, while in Serbia running 500 m for girls and 800 m for boys is used. In addition to protocol differences, previous research indicates the influence of: environmental conditions - the subject alone, encouraged by the examiner, presence of classmates, presence of the opposite sex; competitive factor - two previously ranked subjects performing the test simultaneously; repeated testing, which in some cases leads to poorer results. The question remains regarding the competence of teachers and physical and health education instructors in understanding the test protocols within the proposed battery.
Keywords: *assessment of motor abilities, comparative analysis of test batteries, primary school age*

Introduction

The concept of motor ability is understood and interpreted differently by experts in physical culture. Terms such as: "physical ability," "bio-motor dimension," "psychophysical ability," "anthropomotor characteristics," "kinesiological abilities," and others are used. In order to clarify the above, definitions provided by experts in the field of physical culture will serve us. Motor (physical) abilities are one aspect of a person's movement capabilities or dimensions of personality, which participate in solving motor tasks (Krsmanović & Berković, 1999: 218). Motor abilities "represent the *conditio sine qua non* in every learning of movement tasks of a particular technique, and therefore may be considered the basic value in the overall domain of human motor behavior. A motor ability is that part of the general psychophysical ability that refers to a certain level of development of the basic latent movement dimensions of a human being, which determine the successful execution of movement, regardless of whether these abilities have been acquired through training or not" (Kurelić et al., 1975: 9).

A completely different statement is one in which the term "bio-motor dimensions," as an alternative to the terms psychophysical characteristics and motor dimensions, is considered more acceptable because: "the term psychophysical characteristics also includes the term 'psycho,' which implies the obligation of encompassing a much broader field than the one covered by psychophysical characteristics as is commonly

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understood in practice. Likewise, the term motor dimensions is not precise because it encompasses motor behavior in general, whereas the term bio-motor dimensions encompasses only those motor dimensions related to living beings" (Opavski, 1975: 53). Different considerations indicate that "motor dimensions are those human abilities that participate in solving motor tasks and determine successful movement, regardless of whether these abilities have been acquired through training or not" (Malacko, 1986: 26). One of the definitions indicates that "the concept of anthropomotor characteristics unifies those aspects of a human being that are manifested through identical movement parameters and are measured in the same way, have a common metric, possess analogous physiological and biochemical mechanisms, and require similar technical characteristics" (Đorđević, 1989: 4). Motor abilities are conditioned by genetic factors, to a greater or lesser extent, but their development can also be influenced through specific treatment. The level of development of the basic motor abilities will also determine the success in mastering new movement habits. Motor (physical) abilities are defined as latent motor structures that determine an infinite number of manifest motor reactions and can be measured and described (Findak, 1999: 218).

Assessment of motor abilities

Teachers of physical and health education have the task and obligation to monitor the physical development and the development of the motor abilities of their students within the framework of physical and health education classes (Marković & Šekeljić, 2014). Beginning with the 1972/1973 school year, based on the conclusions of the Educational and Cultural Council of the Assembly of the City of Belgrade from 1971 concerning measures for the improvement of physical education instruction, the City Secretariat for Education made the decision to initiate continuous monitoring of the physical development and motor abilities of male and female students in primary and secondary schools in Belgrade. Thus, the System for Continuous Monitoring of the Physical Development and Motor Abilities of Male and Female Students in Primary and Secondary Schools in Belgrade was established, otherwise referred to as the "System of the So-Called Feedback on the Physical Development and Development of Motor Abilities of Belgrade Youth," which functioned for 24 years (Ivanić, 1996). For the collection of data on physical development and motor abilities, test batteries were designed according to age categories. All tests were selected on the basis of scientific knowledge, practical experience, and a certain number of studies presented through published scientific papers in this field. Owing to the different conditions for the assessment of motor abilities in schools, the test battery could not include a large number of tests, and for this reason one test was selected to monitor each of the basic components of human motor abilities, namely: strength, speed, endurance, and flexibility. Some of the adopted tests, over time, demonstrated certain weaknesses, but it was difficult to replace them with others for formal reasons. Despite all the difficulties, during the period of implementation

of the System, certain modifications were nevertheless made, the most significant of which was introduced in 1995.

Test Batteries for the Assessment of Motor Abilities

Different test batteries have been used and continue to be used worldwide and in Serbia for monitoring the motor abilities of children. The tests for assessing the physical preparedness of younger school-aged children – according to Zatsiorsky and approved by the International Committee for the Standardization of Physical Fitness Tests, established at the International Congress of Sport Sciences held in Tokyo in 1964 – are as follows: the 50 m run, handgrip dynamometry, pull-ups, flexed-arm hang, standing long jump, sit-ups in 30 s, deep forward bend in the standing position, deep forward bend in the sitting position, the 4 × 10 m shuttle run, and the 600 m run (Kukolj, 2006: 222). From 1958 to 1980, the most popular test battery in the United States was the one developed by the American Alliance for Health, Physical Education, Recreation and Dance (AAHPERD). This test battery consisted of two parts: ability assessment tests (600-yard run–walk, 50-yard sprint, and softball throw for distance) and health-related physical fitness tests (one-leg stand, flexed-arm hang, push-ups, and sit-ups). In 1993, the Cooper Institute and AAHPERD established an alliance for the promotion of physical activity among youth, known as FitnessGram, which became the official test battery for the assessment of physical fitness and health-related fitness.

FitnessGram consists of three components identified as important for overall health and physical functioning, namely: aerobic capacity (the PACER test, the one-mile run – walk test, and the walk test for individuals older than thirteen years of age); body composition (assessment of body fat – measured at the upper arm and calf – and body mass index); and muscular strength, muscular endurance, and flexibility (abdominal strength and muscular endurance – curl-ups; trunk extensor strength and muscular endurance – trunk lift; upper-body strength and endurance – a choice between push-ups, modified pull-ups, or the flexed-arm hang; and flexibility – a choice between the sit-and-reach test and the shoulder stretch).

In Slovenia, since the 1989/1990 school year, there has been an organized system for the systematic monitoring of the growth and development of children and youth through the Sports Educational Chart test battery and the GRAPH Sports Educational Chart computer program. The System includes primary and secondary schools, as well as universities. Consent for testing primary school students is provided by their parents, while in secondary schools and at universities consent is provided by the students themselves. During the period from April 1 to April 20 each year, testing is conducted in all schools, as well as at all universities, using the following test battery for the assessment of motor abilities: hand tapping for 20 seconds, standing long jump, sit-ups for 60 seconds, backward obstacle course, deep forward bend on a bench, 60-meter run, and 600-meter run (Kukolj, 2006: 225).

For the assessment of the motor abilities of younger school-aged children in Serbia, during the period from 1978 to 1995, the test battery included the following tests: box transfer – for the assessment of coordination, and from 1984, the standing long jump – for the assessment of leg strength; the 3 × 10 m shuttle run – for the assessment of general speed ability; the 2 kg medicine ball throw – for the assessment of general strength; and ball rebound against a wall – for the assessment of agility. For the assessment of motor abilities from 1995 onward, the test battery included the following tests: the standing long jump – for the assessment of leg strength; ball rebound against a wall – for the assessment of agility; the 2 kg medicine ball throw – for the assessment of overall body strength; and the 30 m flying start sprint – for the assessment of speed.

The test battery was partially revised and included the following tests: ball rebound against a wall – for the assessment of agility; the 2 kg medicine ball throw – for the assessment of overall trunk strength; the standing long jump – for the assessment of leg strength; the flexed-arm hang – for the assessment of the isometric strength of the upper-body muscles and the elbow flexors; the 30 m run from a standing start – for the assessment of speed; the deep forward bend on a bench – for the assessment of flexibility; and the 20 m shuttle run with progressively increasing speed – for the assessment of maximal aerobic endurance (Kragujević, 2005: 203–204).

The test battery for older school-aged children included: the flexed-arm hang with a mixed grip for girls and the pull-up from a free hang for boys, the standing long jump, ball rebound against a wall from a distance of 3 m, the 4 kg medicine ball throw, the 30 m run, and the 500 m run for girls and the 800 m run for boys.

For secondary school students, the test battery included: the flexed-arm hang with a mixed grip for girls and the pull-up from a free hang for boys, the standing long jump, ball rebound against a wall from a distance of 3 m, the 6 kg medicine ball throw for boys and the 4 kg medicine ball throw for girls, the 30 m run, and the 500 m run for girls and the 800 m run for boys.

Eurofit Test Battery

The Eurofit test battery is a standardized battery of tests recommended by the Council of Europe (Council of Europe, Committee for the Development of Sport – European Test of Physical Fitness) for the assessment of the physical development and motor abilities of school-aged children. It has been implemented in schools throughout Europe since 1988, and in 1995 a similar Eurofit test battery for adults was also published. In addition to the most basic procedures for the assessment of physical development, the Eurofit test battery consists of nine motor tests that cover flexibility, speed, endurance, balance, and strength, and they are administered in the following order in order to minimize the effects of fatigue. The recommended order is: the Flamingo test (one-leg balance) – for the assessment of balance; plate tapping

with the preferred hand for 25 touches – for the assessment of the segmental speed of the hand; the sit-and-reach test – for the assessment of the level of flexibility (mobility); the standing long jump – for the assessment of the explosive strength of the leg extensors; handgrip dynamometry of the dominant hand – for the assessment of the static strength of the dominant hand; sit-ups for 30 s – for the assessment of the repetitive strength of the abdominal muscles and hip flexors; the flexed-arm hang – for the assessment of the isometric strength of the upper-body muscles and the elbow flexors; the 10 × 5 m shuttle run – for the assessment of speed; and the 20 m endurance shuttle run – for the assessment of maximal aerobic endurance (Kukolj, 2006: 224). Following the model of the Eurofit test battery, the ALPHA-Fitness test battery, FitnessGram, which has been used since 2013 in mandatory physical fitness testing programs in more than 20 U.S. states, and the Senior Fitness Test, intended for adults over 60 years of age, were developed.

Comparative analysis of the eurofit battery and tests applied in schools in Serbia

A comparative analysis of individual tests from the Eurofit battery and the above-mentioned batteries in Serbia indicates differences in the application of certain tests for the assessment of specific motor abilities, as well as in the testing protocol itself for the assessment of the same motor ability. For the assessment of balance, the Flamingo test versus standing lengthwise on a balance bench is used. In the Flamingo test, the examinee must accumulate 60 s with as few attempts as possible, while in standing lengthwise on a balance bench the examinee has three attempts and the result is total time, with one attempt being interrupted after 20 s. For the assessment of segmental hand speed, in the plate tapping test in the Eurofit battery the examinee's task is to perform 25 touches with the preferred hand in the shortest possible time, while in Serbia the test is performed for 25 s, which is a long period and movement speed decreases.

In the Eurofit battery for the assessment of flexibility, the sit-and-reach test is used, while in Serbia the deep forward bend on a bench is used. The instruments differ as well as the protocol, and material errors by teachers and professors are frequent, not knowing from where the measurement should be taken, so the starting point is often on the bench where the examinee stands, rather than 20 cm above it. For the standing long jump there are no protocol differences, but there is consideration that it should be replaced by the vertical jump. The assessment of static strength of the dominant hand has not been present in Serbian batteries. For the assessment of repetitive strength of the hip flexors in the Eurofit battery, sit-ups for 30 seconds are used, where the task is the highest possible number of repetitions, while in Serbia trunk lifts on a bench are used, which are very demanding. They are performed on an inclined surface, with a stick behind the head and to exhaustion. In the flexed-arm hang there are no differences.

When it comes to speed, the 10 × 5 m shuttle run is used, while in Serbia the 4 × 10 m shuttle run is used. For many years in Serbia, the 30 m sprint from a standing start was used, which truly assessed speed, while both of the mentioned tests assess agility. The 10 × 5 m shuttle run represents a difficulty for

students who are not engaged in regular physical activity or exercise. For endurance, the 20 m progressive shuttle run (Shuttle Run) is used, while in Serbia the 500 m run for girls and the 800 m run for boys is used. Most authors (Kragujević, 2005; Milanović, 2011) agree that the shuttle run is a better test for the assessment of endurance, but it requires technical equipment and a mandatory medical examination of students, so it is applied to a limited extent in regular classes and is mainly used in scientific and professional papers.

Conclusion and implications

What should be asked first is whether the test assesses what it is intended to assess, the units of measurement in which the result is expressed, the competence of teachers to assess motor abilities, whether the assessment is carried out and when, and what is done with the obtained information, when there is no longer a feedback system and an obligation for teachers to send data. A small number of teachers carry out the assessment, while a good part of teachers and professors at the beginning of the school year conduct an initial assessment using their own battery, and the results are in most cases used for grading the student. If the ball rebound against the wall is analyzed, where according to the protocol the task is for the student, from a distance of 1.5 m, to perform as many rebounds as possible in 15 s, practical experience shows that a student with greater body height and longer arms is at an advantage compared to a shorter student in achieving a higher number of repetitions. Previous motor knowledge will also affect the test result; students who train volleyball, basketball, or handball will be at an advantage compared to students who do not engage in sports.

The standing long jump assesses explosive strength, whose heritability coefficient is 0.80. Explosive strength is characterized by muscle contraction, which is excited by maximal stimulation of the central nervous system, whereby a maximal number of nerve and muscle fibers are engaged, with the aim of performing a specific motor task (movement of the body in space, or action of the body on an object from the environment). The test result largely depends on the motor potential of the student, general and specific motor education, and anthropometric characteristics of the student.

There is no general factor of flexibility (mobility), but rather we speak of greater or lesser, better or poorer flexibility of individual body regions. Flexibility is not genetically determined, and through work in younger ages its development can be influenced. This is very important for school physical education. Success in the test depends on anthropometric characteristics, strength of trunk flexors, elasticity of antagonists, time of day, temperature differences, and level of training. The reasons for the heterogeneity of results in the assessment of isometric strength of the upper-body muscles and elbow flexors in primary and secondary school students in the flexed-arm hang are of a complex nature and are difficult to explain without an integrated approach to the problem. Part of the variability can be explained by a mismatch

between biological age and chronological age in students, that is, by differences in the maturity of motor abilities. It is a fact that biological age does not always correspond to calendar age, and that individual differences among students of the same age are large.

The period of younger school age is characterized by significant variability, incompletely developed and insufficiently differentiated motor structures that are still mutually interdependent, as noted by Turek (2006), which further creates problems in the assessment and interpretation of results. The test is influenced by motivational factors (Lazarević et al., 1992). A motivational factor may be expressed in the form of competitive test performance (Marković and Višnjić, 2008). Higher values were obtained when the test was performed simultaneously by two students paired in relation to the results from previous assessment. The environmental setting is very important in motivating male and female students to persist in the flexed-arm hang. Higher values in the assessment are obtained when the test is performed in the presence of the tester and other students than in the presence of only the tester. Matić (1976) changed the testing conditions (students alone in the gym, encouraged by the teacher or tester, presence of the opposite sex). He obtained different results, and the presence of the opposite sex has a much stronger effect on students and their persistence. An important motivational factor is informing about the elapsed time and encouraging students by the teacher to persist in the flexed-arm hang. In repeated measurements, weaker results are often obtained, where a number of students, without any reason, terminate the testing without explanation. This can be explained by the feeling of great pain in the m. biceps brachii during and after the assessment. A weakness of the test is the lack of presentation of results in appropriate measurement units.

In this test, the strength of the arms and shoulder girdle is assessed, and the result is expressed in seconds (s). The second is a unit of measurement for time, while in the International System of Units the unit of measurement for force is the newton (N). In the flexed-arm hang there is a predominant activation of individual muscles, or muscle groups, of the shoulder girdle and arms in an isometric mode of work. The result, in addition to isometric muscular strength, also depends on the anthropometric characteristics of the examinee (body mass) and biomechanical elements (length of the lever of the forearm and upper arm and the angle between them). From this it follows that the load in the test is not equal for students of different body masses. Students with greater body mass experience a greater load, which is why it can be said that this test is only standardized (performed in the same, protocol-defined manner), but not standardized (the same in units of work). Namely, in order for a test to be standardized it is necessary that the external (mechanical) work be the same for all students, which is not the case in this test. External work, according to the basic law of mechanics, depends to the greatest extent on body mass. Therefore, the performed mechanical work for students of different body masses is different (Šekeljić et al., 2013).

It is assumed that repetitive strength is genetically determined, with a heritability coefficient of 0.50, and it results from the strength of individual body segments, that is, individual muscle groups. The sit-up test for 30 s measures exclusively muscular strength, but it also largely depends on motivational structure.

Speed as a motor ability is largely of a dispositional character, with a heritability coefficient of 0.90 to 0.95. Knowing this, it is logical to conclude that the possibilities for significant improvement of this ability are limited. Success in the 30 m run or the 5 × 10 m shuttle run, in addition to well-mastered sprinting technique, largely depends on the motor potential of the leg muscles to perform efficient repetitive ballistic contractions. In addition to speed as the decisive factor, there are many elements that can be defined as explosive and repetitive strength. After a modest contribution regarding the general characteristics of some motor tests, the aim will not be to recommend a final test battery for the assessment of motor abilities of younger school-aged children, but rather to provide available information that teachers and professors of physical and health education will apply if systematic monitoring of motor development is reintroduced.

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https://doi.org/10.46793/STEPAM26.064N
Udk: 81`233-053.5
37.091.33-053.4

ARTICULATION DEVELOPMENT THROUGH RHYTHM, MOVEMENT, AND SONG: AN INTERDISCIPLINARY STEPAM APPROACH IN PRESCHOOL EDUCATION

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Abstract: Articulation difficulties are common in preschool children and may negatively affect speech development, communication, and school readiness. This paper presents the results of an action research study aimed at improving articulation through rhythm, movement, and song within the interdisciplinary STEPAM framework. The study was conducted with sixteen preschool children in a preschool institution in Paraćin, Serbia. The four-week intervention program integrated speech exercises with music, rhythm, movement, dramatization, and parental involvement. Children's articulation was assessed before and after the intervention using an evaluation scale containing target sounds in different word positions. The results showed significant improvement in pronunciation accuracy, motivation, and participation in speech activities. An important aspect of the study was the use of original educational songs created through the author's work with the children's choir *Dar*. The findings suggest that integrating rhythm, movement, and song into preschool practice may represent an effective multisensory approach to articulation development.

Keywords: articulation development, preschool education, STEPAM approach, rhythm and movement, multisensory learning

Introduction

Speech and language development is one of the most important aspects of early childhood, significantly influencing children's cognitive, emotional, and social functioning. In preschool education, articulation development plays a particularly important role because clear and correct pronunciation contributes not only to successful communication but also to the development of self-confidence, social interaction, and readiness for school. Difficulties in the pronunciation of certain sounds are relatively common in preschool children and may negatively affect later literacy development, communication skills, and participation in educational activities. Traditional articulation exercises often involve the repetitive practice of isolated sounds, syllables, and words. Although such approaches may contribute to articulation improvement, they can also reduce children's motivation and engagement, especially in preschool contexts where learning is expected to occur through play, movement, creativity, and active participation. Contemporary preschool education increasingly emphasizes holistic and experiential learning approaches that integrate cognitive, emotional, sensory, and motor experiences into the learning process.

Within this context, the interdisciplinary STEPAM approach offers significant possibilities for integrating speech development activities with rhythm, movement, music, creativity, and embodied learning. STEPAM, as an educational framework that connects science, technology, engineering,

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pedagogy, arts, and mathematics, encourages children's active participation through multisensory experiences and creative exploration. In preschool education, such an approach enables speech and language activities to become more dynamic, meaningful, and motivating for children. Research in the fields of music pedagogy, developmental psychology, and multisensory learning (Hallam, 2010; Shams & Seitz, 2008) indicates that rhythm, melody, movement, and coordinated motor activities may positively influence phonological awareness, auditory discrimination, speech perception, memory, and articulation accuracy. Movement combined with rhythm and verbal expression supports embodied learning processes, in which children learn through the interaction of body, emotions, sensory perception, and cognition (Barsalou, 2008; Glenberg, 2010). Additionally, emotionally engaging and play-based activities increase children's motivation, attention, and willingness to participate in speech exercises.

An important aspect of contemporary preschool practice is also the involvement of families in children's learning processes. Cooperation between preschool teachers, speech therapists, and parents may contribute to greater continuity between preschool and home environments, providing children with more frequent opportunities for articulation practice and reinforcement of acquired speech patterns. The present study emerged from practical observations in a preschool group in which a considerable number of children demonstrated articulation difficulties involving several consonants, particularly R, LJ, L, Š, Z, Č, F, and S. In response to this situation, an action research project was designed in order to explore whether articulation development could be improved through the integration of rhythm, movement, song, and multisensory activities within the STEPAM framework.

The study aimed to examine the effects of an interdisciplinary intervention program based on music, movement, speech exercises, narrative activities, and parental involvement on the articulation development of preschool children. In addition to improving pronunciation accuracy, the research also sought to explore children's motivation, participation, and engagement during articulation activities.

Theoretical framework

STEPAM Approach in Preschool Education

The STEPAM approach is an interdisciplinary educational framework that integrates science, technology, engineering, pedagogy, arts, and mathematics to create engaging learning experiences. In modern preschool education, STEPAM emphasizes creativity, active participation, problem-solving, and experiential learning, helping children develop cognitive, emotional, social, and motor skills simultaneously. Rather than isolating developmental domains, STEPAM promotes holistic learning through various forms of expression. Arts-based and movement-oriented activities are essential, as young children learn best through play, sensory exploration, and emotional engagement. Rhythm, movement, music, storytelling, and creative expression are effective tools for enhancing speech and language development. Incorporating articulation exercises into playful activities can increase motivation and engagement,

supporting broader developmental processes. This interdisciplinary approach also fosters collaboration among educators, families, and specialists, creating a supportive environment where children can actively participate in their own growth.

Rhythm, Movement, and Speech Development

Numerous studies emphasize the connection between rhythm, movement, music, and speech development in early childhood. Rhythm and melodic structures support the development of phonological awareness, auditory discrimination, speech perception, memory, and language processing. Repetitive rhythmic patterns may facilitate the acquisition and automatization of articulation movements, particularly in preschool children who learn most effectively through repetition, play, and sensory experiences. Movement-based learning activities also contribute significantly to speech development. According to embodied learning theories, cognitive processes are closely connected with bodily movement, sensory experience, and emotional engagement (Barsalou, 2008; Glenberg, 2010). When children combine speech production with coordinated movements, gestures, rhythm, and musical activities, articulation exercises become more meaningful and easier to internalize.

Music-based activities may additionally reduce anxiety and increase children's willingness to participate in speech exercises. Songs, rhythmic games, and movement activities create a positive emotional atmosphere that supports attention, motivation, and confidence in verbal expression. In preschool education, integrating speech exercises with rhythm and movement allows articulation practice to become a natural part of play and creative communication rather than a repetitive corrective activity.

Parental Involvement and Learning Continuity

Family involvement represents an important factor in successful preschool interventions. Cooperation between educators, speech therapists, and parents enables continuity between preschool and home environments, providing children with more frequent opportunities for practice and reinforcement. Research suggests that children achieve better developmental outcomes when parents actively participate in educational activities and receive clear guidance on how to support learning processes at home. In articulation development, regular repetition and consistent practice are particularly important because speech habits develop gradually through everyday communication and repeated motor-speech experiences.

In this study, parental involvement was incorporated through daily home-based repetition of songs, rhythm exercises, and articulation activities previously introduced in preschool. Such continuity contributed not only to speech improvement but also to children's motivation and emotional security during the learning process. The combination of preschool activities and family participation reflects the broader educational philosophy of the STEPAM approach, which values collaboration, experiential learning, and active engagement in authentic contexts.

Methodology

Research Design

The study was conducted as an action research project aimed at improving articulation development in preschool children through the integration of rhythm, movement, and song within the interdisciplinary STEPAM framework. Action research was selected because it enables educators to systematically observe, analyze, and improve their own educational practice while simultaneously responding to the developmental needs of children. In this study, the research process included observation, assessment, intervention, reflection, and evaluation of outcomes. The intervention combined speech exercises with music, rhythm, movement, narrative activities, and parental involvement in order to create a motivating and multisensory learning environment.

Participants and Research Context

The research was conducted in a preschool group consisting of sixteen children aged six years enrolled in a preschool institution in Paraćin, Serbia. Initial observation and assessment indicated that a significant number of children experienced articulation difficulties involving several consonants, particularly R, LJ, L, Š, Z, Č, F, and S. The research lasted six weeks during April and May 2025, while the intervention activities themselves were implemented daily over a four-week period. Activities were integrated into regular preschool practice and additionally supported through home-based exercises involving parents.

Research Instruments

Children's articulation development was assessed using a specially designed evaluation scale containing words with target sounds positioned at the beginning, middle, and end of words. The assessment included the following target sounds: R, LJ, L, Z, Š, Č, F, and S. Pronunciation quality was evaluated on three levels: correct pronunciation, partially correct pronunciation, and incorrect pronunciation. The same assessment scale was applied before and after the intervention in order to enable objective comparison of articulation progress. The instrument was developed in cooperation with a preschool speech therapist and adapted to the developmental characteristics of preschool children.

Procedure

The intervention program lasted four weeks and was organized through daily articulation activities integrated into preschool routines and home practice. Each week focused on specific target sounds:

- Week 1: R and F
- Week 2: L and LJ

- Week 3: S and Z
- Week 4: Č and Š

Activities included:

- rhythm exercises,
- movement activities,
- articulation games,
- songs,
- narrative activities,
- imitation and repetition exercises,
- and multisensory speech activities.

Special emphasis was placed on integrating movement and rhythm with pronunciation practice. Children practiced articulation through songs accompanied by gestures, body movement, dramatization, and rhythmic repetition. Specific movements were carefully designed to accompany each target sound and lyrical structure. During articulation activities, children combined pronunciation with gestures, coordinated body movements, imitation, dramatization, and rhythmic actions synchronized with the songs. For example, in the song *"Baba Rada"*, children practiced the sound R while imitating planting radishes, digging, carrying baskets, and harvesting crops through a coordinated narrative of the song. The integration of movement and articulation enabled children to simultaneously engage auditory, visual, motor, emotional, and verbal modalities during speech practice.

The songs used during the intervention were original educational materials created by the author based on many years of experience in children's music education and choir practice. As the founder and conductor of the children's choir Dar, the author has developed numerous music-based activities connecting speech, rhythm, movement, and creative expression.

Parents were actively involved throughout the intervention. They repeated songs and articulation exercises with children at home on a daily basis, ensuring continuity between preschool and family learning environments. Following the intervention period, children's articulation was reassessed using the same evaluation scale in order to determine possible changes in pronunciation accuracy and participation.

Results

The results of the study demonstrated significant improvement in children's articulation following the four-week intervention program based on rhythm, movement, song, and multisensory activities within the STEPAM framework.

Initial assessment indicated that 84.6% of the participating children experienced difficulties in pronouncing one or more target sounds. The most frequently affected sounds were R, LJ, L, Z, Š, Č, F, and

S. Following the intervention, the percentage of children with articulation difficulties decreased to approximately 23%, indicating substantial overall improvement in pronunciation accuracy.

Table 1. Comparative Results of Initial and Final Assessment

Sound	Initial Number of Children	Final Number of Children	Improvement %
R	7	2	71.4%
LJ	7	1	85.7%
L	6	2	66.7%
Z	4	0	100%
Š	2	0	100%
Č	2	0	100%
F	2	1	50%
S	1	0	100%

The greatest improvement was observed in the pronunciation of the sound LJ, where the number of children with articulation difficulties decreased from seven to one, representing an improvement of 85.7%. Significant improvement was also observed in the pronunciation of R and L. Complete improvement was achieved in the pronunciation of the sounds Z, Š, Č, and S, as all children who initially demonstrated difficulties successfully mastered these sounds by the end of the intervention. Although the sound F showed the lowest percentage of improvement, the results still indicated positive progress.

In addition to quantitative changes in articulation accuracy, qualitative observations conducted during the intervention revealed increased motivation, active participation, emotional engagement, and greater confidence in children's verbal expression. Children demonstrated particular enthusiasm during activities involving music, rhythm, movement, and dramatization. The integration of articulation exercises into playful and creative activities appeared to reduce resistance to repetition and encouraged spontaneous participation in speech practice.

Parental involvement also contributed positively to the intervention process. Daily repetition of songs and articulation activities at home provided additional opportunities for practice and reinforcement, supporting continuity between preschool and family environments. Overall, the findings suggest that integrating rhythm, movement, and song into articulation activities within the STEPAM framework may provide an effective and motivating approach to supporting speech development in preschool children.

Discussion

The findings of this study indicate that integrating rhythm, movement, song, and multisensory activities within the STEPAM framework significantly enhances articulation development in preschool children. Improvements in pronunciation suggest that articulation exercises are more effective when part of engaging and meaningful experiences, rather than isolated repetition of sounds. The study emphasizes the importance of linking speech production with body movement, rhythm, gestures, and emotional engagement, which is consistent with contemporary theories of embodied and multisensory learning (Barsalou, 2008; Glenberg, 2010; Shams & Seitz, 2008), allowing children to internalize articulation patterns more naturally. The role of rhythm and musical repetition was crucial for supporting phonological awareness and articulation accuracy, which corresponds with findings on the positive impact of music on children's cognitive and language development (Hallam, 2010; Moreno & Bidelman, 2014), aiding motor coordination, attention, and memory.

A positive emotional atmosphere created through songs and movement increased children's motivation and participation in articulation exercises. Parental involvement was also vital, with daily repetition of songs and exercises creating consistency between preschool and home environments. Original songs developed over years in the children's choir Dar helped facilitate articulation development by combining rhythm, melody, movement, and narrative elements. This transformed articulation practice into a playful experience.

The STEPAM approach not only fosters articulation skills but also promotes motor coordination, creativity, emotional expression, communication, and social participation. However, the study had limitations, including a small sample size and no control group, which restricts generalization. Future research should involve larger samples and longer interventions to explore STEPAM's effectiveness further. Interdisciplinary and multisensory methods show great promise for enhancing articulation development in preschool education.

Conclusion

In conclusion, the findings of this study suggest that articulation development in preschool children may be effectively supported through the integration of rhythm, movement, song, and multisensory learning activities within the interdisciplinary STEPAM framework. The results demonstrated significant improvement in the pronunciation of target sounds following the four-week intervention program. In addition to articulation progress, children showed increased motivation, active participation, emotional engagement, and greater confidence during speech activities.

The study also highlighted the importance of integrating speech exercises into meaningful and

playful experiences. By combining articulation practice with rhythm, movement, music, narrative elements, and dramatization, speech activities became more engaging and developmentally appropriate for preschool children. An important contribution of the study was the use of original educational songs developed through long-term practical experience within the children's choir *Dar*. The integration of music, body movement, and articulation exercises enabled children to simultaneously engage auditory, visual, motor, emotional, and verbal modalities during the learning process. The findings additionally emphasize the importance of parental involvement and continuity between preschool and family environments. Daily home-based repetition of songs and articulation activities contributed to more consistent practice and reinforcement of acquired speech patterns.

Although the study was conducted on a relatively small sample and over a limited period of time, the results indicate that interdisciplinary and multisensory approaches may offer valuable possibilities for improving speech and language development in preschool education. Future research could include larger samples, longer intervention periods, and comparative studies involving control groups in order to further examine the effectiveness of STEPAM-based articulation programs. Overall, the study supports the idea that rhythm, movement, song, and creative expression may become powerful pedagogical tools for fostering articulation development and creating meaningful learning experiences in early childhood education.

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https://doi.org/10.46793/STEPAM26.072SI
Udk: 37.091.12:005.962.131
37.091.39

IMPLEMENTATION OF STEAM PACKAGES: EFFECTS ON TECAHERS FROM THE FIRST EDUCATIONAL CYCLE[8]

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Abstract: This work was part of the proSTEAM project, which developed and piloted STEAM packages in the first cycle of education across four countries. Implementing these packages presents multiple challenges for teachers, including ensuring proper use of materials and activities, monitoring student learning, fostering inquiry and creativity, and coordinating group work with role allocation. The effects on teachers were measured using the STEAM-TSES (STEAM Teacher Self-Efficacy Scale) (Stepanović Ilić et al., 2025), administered after training and again after STEAM package implementation. Additionally, interviews were conducted to explore teachers' experiences in more depth. The sample included 29 teachers from primary schools in Belgrade, who implemented 4–6 lessons from one of three piloted packages in Serbia: Symmetry (Grade 1), Rainfall Measurement (Grades 3–4), and Human Organ Systems. Results show that teachers already had high STEAM-TSES scores, but package implementation led to improvements in subscales related to chemistry, arts, and motivating students for artistic activities. The main challenges reported were integrating STEAM activities into the existing curriculum and coordinating group work, while the greatest benefits were increased student engagement and willingness to learn through STEAM. These findings provide a foundation for systemic implementation of STEAM in the first cycle of education, emphasizing student motivation and the use of accessible, low-cost materials.

Keywords: *STEAM packages, teachers, self-efficacy, STEAM-TSES scale, interviews*

Introduction

In recent decades, rapid technological and societal changes have transformed expectations of education, shifting the focus from knowledge transmission toward developing higher-order thinking, creativity, collaboration, and problem-solving skills (OECD, 2025). Within this context, STEAM education has gained increasing attention as an interdisciplinary approach that promotes meaningful learning and essential 21st-century competencies (Conradty & Bogner, 2020).

There is growing consensus that these competencies should be fostered from the earliest years of education, as early childhood is a critical period for cognitive, motivational, and socio-emotional development (Engel, 2011). Young children naturally engage in exploration, questioning, and experimentation, making inquiry-based STEAM activities particularly well suited to their developmental characteristics (Jirout, 2020). Research suggests that hands-on, integrated learning experiences support

[8] The paper is a result of the evaluation study of the Erasmus+ project: Promoting STEAM in primary school: partnership for disseminating good practices (proSTEAM - 2022 KA201-F39C1E73). Qualitative part of the research is realized with the support of University of Belgrade – Faculty of Philosophy, funded by the Ministry of science, technological development, and innovations (451-03-33/2026-03/ 200163)

conceptual understanding by connecting concrete experiences with emerging abstract thinking (Su et al., 2024; Veziroğlu-Çelik et al., 2025).

However, there are challenges in implementing STEAM in early primary education. Young children rely primarily on concrete reasoning rather than abstract (Piaget, 1952; Stepanović, 2007). Thus, STEAM activities must be developmentally appropriate and adapted to their cognitive capacities, and not directly transferred from programs for older students. Moreover, teachers report difficulties integrating multiple disciplines, limited confidence in teaching science, and insufficient pedagogical preparation for inquiry-based instruction (Baigiati & Evangelou, 2015; Park et al., 2016).

Professional development has therefore been identified as a key factor in successful STEAM implementation. Studies indicate that targeted training can strengthen teachers' interdisciplinary teaching competencies, improve classroom practice, and enhance student learning outcomes (Bassachs et al., 2020; Conradty & Bogner, 2020; Silva-Hormazábal & Alsina, 2023). Despite these findings, relatively little is known about how teachers experience implementing STEAM activities in early primary classrooms after receiving professional support. The present study therefore aims to address this gap.

The context of the research – proSTEAM project

This research is part of the broader Erasmus+ project "Promoting STEAM in Primary School: Partnership for Disseminating Good Practices" (proSTEAM), which addressed the challenges of implementing STEAM in the first cycle of primary education. The project aimed to develop a short professional development program to support the integration of STEAM into regular primary school teaching.

The consortium brought together academics from universities and primary school teachers, from nine partner institutions across four European countries: Portugal, Italy, Lithuania, and Serbia. A central premise of the project was to position primary school teachers as active partners in developing, piloting, and evaluating STEAM educational packages (EPs) for teacher professional development.

The project was implemented in four phases: (1) developing a pedagogical framework for designing the STEAM EPs; (2) developing and piloting the EPs; (3) providing professional development for teachers from non-partner schools; and (4) evaluating the effects of the implemented EPs on participating teachers and their students.

For the purposes of this paper, these phases are briefly outlined, with particular emphasis on the final phase, which examined the effects of the implemented STEAM EPs on teachers.

The pedagogical framework guiding the development of STEAM educational packages

The pedagogical framework for developing the STEAM EPs was based on five principles: (1) the approach to disciplinary integration; (2) the use of themes as the organizing concept; (3) open-ended problems and tasks; (4) recommended pedagogical strategies; and (5) the core components of the STEAM EPs. This paper briefly presents Principles 1, 2, and 5, while Principles 3 and 4 are well established in the STEAM literature[9].

To guide the design of the EPs, a transdisciplinary approach was adopted as the primary model of integration, with an interdisciplinary approach used where appropriate. Although technology and engineering are not explicitly represented in the primary curricula of all participating countries, all STEAM disciplines were meaningfully integrated into every educational package.

Themes served as the central organizing element of the EPs, providing meaningful contexts for connecting disciplines and linking learning to students' everyday experiences (Beane, 1997; Williams et al., 2016). The themes were selected through a comparative analysis of the curricula in the four participating countries and then evaluated by teachers for their relevance to support STEAM learning. This process resulted in 12 themes: Water and the Sustainable Development Goals, Symmetry, Insects, Experimenting with Eggs, Measuring Rainfall, Newton's Disc, The Solar System, Pets and Their Care, The Human Body, Energy Use and Climate Change, Soil, and Paper Recycling.

The framework also defined a common structure for all STEAM EPs. Each package includes a central theme, discipline-specific learning objectives, a lesson overview, and detailed teaching scenarios describing lesson phases, teacher and student activities, required materials, and formative assessment strategies.

The development of STEAM educational packages

The development of the STEAM educational packages (EPs) was guided by the assumption that, although STEAM education is often associated with specialized tools and equipment, the materials should be applicable across schools with different resource levels. Building on the 12 selected themes, each partner country developed three EPs comprising 4–6 lessons. The EPs were then piloted in partners schools. Teachers documented student responses, identified implementation challenges, and suggested improvements. Accordingly, the university and teacher teams refined the EPs, providing an initial validation before their use in the professional development program across the partner countries.

[9] The significance of using open-ended problem is discussed in greater detail in (Agustianingsih & Mahmudi, 2019, Smith & Higgins, 2006), while the implementation of efficient pedagogical strategies grounded in active and inquiry-based learning are described in (Camacho & Legare, 2015; Çimer, 2007; Ivić et al., 2002).

The evaluation of the effects of implementing the STEAM EPs

The main validation phase involved implementing three STEAM EPs in each country: one developed nationally and two developed by partner countries. In each country, 20–30 teachers who were not members of the project team participated in the STEAM professional development program, delivered by the university researchers and teachers who had developed the EPs.

In Serbia, the program involved 28 primary school teachers. During a one-day seminar, trainees were introduced to the STEAM approach, the pedagogical framework, and the EPs, which they subsequently implemented in their regular classroom practice. At the end of the training, teachers received all materials needed for implementation.

The effects of the professional development program were evaluated across all four countries with both teachers and their students.

The aim and design of the research

As noted above, this study is part of a broader four-country evaluation examining the effects of implemented STEAM EPs on students and teachers. This paper focuses on teachers from Serbia who participated in a STEAM professional development program designed to support the implementation of three EPs evaluated in Serbia: Human Body (developed in Serbia for Grade 4), Symmetry (developed in Italy for Grade 2), and Measuring Rainfall (developed in Italy for Grade 3). The aim was to examine changes in teachers' self-efficacy for teaching STEAM following the training, as well as their experiences of implementing the EPs.

A mixed-methods design was employed, combining quantitative and qualitative approaches. In the quantitative phase, teachers completed a self-efficacy scale before the training and after EP implementation to assess changes in their perceived ability to apply STEAM approaches. In the qualitative phase, semi-structured interviews were conducted after implementation to explore teachers' experiences of applying STEAM in regular classroom settings and to gain deeper insight into their perspectives and challenges during implementation.

Method

Participants

The sample was convenient consisting of 28 primary school teachers from Belgrade primary schools. Ten teachers implemented the Symmetry package with their students (aged 7–8). Nine teachers implemented the Rainfall Measurement package with students aged 9, and nine teachers implemented the Human Body package with students aged 10.

Instruments

The STEAM Teacher Self-Efficacy Scale (STEAM-TSES) was created by the university project members from Serbia and Portugal showing good metric characteristics (see Stepanović Ilić et al., 2025). It was used as a pre-test (before the professional development training) and a post-test (after the implementation of the EP), to measure teachers' self-efficacy in teaching STEAM. The STEAM-TSES consists of 36 items organized into nine subscales, rated on a 7-point Likert scale. Teacher self-efficacy in teaching includes five subject-specific subscales: mathematics, biology, chemistry, physics, and art (*I am confident that I can teach mathematics/biology/chemistry/physics concepts effectively* and *I am confident that I can teach arts/artistic expression effectively*). Teacher self-efficacy in motivating students to learn includes three subscales: mathematics, science, and art (*I am confident that I can increase students' interest in mathematics/science/arts*). The final subscale assesses teacher self-efficacy in integrating STEAM disciplines (*I feel confident integrating science, mathematics, and art*). The instrument was administrated via link leading to the scale and teachers were invited to complete the survey before the training and after the implementation of STEAM EPs.

Semi-structured interviews were conducted with 28 teachers after the implementation of the EPs to explore their experiences. The interview guide comprised 17 open-ended questions organized around four themes: (1) teachers' experiences with implementing the STEAM learning packages (*What was the biggest challenge in teaching students STEAM?* and *What was the thing you liked the most?*) (2) changes in teachers' self-efficacy for teaching STEAM disciplines (*Do you find yourself more confident in integrating science ideas mathematics, and art?*) (3) teachers' perceptions of students' engagement, learning, and equity during STEAM activities (*What kind of benefits did your students have from engaging in this way of learning? Do you think this teaching approach has a stronger impact on student's learning outcomes in comparison to the regular way of teaching? Why?*) and (4) opportunities and challenges for the wider implementation of the STEAM in everyday practice (*Do you think that this teaching method is more demanding for teachers? Why? In what way?* and *What would be the biggest obstacles to teaching using the STEAM approach?*). For the purpose of this paper, we analyzed only questions quoted in the brackets.

Data analysis

Paired-samples t-tests and the corresponding non-parametric tests were employed to examine changes in teachers' self-efficacy after the professional development training. Data obtained from the semi-structured interviews were analyzed by inductive thematic analysis.

Results

Quantitative study

For 18 out of 28 teachers pre and post-test data were collected. Given that each STEAM-TSES subscale consists of four items rated on a 7-point Likert scale, the possible scores range from 4 to 28, with higher scores indicating greater teacher self-efficacy. As shown in Table 1, teachers reported relatively high levels of self-efficacy across all subscales already at the pre-test. The highest mean scores were observed for mathematics, followed by biology. The lowest mean scores were found for physics, chemistry and arts, suggesting that teachers felt less confident teaching these subjects prior to the professional development program.

Table 1. Descriptive statistics of pre and post-test measures on the STEAM-TSES

STEAM-TSES subscale	Pre-test M (SD)	Post-test M (SD)
Mathematics Teaching	24.67 (2.28)	25.06 (2.39)
Mathematics Motivation	23.72 (2.53)	24.17 (2.46)
Biology Teaching	23.31 (3.57)	24.44 (3.01)
Chemistry Teaching	20.00 (1.38)	21.67 (1.21)
Physics Teaching	20.22 (5.17)	21.61 (4.94)
Science Motivation	22.61 (2.68)	23.28 (2.47)
Arts Teaching	21.31 (6.06)	22.72 (5.21)
Arts Motivation	21.83 (4.77)	23.06 (4.18)
STEAM Integration	23.33 (3.23)	24.00 (2.81)

Table 2 presents the results of paired t-test for 18 teachers participating in both surveys. Negative mean differences indicate that post-test scores were higher than pre-test ones. Statistically significant improvements of teachers STEAM self-efficacy were observed in teaching biology, chemistry and arts, as well as in their confidence to motivate students towards arts. Results related to the teachers' self-efficacy to teach physics are close to the statistical significance.

Table 2. Results of paired-samples t tests comparing pretest and posttest STEAM-TSES scores

Variable	Mean Difference	95% CI	t (df=17)	*p*
Mathematics Teaching	-0.78	[-2.11, 0.55]	-1.24	.233
Mathematics Motivation	-0.89	[-2.55, 0.77]	-1.13	.275
Biology Teaching	-2.28	[-4.26, -0.30]	-2.43	.027*
Chemistry Teaching	-3.33	[-6.30, -0.37]	-2.37	.030*
Physics Teaching	-2.78	[-5.58, 0.02]	-2.09	.052
Science Motivation	-1.33	[-2.82, 0.15]	-1.89	.076
Arts Teaching	-2.83	[-5.39, -0.27]	-2.34	.032*
Arts Motivation	-2.44	[-4.48, -0.41]	-2.54	.021*
STEAM Integration	-1.33	[-3.58, 0.91]	-1.25	.227

To confirm the robustness of the paired-samples t-test findings, related-samples Wilcoxon signed-rank tests were conducted. The nonparametric analyses corroborated the parametric, revealing statistically significant pretest–posttest differences in teaching biology ($p = .035$), chemistry ($p = .046$) and arts ($p = .021$), as well as in Arts Motivation ($p = .028$). No significant differences were observed for teachers' self-

efficacy in teaching mathematics and physics, motivating students to learning mathematics and science, or STEAM integration.

Qualitative study

The five leading topics were extracted in inductive thematic analysis, two related to their impression about STEAM education effects on students, one to their professional development and two to challenges and conditions needed to apply STEAM in everyday practice.

Theme 1. Student Engagement Through Active and Experiential Learning - Teachers consistently described STEAM as highly engaging as students actively experimented and discovered concepts. They reported increased curiosity, motivation, creativity, responsibility, and persistence, while students remained focused, asked additional questions, and took greater ownership of their learning. Teachers perceived these experiences consistent with the principles of inquiry-based and meaningful learning. As one teacher explained: "What I really liked was how the children responded to this type of activity. It seemed to me that they were much more disciplined than usual because they were actively engaged. They stayed focused and involved throughout the activities. As I mentioned earlier, the emphasis was not on us, the teachers, but on the students themselves. I think they naturally felt important and responsible because they were the ones doing the work and creating a tangible product from their efforts."

Theme 2. Enhancement of Meaningful learning and Functional Knowledge - Teachers believed STEAM supported deeper conceptual understanding by connecting abstract concepts with concrete experiences. Through experimentation, observation, and problem-solving, students developed more functional and transferable knowledge, integrating ideas across disciplines. Teachers perceived this learning as more durable and meaningful because students actively constructed understanding through inquiry and firsthand experience. As one teacher noted: "I think the knowledge is of higher quality, more long-lasting, because it is something the students learned for themselves. It wasn't something I simply told them or something they memorized; they actually saw it, carried it out, and experienced it themselves."

Theme 3. Teacher Professional Growth and Expanding Pedagogical Perspectives - Implementing the STEAM packages encouraged teachers to reflect on their instructional practices and strengthened their confidence in using inquiry-based, interdisciplinary approaches. Many described the experience as professionally rewarding and reported becoming more willing to experiment with innovative teaching methods while recognizing the need for continued professional learning. As one teacher explained: "I feel more competent because the students were motivated, interested, and willing to complete the project. We successfully carried it through together, so I believe I could implement other similar projects in the future."

Theme 4. Practical and Organizational Challenges of STEAM Implementation - Teachers identified several challenges accompanying STEAM implementation. The most common included coordinating collaborative group work, ensuring equal participation, managing time, preparing materials, fitting activities within the prescribed curriculum, and monitoring multiple student groups simultaneously. Some

teachers also expressed uncertainty about facilitating conceptual understanding without traditional instruction, particularly with younger pupils. This is one answer regarding teachers' difficulties to monitor and facilitate group work: "The biggest challenge was group work and making sure that everyone was equally involved. Our role as teachers was crucial in assigning roles and ensuring participation. That was the most difficult part for me…"

Theme 5. Conditions for Sustainable STEAM Implementation - Teachers viewed STEAM as a valuable approach with strong potential for regular classroom use but emphasized that successful implementation requires supportive conditions. They highlighted the importance of curriculum flexibility, sufficient instructional time, access to materials, carefully designed teaching resources, professional development, and, in some cases, parental support. Many argued that STEAM is most sustainable when integrated systematically into school practice rather than implemented as isolated projects. Here is the one authentic response: "We talk about it, but until it is implemented systematically, nothing much will come of it. There are many things that could be done, but they often don't occur to us because the curriculum is fragmented."

Discussion

The findings indicate that even a relatively short STEAM professional development program can enhance teachers' confidence in implementing this approach and promote positive changes in classroom practice. The results revealed significant improvements in teachers' self-efficacy for teaching biology, chemistry, and arts, as well as in motivating students to engage with the arts. These findings are encouraging, given previous research identifying teachers' lack of confidence in teaching science as a major barrier to STEAM implementation (Baigiati & Evangelou, 2015; Park et al., 2016). No significant gains were found for mathematics or STEAM integration, likely reflecting ceiling effects, as teachers reported high baseline confidence in these domains.

The qualitative findings show that teachers perceived the STEAM EPs as highly effective in increasing students' engagement and motivation, while particularly enhancing the quality of learning outcomes. These observations are consistent with previous research demonstrating that inquiry-based, hands-on STEAM activities foster meaningful learning by linking concrete experiences with conceptual understanding (Jirout, 2020; Su et al., 2024; Veziroğlu-Çelik et al., 2025).

Our finding suggest that the implementation of the STEAM EPs encouraged teachers to reflect on their instructional practices and increased their willingness to adopt inquiry-based and interdisciplinary approaches. This finding extends previous evidence that professional development enhances teachers' competence for STEAM implementation (Bassachs et al., 2020; Conradty & Bogner, 2020; Silva-Hormazábal & Alsina, 2023).

However, Serbian teachers identified significant barriers to implementing STEAM activities, including insufficient financial resources for preparing teaching materials, limited instructional time due to extensive curriculum demands, and the challenges of managing collaborative classroom activities. These findings are consistent with previous studies showing that inadequate pedagogical preparation and organizational constraints remain major obstacles to STEAM implementation (Baigiati & Evangelou, 2015; Park et al., 2016), while also reflecting systemic challenges within the Serbian education. According to OECD (2020) and UNESCO Institute for Statistics (2026), public investment in education in Serbia remains below the OECD average, and the long-term decline in education expenditure as a share of GDP has constrained the modernization of schools and the provision of adequate teaching materials and educational resources. Moreover, researchers documented shortcomings in initial teacher education in Serbia, as insufficient preparation for contemporary student-centered and integrated teaching approaches, with overloaded curricula remaining predominantly oriented toward traditional instructional practices (Đorđević et al., 2020; Kovač Cerović et al., 2015). This may encourage reliance on teacher-centered instruction despite generally positive attitudes toward active learning (Milanović & Maksimović, 2021). Another important challenge concerns the management of collaborative student work. Although facilitating effective group work is widely recognized as a demanding aspect of teaching (van Leeuwen & Janssen, 2019), Serbian teachers' difficulties may also be associated with limited opportunities during their initial teacher education. Accordingly, our respondents emphasized that sustainable STEAM implementation requires greater curriculum flexibility, adequate resources, and continuous professional support.

This study has several limitations. It involved a relatively small convenience sample from a single country, with complete pre- and post-test data available for only part of the sample. Future research should examine the long-term effects of STEAM professional development using larger, more diverse samples.

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INTEGRATION OF DIGITAL EDUCATIONAL TECHNOLOGIES AND STUDENT MOTIVATION IN PHYSICAL EDUCATION

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Abstract: Contemporary schooling faces the challenge of integrating digital educational technologies into physical education, which is particularly significant for student motivation and active participation. The aim of this paper is to analyze the possibilities of applying digital tools in physical education classes and their impact on student motivation. The sample of the study consists of relevant domestic and international research, as well as examples from teaching practice in lower primary school grades. The method applied is theoretical-analytical. The results of the review indicate that tools such as PowerPoint, Kahoot, WordWall, Scratch, InShot, and LearningApps enable active student participation, foster collaborative and competitive spirit, stimulate critical thinking, and contribute to the long-term acquisition of motor skills. Practical examples show that the use of digital technologies in lower grades leads to increased attention, curiosity, and persistence among students, as well as better understanding of teaching content. At the same time, challenges have been identified, such as insufficient digital literacy among teachers and the risk of reduced physical activity due to excessive use of technology. The conclusion is that digital educational technologies have great potential to improve physical education, provided that teachers act as facilitators of learning and apply digital tools in accordance with instructional goals. The pedagogical implication of the study is that technology should serve as a complement, rather than a substitute, for physical activity, and that continuous professional development of teachers in the field of digital literacy is essential.

Keywords: *educational technologies, physical education, student motivation, active learning, interactive learning.*

Introduction

Contemporary school instruction must transcend the mere reproduction of knowledge characteristic of traditional educational paradigms, wherein pupils are conceptualised as passive recipients and the pedagogical process is restricted to a unidirectional transfer of information. Conversely, contemporary pedagogy necessitates that pupils function as active participants within the instructional process. Learning should be realized through inquiry, collaboration, and creation, thereby fostering critical thinking and autonomous action. The inherent limitations of traditional instruction can be effectively mitigated by restructuring the respective roles of educators and learners.

Inquiry, collaboration, and cooperative creation constitute the cornerstone for developing pupils' critical thinking and autonomy. Within this framework, physical education (PE) assumes a distinct pedagogical significance. It is structured to provide intrinsic satisfaction to all pupils, irrespective of their individual inclinations or physical capabilities. Empirical evidence underscores that student motivation not only plays a pivotal role in academic achievement but also represents a vital educational outcome in its own right (Đorđić, 2012; Živanović, 2018). Furthermore, Živanović (2018) observes that pupils who experience satisfaction during PE classes exhibit significantly higher levels of physical activity outside the school environment. Consequently, understanding student motivation in PE has direct implications for enhancing

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instructional quality, specifically in establishing a learning environment that fosters sustained and engaged participation. Modern instructional practices are directed towards the holistic development of learners, placing particular emphasis on motivational dynamics. The efficacy of learning depends heavily upon student motivation, which is recognized as a potent driving force that cultivates perseverance and a positive disposition towards the educational process.

Addressing these pedagogical challenges, this paper examines the potential contributions of digital educational technologies towards enhancing student motivation within physical education classes. The methodological advantages of technological implementation are analysed in comparison to traditional instructional modalities, alongside strategies for integrating these tools into PE practice to stimulate engaged and persistent student participation. Concurrently, the paper delineates the limitations and challenges associated with technological application in this specific instructional domain. This study is designed as a theoretical-analytical research paper incorporating a qualitative analysis of pedagogical practice, grounded in established didactic and psychological theories of motivation and educational technology. The overarching aim of this paper is to deepen the understanding of the affordances and constraints of technology integration in physical education instruction, with a primary focus on optimizing student motivation.

Characteristics of learning with educational technologies

Premised upon the paradigm of pedagogical optimization through technological integration, Ristić and Mandić (2023) define educational technology as a systematic and interactive process of instructional and training design. They note that alternative terms, such as teaching technology or instructional technology, are frequently deployed interchangeably within the literature. Similarly, Matijević (1999) conceptualises educational technology as a *terminus technicus*, denoting a deliberate synthesis of programmes, procedures, and instruments grounded in empirical research concerning instructional processes. Whilst this concept has been extensively interrogated in academic literature—with numerous authors highlighting its didactic affordances alongside certain constraints—its primary objective remains the streamlining and optimization of pedagogical delivery.

Within the domain of physical education (PE), the characteristics of technology-enhanced learning manifest through heightened instructional interactivity, an orientation towards active learning, the visual representation of curricular content, and substantially elevated pupil motivation. Digital instruments facilitate bidirectional communication, rapid feedback loops, and active engagement via quizzes, simulations, video tutorials, and gamified applications, thereby stimulating curiosity and learner involvement. Knowledge acquired through active and interactive modalities is empirical recognized to foster deeper comprehension, enhance long-term retention, and cultivate critical thinking in children.

Furthermore, active learning constitutes a core component of professional development, equipping educators with diverse methodologies for child-centred instruction (Ivić, Pešikan and Antić, 2001). This methodological shift fundamentally redefines the educator's role, placing the pupil at the centre of the pedagogical process whilst transforming the teacher into a facilitator who encourages independent reasoning and autonomous participation.

Interactive learning, which functions synergistically with active learning, is predicated upon reciprocal, bidirectional communication and the exchange of information, ideas, and perspectives. A defining feature of this paradigm is that pupils transcend the role of passive information consumers; instead, digital tools enable them to acquire requisite theoretical knowledge, develop motor skills, and enhance digital literacy. Concurrently, educators can adapt instructional content to accommodate heterogeneous ability levels. Modern technology facilitates differentiated learning, empowering each pupil to progress autonomously according to their individual capacities, with the added benefit of home-based monitoring assuming adequate technical infrastructure is available. In primary education, the use of graphic elements and visual symbols has proven exceptionally stimulating, as simple schematics ease the comprehension and internalization of motor tasks. Gamified activities serve as potent catalysts for heightened motivation and task focus. For instance, during PE sessions with first-grade primary school pupils, warm-up routines can be represented through a series of pictograms—such as a sun icon indicating arm extension, a cloud representing respiratory control, and arrows directing locomotor trajectories.

Interactive applications, such as Kahoot and WordWall, foster both competitive and cooperative dispositions through quizzes and games that stimulate cognitive curiosity. Video editing tools like InShot, alongside platforms such as YouTube, facilitate the precise visualization of movement patterns and proper kinematic execution, bridging school instruction and home practice. Furthermore, the Scratch application allows for the creation of educational narratives and simulations that introduce sports elements creatively, whilst PowerPoint is utilized for designing structured presentations, interactive games, and associative puzzles that bolster attention spans. Similarly, LearningApps optimizes the learning process through customizable interactive assignments.

Ultimately, the paramount characteristic of technology-enhanced learning resides in its intrinsic pedagogical value. It is incumbent upon educators to continuously develop their digital competences and pursue professional development. Crucially, because the foundational component of physical education is physical exertion and motor movement, educational technologies must be conceptualized strictly as a longitudinal supplement to traditional methods, rather than a substitute. The overarching objective of educational technology in this domain is to stimulate motor development and cultivate healthy lifestyle habits, thereby preserving the primary teleological goals of physical education: physical activity and public health.

Previous research

Empirical investigations into the integration of educational technologies within physical education (PE) instruction underscore the significance of digital tools as vital adjuncts to traditional pedagogical modalities. Current literature increasingly highlights their capacity to catalyze student motivation and optimize instructional delivery. Within contemporary pedagogical discourse, it is widely asserted that technology must not eclipse physical exertion; rather, it should function strictly as an instrument for instructional enhancement and the preservation of pupil health. A critical synthesis of extant research delineates both the systemic constraints and the affordances of purposeful technological implementation in PE settings.

In their seminal work, Casey, Goodyear and Armour (2017) posit that digital technologies in PE can substantially enhance learner motivation and facilitate self-reflection through mobile applications, video analysis, and interactive platforms. The authors contend that educators must develop robust digital competences to ensure that technological deployment remains pedagogically justified and auxiliary to physical activity, rather than becoming an end in itself. Corroborating these insights, Dmitriev et al. (2012) conceptualise educational technologies within physical culture as potent catalysts for motivation, visual learning, and the cultivation of health-oriented habits, while explicitly demanding a balanced and regulated implementation. They reinforce the paradigm that educational technology should support, rather than supplant, physical culture and somatic health.

The foundational role of primary physical education is further accentuated by Sinđelić (2024), who argues that a systematic pedagogical approach in early childhood education fosters motor proficiency and establishes positive behavioral dispositions toward lifelong physical activity. According to this author, the early internalization of movement patterns forms the bedrock for continuous physical development. Concurrently, Goodyear and Dudley (2015) identify an evolution in the professional identity of PE teachers, who are increasingly conceptualized as facilitators of learning. This shifts the focus toward learner-centered environments where, as Perlman (2018) observes, technology significantly amplifies student motivation, provided its implementation is systematically planned and pedagogically oriented. Expanding upon this framework, Harvey and Pill (2019) note that digital devices and video feedback mechanisms support not only motivational dynamics but also the development of critical thinking and self-reflective capabilities among learners.

The deployment of gamification strategies via interactive software such as Kahoot and WordWall represents another critical dimension of modern instruction. Pejić (2021) demonstrates that gamified PE environments significantly boost pupil motivation, enhance instructional dynamics, and foster both cooperative and competitive dispositions. Crucially, the author cautions that gamification must remain aligned with primary curricular objectives rather than serving as a detached technological novelty.

However, the efficacy of such mobile applications remains highly contingent upon institutional infrastructure. Ristić (2018) notes that successful implementation requires adequate technical support and comprehensive digital literacy among educators. In this context, digital literacy transcends technical operation, requiring a profound understanding of the technology's intrinsic pedagogical value. Finally, Lukić et al. (2019) emphasize the necessity for educators to discern heterogeneous motivational profiles within the cohort, allowing for differentiated instruction that fosters sustained autonomous motivation and a positive disposition toward physical culture.

Based on a critical synthesis of the aforementioned literature, it can be concluded that educational technology in physical education holds profound potential to elevate student motivation, cultivate critical thinking, and embed health-promoting habits. This potential is unlocked exclusively when technological intervention is pedagogically justified, balanced, and strictly directed toward the physiological and motor development of children. The consensus across contemporary scholarship mandates that technology yields value only when it serves established instructional goals, with the educator effectively navigating the process as a facilitator of learning.

Application of educational technologies in physical education teaching

Aligned with the aforementioned theoretical framework, various digital instruments were integrated into physical education (PE) instruction, with their resultant outcomes systematically evaluated through empirical field examples. The integration of educational technologies within PE delivery is delineated here based on experiential data derived from active teaching practice. Specifically, this section illustrates a structured lesson plan focused on curricular unit acquisition through interactive applications, aiming to optimize pupil motivational dynamics. Furthermore, the operationalization of distinct technological modalities within PE is outlined, reaffirming the paradigm that technology must function as an auxiliary mechanism to support, rather than supplant, physical exertion. Crucially, these interactive applications and digital devices serve as viable complements to traditional pedagogical modalities.

The primary instructional intervention focused on the methodical progression of a gymnastics unit: the forward roll, backward roll, and dive roll (Serbian: *kolut napred, kolut nazad i leteći kolut*). This unit was implemented within a primary school cohort. During the introductory phase of the lesson, a PowerPoint presentation was deployed to stimulate situational motivation and cognitive interest; the visual content delineated anatomical alignment and correct posture as foundational prerequisites for subsequent motor skill acquisition. Following this introductory phase, the instructional sequence transitioned into preparatory and warm-up exercises designed to physiologically prime the musculature for high-amplitude physical exertion in the main phase of the lesson. The cohort was subsequently partitioned into small groups, wherein the InShot application was utilized to deliver video-based instructional cues demonstrating the precise kinematic execution of forward, backward, and dive rolls. Observational data indicated heightened learner

motivation and sustained attentiveness; moreover, through bidirectional dialogue concerning the theoretical underpinnings of movement, pupils successfully internalized the principles of postural alignment. In the concluding phase of the lesson, a PowerPoint-based formative quiz was administered, configured to redirect pupils back to the prompt until the correct response was achieved. This task required collaborative reasoning, cooperative peer interactions, and team cohesion.

Pedagogical practice demonstrated that the strategic deployment of educational technologies in PE constitutes a salient catalyst for student motivation. The utilization of PowerPoint proved highly efficacious in elevating engagement. The introductory presentation provided a systematic and visual orientation to the curricular content, thereby securing greater pupil focus for the remainder of the session. Furthermore, PowerPoint was configured to host gamified elements, such as associative word puzzles and interactive "hide-and-seek" interfaces, which enriched the instructional environment through structured play and interactivity.

In a separate instructional intervention designed to introduce fundamental basketball skills, the Scratch application was utilized during the introductory phase to present an interactive, narrative-driven digital story to the primary school pupils. This was followed by a preparatory somatic phase involving dynamic stretching and shaping exercises. In the main instructional phase, a video tutorial was rendered via the InShot application, illustrating optimal kinematic parameters for basketball dribbling. The session culminated in a sports-centric formative evaluation using the Kahoot platform. The instructional delivery remained highly dynamic, characterized by consistent interactive communication and substantial physical exertion, whilst pupils maintained high levels of motivation and cognitive focus.

Concurrently, interactive software platforms such as WordWall and LearningApps significantly augmented student motivation through gamified tasks. These digital tools were deployed during the cool-down phase of the lesson to facilitate the physiological return to a baseline resting state. The gamified tasks were intrinsically aligned with the lesson's learning objectives, necessitating theoretical comprehension for successful participation. Pupils exhibited elevated curiosity and cognitive engagement, consistently anticipating subsequent digital interventions. This pedagogical approach prioritises interactive content and active student engagement, whereby knowledge is constructed dynamically through cognitive processing, motor execution, and physical activity. Such field practices establish a robust framework for high-quality instructional delivery that departs from passive learning paradigms, provided that these educational technologies are implemented within pedagogically balanced parameters.

Advantages and disadvantages of integrating technology in physical education teaching

In alignment with contemporary empirical discourse regarding the dual nature of technological integration, Mehmedović and Hajrić (2024) demonstrate that the deployment of modern digital instruments

exerts a profoundly positive effect on student motivation, streamlines content accessibility and internalization, and enhances digital literacy among both educators and learners. Conversely, their study delineates specific systemic drawbacks that warrant rigorous and critical investigation. Excessive instructional reliance on digital devices within the learning environment can precipitate a decline in somatic exertion and attenuate direct interpersonal communication among peers. A particularly salient deficit highlighted in their research relates to the suboptimal level of digital literacy among teaching staff, a factor that critically constrains the effective operationalization of educational technologies within physical education (PE) frameworks (Ristić, 2018; Casey, Goodyear and Armour, 2017). The conclusions of their study resonate with broader kinesiology research; given that physical culture fundamentally prioritizes physiological movement and the cultivation of prosocial peer dynamics, an uncritical or unmodulated reliance on digital tools poses substantial limitations and latent adverse outcomes.

Because physical education is structurally predicated upon motor proficiency and continuous physiological expenditure, the paramount benefit of educational technology lies in its capacity to stimulate child kinetics. Contemporary instruction seeks the holistic development of the child, transcending the spatial and structural constraints of traditional teaching paradigms to position multifaceted learner activity at the core of the curriculum. The strategic implementation of educational technology serves to further "vitalize" this process. Through the deployment of digital applications, interactive software, and gamified platforms, instructional delivery becomes structurally dynamic, thereby amplifying intrinsic motivation and active student engagement. A highly significant affordance is the capacity for instructional differentiation and personalization, alongside the precise visualization of locomotor tasks via video analysis. This visualization uniquely contributes to a deeper cognitive comprehension of technique and facilitates real-time error correction. Furthermore, digital assessment tools empower educators to measure pupil achievements with heightened objective accuracy, whilst simultaneously fostering health literacy and an awareness of the importance of lifelong physical activity among learners.

Conversely, critical constraints persist regarding the absolute dependence of the instructional framework on hardware configurations and institutional network infrastructure, which presents a significant barrier in environments lacking robust infrastructural support. This is particularly challenging given that PE curricula are delivered heterogeneously across indoor gymnasiums and outdoor school environments. Moreover, the literature confirms that excessive technological deployment can paradoxically diminish physical activity if implemented without stringent pedagogical oversight—specifically in scenarios where pupils lapse into passive observers rather than mastering motor execution through active physical participation. Over-reliance on these tools may also erode spontaneous social communication, an outcome that is uniquely detrimental within physical education due to the discipline's intrinsic reliance on cooperative socialization. Ultimately, while digital literacy represents a positive outcome of technological integration, modern instruction mandates sophisticated digital competence from educators to guarantee that

technological intervention is directed exclusively toward the best interests of the child. Consequently, a deficit in teacher digital literacy remains one of the most distinct structural barriers to effective technology-enhanced physical education delivery.

Conclusion

The distinct contribution of this paper resides in the presentation of empirical pedagogical interventions demonstrating the integration of educational technologies within physical education (PE) instruction, thereby serving as a replicable model for educators in daily school practice. By illustrating the functional operationalization of these digital instruments, this study opens up novel avenues for subsequent methodical and empirical investigations into their longitudinal effects. Within PE instruction, educational technology is conceptualized as a powerful mechanism for enhancing student motivation and monitoring motor progression; however, it remains critically mandated that technology acts exclusively as a supplement to, rather than a substitute for, somatic practice. Contemporary physical education delivery is increasingly unfeasible without the strategic adoption of technological dimensions that serve to optimize the instructional framework. Modern pedagogy demands a high degree of teacher creativity and professional competence, while requiring active, autonomous participation from learners. Consequently, educational technologies emerge as pivotal instruments that facilitate both active and interactive learning paradigms. They provide the necessary infrastructure to pivot physical education toward a learner-centered approach, thereby fostering heightened student motivation, sustained attention spans, optimal knowledge internalization, the cultivation of cooperative and competitive dispositions, and the advancement of digital literacy.

Grounded in the comprehensive theoretical synthesis and field-based insights examined throughout this study, evidence confirms that the systematic integration of digital tools and interactive applications in PE substantially elevates pupil motivation. These digital interventions encourage a more active learner role and foster a positive behavioral disposition toward physical culture, aligning seamlessly with established curricular and national educational objectives.

Concurrently, this research highlights systemic limitations within contemporary school systems, specifically the insufficient evaluation of physical education delivery and the urgent necessity for institutional, structured professional development for teaching staff regarding technology-enhanced instruction. It is particularly underscored that in institutional practice, physical education is frequently subjected to pedagogical marginalization and placed in a lower rank relative to other academic disciplines. This occurs despite a robust body of international empirical evidence demonstrating that regular physical exertion and quality PE instruction exert a profound influence on the holistic psychophysical development of children. The institutional neglect of physical education classes poses severe risks to the physiological,

cognitive, and social development of pupils. This reality further accentuates the critical need for a systematic re-evaluation of the discipline and a carefully planned, pedagogically driven integration of modern educational technologies.

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ACQUISITION OF DIALECTAL VOCABULARY AMONG STUDENTS: IMPLICATIONS FOR THE APPLICATION OF THE STREAM APPROACH IN SERBIAN LANGUAGE TEACHING

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Abstract: This paper examines the acquisition of dialectal vocabulary among secondary school students and the influence of context on the comprehension of dialectal lexical items. The research focuses on dialect words from Momčilo Zlatanović's *Dictionary of Southern Serbian Speech*, which denote female persons characterized by specific physical or personality traits. The aim of the study was to determine the extent to which students understand these lexical items, as well as to explore the potential application of the STREAM approach in Serbian language teaching. The study was conducted in two phases on a sample of students from both urban and rural areas: interpretation of lexical items without context and interpretation of the same items within sentences. The results show that students significantly better understand dialectal vocabulary when it is presented in context, while isolated interpretation often leads to incorrect and associative answers. It was also observed that students are more successful in recognizing lexical items that are part of their everyday speech environment. Based on the findings, a model lesson grounded in the STREAM approach was designed and implemented. The lesson was designed to provide opportunities for active student participation, collaborative work, digital literacy development, and creative expression. The conclusion highlights the importance of context in understanding dialectal vocabulary, as well as the pedagogical implications of the STREAM approach for Serbian language instruction.

Keywords: dialectal vocabulary, STREAM approach, Serbian language teaching, digital literacy, creative learning.

Introduction

The subject of this research consists of dialectal expressions from *The Dictionary of the Speech of Southern Serbia* by Momčilo Zlatanović, which denote female persons characterized by physical appearance or certain personality traits. In order to determine the extent to which secondary school students are able to interpret these words, they were first asked to independently write down their meanings and then to interpret the same lexical items when they appeared in sentence context. The research problem lies in students' insufficient understanding of dialectal vocabulary, as well as their frequent reliance on associative interpretation of words outside context. This problem indicates the need for a more dynamic and context-based teaching approach. Therefore, the STREAM approach is considered a possible methodological framework that enables interdisciplinary and contextual learning, with the aim of improving students' understanding of dialectal vocabulary.

From this aim, the following tasks are derived: 1) to determine which lexemes were known to most students, 2) which lexemes were completely unknown, 3) for which lexemes the greatest surprise was observed, and 4) in relation to which lexemes the greatest rural–urban differences exist.

The Dictionary of the Speech of Southern Serbia was compiled by Dr. Momčilo Zlatanović. The

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material for this dictionary was collected from living folk speech and oral poetry. The presented lexical sample from Zlatanović's dictionary, incorporated into the SANU Dictionary, undoubtedly enriches the Serbian language with folk vocabulary that reflects a specific aspect of human attitudes toward work, the acquisition of wealth, fertile or infertile land upon which quality of life depends, as well as attitudes toward individuals unable to work, etc. A more detailed analysis of the definitions of these lexemes shows that they are mostly descriptive in nature, sometimes supplemented with a relative synonym from the standard literary language. This means that in such cases there are conditions for this type of vocabulary, originating from the people, to be further studied and integrated.

Language does not exist on its own; as a means of communication within an organized human community, it cannot be free from ideological, political, and cultural influences that shape the thinking of members of a given culture. It is not merely a referential tool, but a living organism that embeds cultural meanings within the intended messages of speakers (Biti 2008: 51).

Language reflects cultural and social attitudes, and as such it is not neutral but shaped by ideological and cultural influences. These influences are often embedded in stereotypes, which affect perception and interpretation of meaning. Stereotypes tend to overemphasize differences between groups while reducing differences within groups (Breglec 2015: 216). Research on gender stereotypes shows that women are often associated with both physical and personality-based traits that are socially constructed (Trebješanin 87–95; Baldwin 2021: 497).

Many of the lexemes discussed in this paper denote undesirable traits and also have onomatopoeic origins. In addition, some lexemes refer to physical deformities. An analysis of the selected lexical material shows that the number of nouns with desirable and undesirable meanings is almost equal, although those expressing undesirable traits slightly predominate. Rajna Dragićević notes that the traits most frequently noticed by speakers of the Serbian language are physical ones, particularly those related to reproductive ability, walking difficulties, aging, and body weight. From this list of nouns, it can be seen how a woman with desirable traits is expected to look: she must not be too thin or too overweight, must not have visible deformities, and must be hardworking, etc. (Dragićević 2010: 117).

Language reflects the culture of a particular society. 'Therefore, prejudices transmitted through language (stereotypes) are cyclical in nature. Language reflects societal attitudes, and those attitudes are then transmitted through language. In this way, stereotypes become embedded in everyday language use and influence the interpretation of lexical meanings' (Breglec 2015: 219).

Methodological framework

In order to examine students' knowledge of female-related terms, we considered secondary school students living in both urban and rural areas to be the most suitable participants, since they communicate daily both among themselves and with older members of the community. Given the fact that they live in a dialectal area where informal speech is predominantly dialectal, we assumed that they would be able to interpret the meanings of these expressions.

Research Hypotheses

– It was hypothesized that students would better understand dialectal expressions when they were presented in context.

– It was hypothesized that students from rural areas would demonstrate better knowledge of dialectal vocabulary.

– It was hypothesized that the STREAM approach could provide a suitable methodological framework for teaching dialectal vocabulary.

Research Methods

The primary methods used in this research are descriptive and statistical methods.

The STREAM approach as a methodological framework

In language teaching, the STREAM approach is an interdisciplinary model that promotes active knowledge construction through inquiry, interpretation, and creative expression. In this study, STREAM was used as a methodological framework to support the acquisition of dialectal vocabulary through contextual analysis, collaborative group work, and the use of digital tools. The approach was selected due to its ability to integrate linguistic analysis with creative, analytical, and technological skills, making it particularly suitable for the study of dialectal vocabulary, where meaning is strongly dependent on context. STREAM (Science, Technology, Reading, Engineering, Arts and Mathematics) represents an extension of the STEAM model through the inclusion of Reading as a distinct component. The approach emphasizes interdisciplinary learning, critical literacy, project-based activities, creativity, and the application of knowledge in authentic contexts (Yakman, 2008; Perignat & Katz-Buonincontro, 2019).

In language education, STREAM provides opportunities for connecting linguistic content with cultural heritage, digital technologies, artistic expression, and research-based learning. Dialectal vocabulary is particularly suitable for this type of interdisciplinary work because it simultaneously reflects linguistic, historical, cultural, and social dimensions of a speech community. Through project-based activities, students can investigate dialectal expressions, collect language data, analyze meanings, compare linguistic forms, and present their findings using digital and creative tools.

The STREAM approach was not used as an experimental variable during the testing phase. Instead, the results of the research served as the basis for designing and implementing a model lesson grounded in

STREAM principles. In this way, the research findings informed the pedagogical application of the approach.

Timeframe and Course of the Research

The research was conducted in February and March 2026. The study included a total of 110 lexical items. It was carried out in two phases. In the first phase, students were given the lexical items without context, 10 per day. In the second phase, they were asked to interpret the same lexical items, but presented in context. In sentences taken from the *Dictionary of the Speech of Southern Serbia*, and some additionally created, the target words were underlined and students were required to write down their meanings. Students also received 10 words per day. The research lasted 22 days.

Research Sample

The sample of this research consisted of students from the Technical School in Vranje, final-year students. There were 29 students from urban areas and 21 from rural areas.

Analysis and presentation of results

A total of 110 lexical items denoting female persons characterized by physical appearance or personality traits were analyzed.

Nouns Motivated by Physical Characteristics – Analysis

Urban students gave 100% correct answers (CA) for the lexemes *gluvla* and *lopovka*[12]. There was no ambiguity with these lexemes, as they are known to everyone. The noun *legačka* had a satisfactory number of correct answers (55%). Slightly better results (69%) were achieved when the word appeared in context: *Od tuj legačku rabota nema*, while incorrect interpretations included 'a woman who sleeps all day' and 'lazy woman'. It seems that students, when interpreting this lexeme, relied on associations related to a person who is always lying down. Most words have a transparent morphological structure (such as *gluvla, lopovka, kezla, trošadžika*, etc.), which made it easier for students to interpret their meanings.

Rural students correctly interpreted the lexeme *veseldžika*, with 20 correct answers (95%), both in isolation and in the sentence: *Golema je veseldžika, samo igra i poje*. The highest number of correct answers (100%) was recorded for the lexemes *gluvla* and *dinardžika*. The lexemes *kradovka* and *lьžovka*[13] had a high number of correct answers, mainly because these lexemes are frequently heard in everyday speech. Students showed better understanding when these lexemes were interpreted in context: *Kakva je kradovka, sve oće da ti uzne*; *Kakva lьžovka, kako zine takoj izlьže*.

[12] The results are presented descriptively due to space limitations.

[13] There are numerous variant forms used to denote a person who lies: *lažara*, *laža*, *lažov*, *lažac*, etc., all of which are directly motivated by the verb *lagati* ('to lie'). The lexeme *lažov* is considered by Klajn to be a derivative formed from an adjectival base (the adjective *lažljiv* 'deceitful') with the suffix *-ov* of Hungarian origin (Štasni 2013: 80). The noun *lažovka* is derived from the masculine noun *lažov*.

All students gave correct interpretations of the nouns *lopovka, rьčkoljka, skržla, cerla,* and *tutubanka*, where the number of correct answers was 100%. All these lexemes are familiar to them because they can be heard in informal speech, so it was not difficult for students to interpret them correctly both in isolation and especially when they appeared in context.

Regarding urban students, they least recognized the lexeme *šmrkla* (7%), and even in context the number of correct answers (28%) did not significantly increase *Ne mogu više da te trpim kude viješ šmrklo nijedna*. No correct meanings were given for the lexemes *ćardžika, uročulja,* and *flinčiče*, and this did not change even when they were presented in context. Although there were many omissions, for the lexeme *flinčiče* students most often wrote interpretations such as 'seductress,' 'annoying person'.

Among rural students, the main problem was the lexeme *zloverka*, where the percentage of correct answers (19%) did not improve even in context. The most common answers were: 'a person who is evil', 'a person who is always bothered by everything', 'a person who speaks badly'.

Students did not give any correct answers for the lexemes *dilindara* and *drdla*. The most frequent incorrect answers were: for *dilindara* — 'unwanted woman', 'cynical', 'rude'; for *drdla* — 'a woman who behaves provocatively', 'someone who talks nonsense', 'stubborn person'.

The most common answers for the lexeme *brljača* were: 'someone who makes a mess', 'a clumsy person', etc. Immediately after these come the nouns *vešterulja* and *gmecla*, with 3 correct answers each, where the percentage did not change even after the words were given in context (*Kad će ti ta utepana gmecla toj uradi?*). These are words where the root may have triggered associations with the correct meaning, but students still made mistakes and gave interpretations that were far from accurate.

The greatest rural–urban difference in knowledge was observed for the lexemes *jedačka, laparajka, dzurla,* and *pьškalica*. It was expected that a higher number of correct answers in context would be given for the last lexeme, as its meaning is clearly suggested in the sentence: *Golema je jedačka, sve jede ne probira*. It was observed that urban students better interpreted the meaning of the lexeme *džurla*. This is particularly surprising, since they showed better understanding than rural students, especially in contextual usage.

A difference also exists for the noun *laparajka*, where urban students had 34% correct answers, while rural students had almost 5%. The lexeme *pьškalica* was correctly interpreted by 41% of urban students, while only 10% of rural students gave correct answers. Overall, it can be concluded that urban students were slightly more skilled in interpreting meanings.

Table 1. Lexemes Motivated by Physical Characteristics – Comparison of Urban and Rural Students[14]

Lexeme	Urban students without context (%)	Urban students in context (%)	Rural students without context (%)	Rural students in context (%)
gluvla	100	100	100	100
legačka	55	69	48	60
šmrkla	7	28	12	18

[14] The tables present selected representative lexemes from the full dataset (N urban=29, N rural=21).

lopovka	100	100	100	100
kradovka	78	90	85	95
lьžovka	80	92	88	96
jedačka	60	75	40	70

Nouns motivated by personality and physical traits

Urban students achieved the highest number of correct answers (86%) for the lexemes *zubla*[15] and *skubla*. The most common answers were: for *zubla* — 'a woman with large teeth', 'a woman with big teeth'; and for *skubla* — 'a woman with unkempt hair', 'a woman with messy hair', 'a woman who is shaggy and uncombed'.

The meaning of the lexemes *debeladara* and *ćorla* was known by 82% of students, and when these lexemes were presented in context (*Odala se na sedenje, bidnala debeladara* and *Ništa ne vidi kakva je ćorla*), the number of correct answers increased to 100%. More than half of the students (62%) knew the meaning of *buvla*, with the most common answers being: 'a woman full of fleas', 'a woman who has fleas'. A similarly good result was recorded for the lexeme *ždrigla*, whose meaning was known by 72% of students, especially in context: *On li će uzme tuj ždriglu, gledaj kolka je.*

Regarding word-formation structure, students were able to correctly interpret these words because they are part of their everyday informal speech, as well as the speech of older members of their community.

The lexemes *ćopla* and *ćorla*, which refer to physical impairments of a person, are well known to students from rural areas, as they are often used in emotional situations or quarrels. These are highly productive naming patterns motivated by the way a person moves in a way that deviates from normal walking, as in the lexeme *ćopla*.

The noun *štrokla* was correctly interpreted by 90% of students. In the sentence *Vidiš kakva je štrokla i neperčina*, as many as 95% gave correct answers. The noun *štrbla* was correctly interpreted by 85% of students, while *šugla* was correctly interpreted by 80%. These words appeared in context as follows: *Taj pa štrbla nema zub u glavu* and *Što se ne opereš, šuglo*, with the most common answers being: 'a woman without teeth', 'a woman who has no teeth', and for *šugla*: 'dirty woman', 'unclean woman'. The lexeme *zubla* also had a satisfactory number of correct answers (85%).

Regarding these lexemes (*ćopla, ćorla, šugla, štrbla,* and *štrokla*), they are dialectal, but standard-language adjectives such as *ćopav*, *ćorav*, *štrokav*, as well as the noun *šuga*, exist in dictionaries. Students

[15]Štasni points out that the secondary meanings of the lexeme *zub* ("tooth") emerged under the influence of metaphorical associations induced by semantic components related to the tooth's shape, position, and sharpness. Furthermore, all derivatives motivated by the primary meaning of the lexeme *zub* and denoting a human referent carry a strongly negative connotation (Štasni 2013: 122).

were able to explain their meanings because these words are used in everyday speech (e.g., *ćopava*, *ćorava*, *štrba baba*, *štrokava žena*).

Based on context, in the sentence *Pogledaj ovu smьklu ni čarape ne znaje da obuje*, students interpreted the lexeme *smьkla* as: 'a woman with torn stockings', 'a woman who tore her stockings', and 'a clumsy woman'. Low percentages of correct answers were also recorded for the nouns *bьpla* (7%) and *gušla* (4%). A significant increase in correct answers (93%) was observed when these lexemes were interpreted in context, especially for *bьpla*: *Kakva bьpla, na vola rep će iščupa.*

The greatest rural–urban differences in knowledge were observed for the lexemes *druslača*, *ždrigla,* and *kožla*. Urban students showed better knowledge, especially for *druslača*, where almost 50% of answers were correct, while rural students did not provide any correct answers when the word was given in isolation. The lexeme *ždrigla* was correctly interpreted by 70% of urban students, while this was not the case among rural students (35%). Similar results were recorded for *kožla*. The results indicate that urban students achieved slightly higher levels of accuracy in interpreting certain dialectal lexemes.

Table 2. Lexemes Motivated by Personality and Physical Traits – Comparison of Urban and Rural Students

Lexeme	Urban students without context (%)	Urban students in context (%)	Rural students without context (%)	Rural students in context (%)
zubla	86	86	70	80
debeldara	82	100	75	95
ćorla	82	100	78	92
bьpla	7	93	5	85
gušla	4	70	3	65
šugla	80	85	78	88

Application of the STREAM approach in Serbian language teaching

After the conducted research, an exemplary lesson was organized in which the STREAM approach was applied in Serbian language teaching. The lesson was designed based on the obtained research results, with the aim of enabling students to acquire dialectal vocabulary through collaborative work, creative activities, the use of digital tools, and the practical application of language in context. In this way, students became active participants in the process of discovering, understanding, and applying dialectal lexis.

In the introductory part of the lesson, the teacher motivates students by presenting several dialectal words, which students first interpret by relying on their own intuition and previous linguistic experience. This phase aims to activate prior knowledge and stimulate interest in further work. In the central part of the lesson, students work in groups and first interpret lexical items without context, and then analyze the same items within sentences. By comparing the obtained answers, the importance of context in understanding word meaning becomes evident, thereby developing skills of linguistic analysis, reasoning, and critical thinking. The obtained results are entered into digital tools, followed by their analysis and comparison of the percentage of correct answers, which also develops students' digital literacy and their ability to interpret

data.

In the creative phase of the lesson, students present the meanings of dialectal words through dialogue, dramatic performance, drawings, or visual interpretations, while other students attempt to infer the meanings of the lexical items based on context. Such activities encourage cooperation, communication, creativity, and active language use in different forms of expression. In the final part of the lesson, guided by the teacher, students formulate conclusions about the importance of context in understanding dialectal vocabulary, as well as the limitations of an intuitive approach in interpreting unknown words. The importance of preserving dialectal vocabulary as part of linguistic and cultural heritage is also emphasized.

As a continuation of the activity, students are given a project-based homework assignment titled 'Dialectisms in My Region'. The task requires students, working in pairs or groups, to interview older family members or local residents and collect dialectal words from their environment. They are expected to record their meanings, provide example sentences, and describe the context in which they are used, and then present the collected material in the form of a digital presentation, poster, short video, or mini-dictionary, using various digital tools. In this way, students have opportunities to develop research, linguistic, digital, and creative competencies, as well as awareness of the importance of preserving local speech and linguistic heritage.

The integration of STREAM components can be observed through various classroom activities. The Science component is represented by researching dialectal vocabulary and collecting linguistic data from dictionaries, interviews, and students' language environments. Technology is incorporated through the use of digital tools, presentations, online questionnaires, and multimedia content. Reading skills are developed through the interpretation of dictionary entries, contextual examples, and dialectal texts. The Engineering component is reflected in the planning and creation of educational products such as digital dictionaries, glossaries, posters, and classroom exhibitions. Arts are included through dramatization, illustration, creative writing, and visual presentations of dialectal expressions. Finally, the Mathematics component is applied through the statistical analysis of research results, calculation of percentages, comparison of data, and graphical presentation of findings. Together, these activities demonstrate how the STREAM approach enables interdisciplinary learning while simultaneously promoting language acquisition, creativity, critical thinking, and digital competence.

Conclusion

Based on the conducted research and analysis of the obtained results, it can be concluded that students demonstrate significantly better understanding of dialectal lexis when lexical items are presented within a contextual framework. Isolated presentation of words often leads to associative and intuitive interpretations, which are frequently incorrect, confirming the crucial role of context in lexical

comprehension.

The study also indicates that students generally understand dialectal vocabulary that is part of their everyday communicative environment, regardless of whether they come from urban or rural areas. Although certain differences between urban and rural students were observed for specific lexemes, these differences are not consistent and depend more on familiarity with particular expressions than on place of residence.

The findings suggest that the STREAM approach may provide a promising pedagogical framework for contextualized learning and the teaching of dialectal vocabulary. The proposed STREAM-based activities create opportunities for active participation, collaborative learning, and creative expression. Overall, the results confirm that context plays a significant role in the understanding of dialectal vocabulary, while the STREAM approach offers a promising pedagogical framework for its teaching in secondary education.

Source: Zlatanović, M. (2011). *Dictionary of the speech of Southern Serbia*. Vranje: Aurora.

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ПРИЛОГ 1
Употребљене лексеме у истраживању

Bьpla, Buvla, Bućla, Bandoglavka, Besnakulja, Brljača, Vrcla, Vešterulja, Veseldžika, Gmecla, Grbla, Gušla, Gvacla, Gluvla, Gologlavka, Debeldara, Dilindara, Dinardžika, Drdla, Dropla, Drtla, Drčla, Druslača, Durla, Dzucla, Žutla, Ždrigla, Žljebača, Žmurača, Zaguljka, Zubla, Zloverka, Zalogarka, Jedačka, Kavgadžika, Kanturka, Kezla, Kimnuša, Klještavica, Kokodajka, Komsidžika, Kradovka, Krеštavica, Kržla, Kuska, Kutlača, Kožla, Krivla, Lьžovka, Lajkavica, Laparajka, Legačka, Lingurka, Lisica, Lopovka, Lundzarka, Mevla, Maznenka, Mьcla, Mrmoljka, Mrsoljača, Muvatorka, Murdarka, Mucla, Nadrgavka, Nemturača, Nenaješnica, Nerabotnica, Obrtelka, Ocrepulja, Pьnjkaruša, Pьškalica, Pišmandžika, Pljampadžika, Prgavka, Prčla, Rьmpalika, Rьčkoljka, Redilja, Rečlika, Rovla, Rumenlika, Sirdžika, Skržla, Smьќničarapa, Smucla, Skapla, Skubla, Smьќla, Trakataljka, Trošadžika, Trtla, Tutla, Tutubanka, Ćorla, Ćardžika, Ćopla, Ulizulja, Uročulja, Flintiče, Cerla, Dzurla, Šmrkla, Škembla, Šugla, Štrbla, Šuntavka, Štrokla, Šmokljanka, Džabalepka.

https://doi.org/10.46793/STEPAM26.101S
Udk: 37.091.3::004-053.5

PERFORMANCE AND ENJOYMENT OF PRIMARY PUPILS IN THE BEBRAS CHALLENGE TASKS

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Abstract: This study examines the relationship between task performance and enjoyment among third-grade pupils completing four Bebras Challenge tasks. The study was conducted within the UTRINKI project, a Slovenian national initiative introducing computer science and computational thinking instruction in primary schools. A cross-sectional quantitative design was employed with a final sample of 155 pupils from six primary schools. Task performance was scored dichotomously, while enjoyment was measured using a 3-point Likert-type scale. Cochran's Q and Friedman tests revealed significant differences in both correctness and enjoyment across tasks. Post-hoc analyses further revealed that enjoyment ratings were significantly higher for tasks with higher correctness rates, suggesting that easier tasks are more enjoyable to pupils. Spearman's rank-order correlation showed a statistically significant moderate positive relationship between overall task performance and enjoyment ($\rho = 0.345$, $p < 0.001$), indicating that pupils who performed better tended to enjoy the tasks more. These findings highlight the importance of appropriately calibrated task difficulty when introducing computational thinking activities in primary education.

Keywords: *computational thinking, Bebras Challenge, task enjoyment, task performance, primary education.*

Introduction

Computational thinking (CT) has been widely recognized as a fundamental skill for the 21st century. Wing (2006) defined CT as the ability to solve problems, design systems, and understand human behavior by drawing on concepts fundamental to computer science. Since this seminal work, CT has been increasingly integrated into primary and secondary school curricula in Europe (Bocconi et al., 2022). There is a growing consensus that CT practices, such as decomposition, pattern recognition, abstraction, and algorithmic thinking, are valuable problem-solving skills applicable across disciplines (Shute et al., 2017; Yadav et al., 2022).

One of the most widely used tools for engaging pupils with CT is the Bebras Challenge, an international informatics competition founded by Prof. Valentina Dagiene (Dagiene & Sentance, 2016). Since its inception in 2004, the initiative has grown into an international contest that promotes informatics and CT among school students of all ages. The tasks focus on problem-solving skills and do not require prior programming experience. In 2024, the challenge involved over 3 million students from more than 80

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countries (Raspberry Pi Foundation, 2025). There is evidence that Bebras tasks can be used in school curricula as effective tools to promote problem-solving skills and CT in pupils (Delal & Oner, 2020; Lehtimäki et al., 2022). In Slovenia, the UTRINKI project has adopted the Bebras Challenge as part of its effort to introduce computer science education and CT instruction in primary schools.

Despite the growing use of Bebras tasks in primary education, relatively little is known about whether and to what extent young pupils enjoy them. Understanding this is important, as positive learning experiences have been linked to greater intrinsic motivation and sustained engagement (Ryan & Deci, 2000). The present study, therefore, examines pupils' enjoyment of Bebras tasks and, more specifically, their relationship with task performance among third-grade pupils who completed four Bebras Challenge tasks within the UTRINKI project. The study was guided by the following research question:

Is there a significant relationship between task performance and enjoyment in Bebras Challenge tasks among third-grade pupils?

Methodology

Research Design and Sample

This study employed a cross-sectional quantitative design. Pupils were administered four tasks and rated their enjoyment of each task immediately after completing it. The study was conducted within the UTRINKI project, a Slovenian national initiative introducing computer science and CT instruction in primary schools. Ethical approval was granted by the Ethics Committee of the Institute for Modern Technologies, University of Maribor (Approval Reference Number: 02.EC_2026).

The initial sample comprised $N = 170$ third-grade pupils from six primary schools participating in the UTRINKI project. One participant was excluded due to invalid data entry, and 14 (8.2%) were excluded for incomplete responses, yielding a final analytic sample of $N = 155$ pupils.

Instrument

Task performance was assessed using four tasks selected from the Slovenian ACM Bebras Competition (ACM Slovenija, 2025), which is part of the international Bebras Challenge. Each task was scored dichotomously (1 = correct, 0 = incorrect). The tasks engaged pupils in pattern recognition, abstraction, algorithmic thinking, and decomposition. The tasks were originally in Slovenian and are presented in Figures 1–4.

Rainbow Parrot: Pupils identified a color pattern across three parrots and applied it to color the fourth, ensuring no color repeated in the same body position.

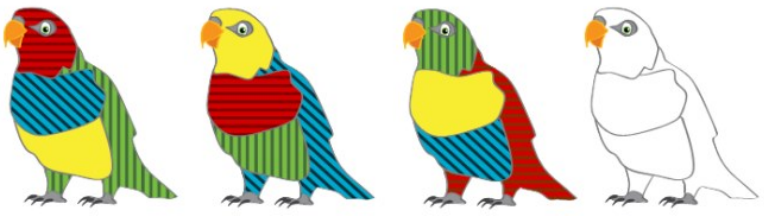

Figure 1: Rainbow Parrot

Birdhouse: Pupils selected the correct birdhouse from six options based on two criteria — two windows and a heart symbol.



Figure 2: Birdhouse

Table Setting: Pupils determined the correct order in which Beaver Bob placed items on the table by analyzing a visual scene and selecting from four sequences.

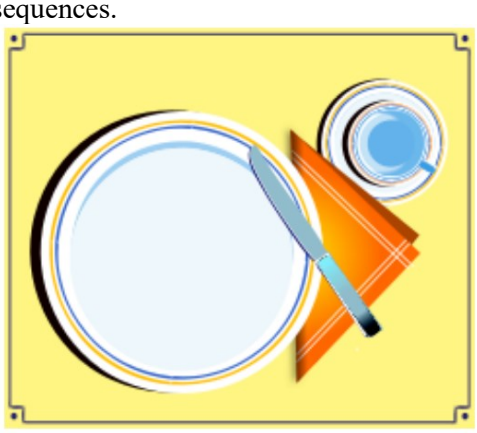

Figure 3: Table Setting

Alphabet: Pupils decoded a sequence of symbols into Slovenian letters using a provided symbol-to-letter key.

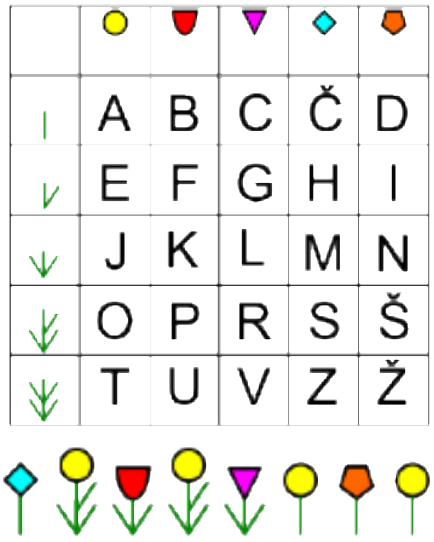

Figure 4: Alphabet

Following each task, pupils responded to three items: (1) an enjoyment rating, (2) a self-assessment of perceived correctness, and (3) an open-ended explanation of their solution strategy. The present study focuses exclusively on task performance and enjoyment ratings; the remaining items fall outside the scope of this paper.

Enjoyment was measured using a single-item 3-point scale. After completing each task, pupils

rated how much they enjoyed it: (1) *No, I did not enjoy it*, (2) *So-so, it was okay*, or (3) *Yes, I enjoyed the task*.

Data Collection and Analysis

Data were collected during regular school hours using a paper-and-pencil test administered by teachers. The data collection session lasted approximately 45 minutes and followed a standardized procedure across all six schools. For each task, pupils first attempted a solution and then rated their enjoyment using the scale described above. Tasks were presented in a fixed order.

Descriptive statistics were calculated for each task separately. Cochran's Q test was used to compare correctness rates across the four tasks. The Friedman test examined differences in enjoyment ratings across tasks, followed by Wilcoxon signed-rank post-hoc tests with Bonferroni correction. Spearman's rank-order correlation examined the relationship between total correctness (0–4) and total enjoyment (4–12) at the pupil level. The significance level was set at $\alpha = 0.05$. All statistical analyses were conducted in IBM SPSS Statistics (Version 31.0.0.0).

Results

Descriptive Statistics

Table 1 presents the percentage of correct responses and enjoyment ratings for each of the four tasks. Rainbow Parrot and Birdhouse tasks were solved correctly by the vast majority of pupils (92.9% and 94.2%, respectively), while Table Setting and Alphabet tasks were more challenging (55.5% and 67.7%). In terms of enjoyment, Rainbow Parrot and Birdhouse tasks received higher mean ratings ($M = 2.88$ and $M = 2.83$) than Table Setting and Alphabet tasks ($M = 2.64$ and $M = 2.55$), indicating that easier tasks were also rated as more enjoyable.

Table 1. Descriptive Statistics for Correctness and Enjoyment by Task

Task	Correct (%)	M	SD	Rating 1 (%)	Rating 2 (%)	Rating 3 (%)
Rainbow Parrot	92.9	2.88	0.36	1.3	9.0	89.7
Birdhouse	94.2	2.83	0.41	1.3	14.8	83.9
Table Setting	55.5	2.64	0.56	3.9	28.4	67.7
Alphabet	67.7	2.55	0.71	12.9	18.7	68.4

Note. M = mean enjoyment rating; SD = standard deviation; Rating percentages refer to the proportion of pupils selecting each Likert point.

Differences Between Tasks

To examine whether the four tasks differed significantly in correctness, Cochran's Q test was conducted. The test revealed a statistically significant difference, $Q(3) = 104.27$, $p < 0.001$, indicating that the proportion of correct responses varied across tasks.

A Friedman test was used to assess differences in enjoyment ratings across the four tasks. The test yielded a statistically significant result, $\chi^2(3) = 46.73$, $p < 0.001$, showing that enjoyment differed

significantly across tasks.

Post-hoc comparisons were conducted using Wilcoxon signed-rank tests with Bonferroni correction ($\alpha = 0.0083$). Results are presented in Table 2. Rainbow Parrot and Birdhouse tasks did not differ significantly in enjoyment ($p = 0.568$), nor did Table Setting and Alphabet tasks ($p = 0.859$). However, all comparisons between the higher-correctness tasks (Rainbow Parrot and Birdhouse) and the lower-correctness tasks (Table Setting and Alphabet) were statistically significant ($p < 0.001$), indicating that pupils enjoyed the easier tasks significantly more.

Table 2. Post-Hoc Wilcoxon Signed-Rank Tests for Enjoyment Ratings (Bonferroni Corrected)

Comparison	W	*p* (uncorrected)	*p* (Bonferroni)
Rainbow Parrot vs Birdhouse	150.0	0.095	0.568
Rainbow Parrot vs Table Setting	196.0	< 0.001	< 0.001
Rainbow Parrot vs Alphabet	80.0	< 0.001	< 0.001
Birdhouse vs Table Setting	211.5	< 0.001	< 0.001
Birdhouse vs Alphabet	229.0	< 0.001	< 0.001
Table Setting vs Alphabet	632.0	0.143	0.859

Note. Bonferroni-corrected significance threshold: $\alpha = 0.0083$.

Relationship Between Correctness and Enjoyment

To examine the relationship between overall task performance and enjoyment, a Spearman rank-order correlation was computed between the total number of correct responses and the total enjoyment score. The analysis revealed a statistically significant moderate positive correlation, $\rho = 0.345$, $p < 0.001$, $N = 155$. This indicates that higher task performance was associated with greater task enjoyment. However, given the cross-sectional nature of the data, causal conclusions cannot be drawn.

Conclusion

This study examined the relationship between task performance and enjoyment among third-grade pupils completing four Bebras Challenge tasks. The findings indicate that pupils generally enjoyed all four tasks, with the majority selecting the highest enjoyment rating. Enjoyment ratings differed significantly across tasks, with post hoc analyses showing that Rainbow Parrot and Birdhouse were enjoyed significantly more than Table Setting and Alphabet. Notably, Rainbow Parrot and Birdhouse tasks also had considerably higher correctness rates than Table Setting and Alphabet tasks, suggesting a parallel pattern in which easier tasks were enjoyed more. Furthermore, a statistically significant moderate positive correlation was found between overall task performance and overall enjoyment, indicating that pupils who performed better tended to enjoy the tasks more.

These findings are consistent with cognitive evaluation theory (Ryan & Deci, 2000), which suggests that experiences of competence support intrinsic motivation and enjoyment. When pupils successfully solve a task, they may experience a sense of mastery that enhances their enjoyment. This has practical implications for the design and selection of CT tasks in primary education — tasks should be appropriately challenging to promote both success and positive affect.

Several limitations should be noted. First, the cross-sectional design does not allow causal conclusions. Second, enjoyment was measured with a single item, which limits the depth of measurement. Third, the sample was drawn from schools already participating in the UTRINKI project and is not representative of the broader primary school population. Fourth, the very high correctness rates on the Rainbow Parrot and Birdhouse suggest that these tasks may have been insufficiently challenging, indicating that task difficulty should be more carefully calibrated to the pupils' level. Lastly, the study did not formally test the relationship between task difficulty and enjoyment at the task level. This observation is descriptive and should be investigated more rigorously in future research.

Acknowledgment

This research was funded by the Republic of Slovenia, Ministry of Education, grant number 303-50/2023/62 as part of the UTRINKI project.

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https://doi.org/10.46793/STEPAM26.107K
Udk: 373.2.011.3-051:159.928.23

NARRATIVE AS A FRAMEWORK FOR INTEGRATED STEP(A)M ACTIVITIES: FROM THE CONCEITED PEACOCK TO INTEGRATED LEARNING[17]

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Abstract: Narrative may serve as a meaningful pedagogical framework for integrated STEP(A)M learning, particularly in early childhood education. The aim of this study was to examine pre-service preschool teachers' attitudes toward narrative-based integrated STEP(A)M learning, their self-assessed competence in applying this approach, and the challenges they perceived when integrating different STEP(A)M components. The study included 66 pre-service preschool teachers. Following activities based on the literary text *The Conceited Peacock*, participants completed a questionnaire on attitudes toward narrative and self-assessed competence in designing integrated STEP(A)M activities. Data were analyzed using descriptive statistics and non-parametric tests. The findings revealed very positive attitudes toward narrative as a framework for integrated learning. Students recognized its value for connecting learning and play, encouraging creativity, and identifying scientific concepts within stories. Engineering and Technology were perceived as the most challenging components to integrate. Prior knowledge of the STEP(A)M approach was associated with greater confidence in designing learning provocations. The findings highlight the importance of incorporating narrative-based integrated STEP(A)M approaches into initial preschool teacher education and providing opportunities for interdisciplinary instructional planning.

Keywords: STEP(A)M approach, narrative, integrated learning, preschool teacher education, interdisciplinary learning

Introduction

Contemporary education increasingly emphasizes the importance of integrated learning, which enables connections among different domains of knowledge and supports the development of competences required in modern society, such as critical thinking, creativity, collaboration, and problem-solving skills. In this context, STEM and STEAM approaches are recognized as important frameworks for overcoming fragmented learning and for designing meaningful and functionally interconnected educational experiences (Bybee, 2013; Honey et al., 2014). This is particularly relevant in early childhood education, where children learn through play, exploration, movement, and direct experience, making integrated approaches especially valuable from a pedagogical perspective. The inclusion of narrative within integrated STEP(A)M learning further expands the possibilities for connecting different learning domains. Narrative enables abstract

[17] This publication was prepared within the framework of the bilateral scientific project "Creativity, Critical Thinking, and Problem-Solving across STEAM Disciplines", jointly implemented by the Faculty of Education, University of Kragujevac (Serbia), and the Facultad de Ciencias Físico Matemáticas, Benemérita Universidad Autónoma de Puebla (Mexico).
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concepts and scientific ideas to be presented within a meaningful and developmentally appropriate context that is close to children's experiences, thereby contributing to increased motivation, understanding, and engagement (Bruner, 1986; Norris et al., 2005). At the same time, stories may function as integrative frameworks that connect scientific inquiry, artistic expression, physical activity, and collaborative learning into a unified educational experience. Although numerous studies emphasize the importance of integrated STEAM education and the educational potential of narrative-based learning, there is still limited understanding of how pre-service preschool teachers use literary texts as a starting point for designing integrated STEP(A)M activities. In line with this, it is not clear which components of such an approach they perceive as the easiest or the most challenging to implement in practice. This issue is particularly important in the context of initial teacher education, where competences for interdisciplinary planning and the implementation of contemporary pedagogical approaches are developed.

Therefore, the aim of this study was to examine how pre-service preschool teachers use narrative as a framework for designing integrated STEP(A)M activities and how they assess their own preparedness for implementing such an approach in their future professional practice. More specifically, the study focused on examining students' attitudes toward narrative as a framework for integrated STEP(A)M learning, identifying the STEP(A)M components that students integrate most easily and those they perceive as the most challenging, as well as exploring differences in self-assessed competences with respect to prior experience and familiarity with the STEP(A)M approach.

The paper is organized into several sections. Following the introduction, the theoretical background discusses integrated STEP(A)M learning, narrative as a framework for learning, embodied learning approaches, and teacher competences in initial teacher education. The methodology section presents the research design, sample, instruments, and data analysis procedures. The results and discussion section focuses on students' attitudes, self-assessed competences, and challenges related to designing integrated STEP(A)M activities. Finally, the conclusion summarizes the main findings of the study and discusses implications for educational practice.

Theoretical Background

STEP(A)M and Integrated Learning

Integrated teaching represents an innovative approach in contemporary education, as it enables the connection of different domains of knowledge and creates meaningful contexts for learning. Literary texts have particular potential as a starting point for the integration of educational content. As emphasized by Stanković and Milovanović (2024), the use of literary texts in teaching enables the integration of linguistic, artistic, and scientific aspects of learning, thereby fostering the holistic development of students. These authors stress that literary texts may serve as stimuli for inquiry-based activities, critical thinking, and

creative expression, which makes them suitable for integration with natural science content. Of particular importance in work with young children is the fact that literary texts enable the contextualization of abstract concepts. In this way, children acquire and connect knowledge with everyday experience and their own understanding of the world. According to the findings of Stanković and Milovanović (2024), teachers recognize the value of such an approach, while simultaneously pointing to the need for additional support and professional development in the planning and implementation of integrative teaching. Within contemporary educational trends aimed at developing critical thinking, creativity, collaboration, and complex problem-solving skills (Beers, 2011), STEM is increasingly recognized as an opportunity to overcome the fragmentation of educational content and to design functional and interconnected learning experiences (Bybee, 2013; Honey et al., 2014). The integration of disciplines implies their meaningful interconnection within a common problem, activity, or learning experience. The STEP(A)M approach is based on the idea that knowledge acquires its full value only when it can be connected and applied across different contexts, while teacher expertise is recognized as one of the key factors for the successful integration of different learning domains and the implementation of such an approach in educational practice (Honey et al., 2014). The integration of disciplines involves connecting them around a problem or task that requires multiple perspectives (Bybee, 2013). The inclusion of arts within the STEAM framework broadens this perspective and enables scientific content to be viewed through the lens of aesthetic experience and diverse forms of expression (Land, 2013; Perignat & Katz-Buonincontro, 2019). Particularly in preschool and primary education, where learning is often implemented through thematic and integrated activities, such an approach carries significant pedagogical potential. Research in early STEAM education indicates that integrated activities based on inquiry, play, and creative problem-solving may contribute to the development of scientific literacy, creativity, and positive attitudes toward learning among preschool children (Ata Aktürk & Demircan, 2017; Bers, 2018).

Narrative as a Framework for Learning

One possible way of encouraging the integration of different learning domains is through narrative. According to Bruner (1986, 1991), narrative represents a means of placing abstract concepts within a meaningful and developmentally appropriate context that is close to children's experiences. Narrative thinking, as described by Bruner (1986), enables the organization of experience into temporally and meaningfully connected wholes. In educational settings, stories may function as structural frameworks that connect different contents into coherent learning experiences. Research in science education indicates that narrative can contribute to a deeper understanding of complex concepts and increased student engagement. In this context, Avraamidou and Osborne argue that science is fundamentally a process of developing causal explanations of the material world. According to these authors, cause-and-effect relationships may be communicated more effectively through the use of narrative components such as causality, intentionality,

and temporality, which are often insufficiently emphasized in traditional scientific texts. Research further suggests that narrative explanations can enhance understanding and retention of knowledge because they do not merely present isolated facts, but rather organize events into meaningful and logically connected sequences that emphasize causal relationships and human intentions. Such an organizational function of narrative has pedagogical value, as it enables learners to perceive interconnected systems of ideas and promotes deeper understanding of content instead of the acquisition of isolated and disconnected concepts (Norris et al., 2005). The authors also point out that students more easily comprehend and retain content organized through familiar cognitive schemas of narrative than through traditional expository and argumentative texts, whose structures are often less familiar and more difficult to understand (Avraamidou & Osborne, 2009; Norris et al., 2005). Integrating educational content into story structures has also been associated with reduced cognitive load, particularly when stories are shorter and simpler (Fisch, 2000). Furthermore, narrative may function as a powerful integrative framework that connects inquiry, creative expression, physical activity, and collaborative learning. It is also important to note that narrative may influence students' motivation and identification with educational content (Dahlstrom, 2014). For this reason, narrative has the potential to serve as a starting point for integrated STEP(A)M activities in which scientific concepts are explored through play, movement, experimentation, artistic expression, and collaboration.

Embodied Learning and Physical Activity in STEP(A)M

Contemporary research indicates that embodied learning may contribute to a deeper understanding of abstract concepts through movement, gestures, and physical activity (Skulmowski & Rey, 2018). In the context of early childhood education, embodied learning approaches enable children to construct knowledge through direct experience and interaction with their environment. Such approaches are particularly important within integrated STEP(A)M learning because they connect cognitive, motor, and creative aspects of development, while cognitive benefits may be achieved through various forms of movement, providing preschool teachers and educators with flexibility in designing programs and activities for children (Vazou et al., 2020). Within STEP(A)M environments, physical activity may become an integral part of inquiry, experimentation, and learning processes.

Teacher Competences and Initial Teacher Education

Interdisciplinary approaches simultaneously place high demands on teachers and preschool educators. The concept of pedagogical content knowledge (Shulman, 1987) emphasizes the necessity of connecting subject-specific and pedagogical knowledge, while the TPACK model (Koehler & Mishra, 2009) additionally highlights the importance of the technological component in instructional planning. In practice, technical and technological domains often represent the greatest challenge for students and

educators when designing integrated activities, although the integrative and creative aspects of such approaches are generally perceived positively. However, within the context of initial preschool teacher education, there is still insufficient understanding of how future preschool teachers specifically design integrated STEP(A)M activities using literary texts as narrative frameworks. It is particularly important to examine which STEP(A)M components students integrate more easily and which they perceive as more challenging, as well as the extent to which they assess themselves as competent for implementing such approaches in practice. It is precisely during the period of initial teacher education that professional beliefs, instructional planning models, and competences for interdisciplinary work are developed, making this phase especially relevant for examining readiness to implement integrated approaches. In this regard, initial teacher education plays a crucial role in developing competences for creative, interdisciplinary, and integrated instructional planning, particularly when pre-service teachers simultaneously attend courses and apply learned strategies in practice, enabling them to test and reconsider theoretical concepts in authentic educational situations (Darling-Hammond, 2006). Therefore, in addition to developing a theoretical understanding of the STEP(A)M approach, it is important to provide students with practical experiences in designing activities that connect different learning domains into meaningful and applicable educational experiences.

Based on the presented theoretical assumptions, there is a need to gain a deeper understanding of how pre-service preschool teachers use narrative as a framework for integrated STEP(A)M learning, the challenges they encounter during instructional planning, and the areas in which additional methodological support may be needed during initial teacher education.

Method

The aim of the study was to examine how pre-service preschool teachers use narrative as a framework for designing integrated STEP(A)M activities and to explore their self-assessed competence in applying this approach in future educational practice. This aim was addressed through the following research tasks:

1. To examine students' attitudes toward the use of narrative as a framework for integrated STEP(A)M learning.
2. To analyze which STEP(A)M components students integrate most easily and which they find most challenging when designing activities.
3. To examine differences in students' attitudes and self-assessed competence in applying the STEP(A)M approach with respect to their prior experience working with children and their prior knowledge of the STEP(A)M approach.

Instrument

Data were collected using a questionnaire consisting of two parts. The first part gathered background information on students' prior experience working with children and their prior knowledge of the STEP(A)M approach. The second part of the questionnaire comprised two sections. The first section examined students' attitudes toward narrative as a pedagogical tool, including their perceptions of its usefulness, motivational potential, and relevance for integrated learning. It was measured using six Likert-type items (Table 1). Participants indicated their level of agreement with each statement on a five-point scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Table 1. Items measuring attitudes toward narrative as a pedagogical tool

Item label	Item
I1	*I easily understood the story.*
I2	*The story is suitable as a starting point for integrated activities .*
I3	*I can identify scientific phenomena in the story.*
I4	*The story motivated me to design activities.*
I5	*The story stimulated my creative thinking.*
I6	*Narrative is a good way to integrate learning and play.*

The second section examined students' self-assessed competence in applying the STEP(A)M approach through two direct self-report items and five task-based indicators. Perceived ability was measured using one Likert-type item (*I am able to design a learning provocation based on the story*), rated on the same five-point agreement scale (1 = strongly disagree, 5 = strongly agree), with higher scores indicating greater perceived competence. Perceived task difficulty was assessed with the item *How difficult was the task for you?*, rated on a five-point scale ranging from 1 (very easy) to 5 (very difficult). For this item, lower scores indicate lower perceived task difficulty (i.e., higher perceived competence), whereas higher scores indicate greater perceived difficulty (i.e., lower perceived competence).

To complement these measures, five task-based indicators were included. Students identified the STEP(A)M component they believed they had integrated most successfully and the component they found most difficult to integrate. They also indicated the main factor contributing to successful integration, the primary reason why a particular component was challenging to integrate, and the most challenging aspect of designing the integrated activity.

Sample

The study was conducted during the 2025/2026 academic year and included 66 final-year pre-service preschool teachers from the Academy for Applied Preschool Teaching and Health Studies in Aleksinac and the Faculty of Education in Jagodina, University of Kragujevac.

For the purposes of the analysis, students were classified into three groups according to their prior experience working with children and their prior knowledge of the STEP(A)M approach (low, moderate, and high). The structure of the sample is presented in Table 2.

Table 2. Distribution of participants according to prior experience working with children and prior knowledge of the STEP(A)M approach

		Low	Moderate	High
Prior experience	F	17	28	21
	%	25.8	42.4	31.8
Prior knowledge	F	29	30	7
	%	43.9	45.5	10.6

Data processing and analysis

Descriptive statistical methods were used for data processing (mean, standard deviation, frequencies, and percentages). The normality of the data distribution was examined using the Shapiro–Wilk test. As the assumption of normality was not met, non-parametric statistical procedures were applied. Differences in students' attitudes and self-assessed competence with respect to prior experience working with children and prior knowledge of the STEP(A)M approach were examined using the Kruskal–Wallis test. When statistically significant differences were identified, Dunn's post hoc test was performed to determine pairwise group differences. Statistical analyses were conducted using IBM SPSS Statistics.

Results and Discussion

The first research task was to examine students' attitudes toward the use of narrative as a framework for integrated STEP(A)M learning. The descriptive statistics for the six Likert-type items are presented in Table 3.

Table 3. Students' attitudes toward narrative as a framework for integrated STEP(A)M learning

Item	**Mean**	**SD**
I1	4.53	0.95
I2	4.45	0.75
I3	4.65	0.77
I4	4.29	0.91
I5	4.50	0.77
I6	4.67	0.71

According to the interpretation of the Likert scale, values within the interval [4.20–5.00] indicate a very high level of agreement. The obtained results show that students expressed very positive attitudes toward the use of narrative as a framework for integrated STEP(A)M learning. They reported that they easily understood the story (M = 4.53), recognized it as a suitable starting point for integrated activities (M = 4.45), and identified scientific phenomena that could be explored with children (M = 4.65). Furthermore, students perceived the story as motivating for designing activities (M = 4.29) and as stimulating their creative thinking (M = 4.50). The highest level of agreement was found for the statement that narrative is a good way to integrate learning and play (M = 4.67).

These findings suggest that students recognize the pedagogical value of narrative as a meaningful framework for integrated STEP(A)M learning. The high ratings regarding the use of narrative as a starting point for integrated activities are consistent with Bruner's (1986, 1991) view of narrative as a means of organizing experiences into meaningful wholes that support learning. Likewise, students' recognition of scientific phenomena within the story supports previous research indicating that narrative facilitates the understanding of scientific concepts by placing them within coherent and meaningful contexts (Avraamidou & Osborne, 2009; Norris et al., 2005). Furthermore, the positive evaluation of narrative as a basis for integrated activities, as well as its potential to stimulate creativity and motivate students to design activities, is consistent with findings suggesting that stories enhance engagement, reduce cognitive load, increase motivation, and provide a natural context for connecting different learning domains (Dahlstrom, 2014; Fisch, 2000). The findings also support the view that literary texts can serve as stimuli for inquiry-based activities, creative expression, and critical thinking, thereby fostering integrated learning experiences (Stanković & Milovanović, 2024). Finally, students' strong agreement that narrative is a good way to integrate learning and play is particularly important in the context of early childhood education, where play represents a natural mode of learning. This finding is consistent with previous research showing that integrated, play-based activities contribute to the development of scientific literacy, creativity, and positive attitudes toward learning among young children (Ata Aktürk & Demircan, 2017; Bers, 2018).

The second research task focused on students' self-assessed competence in applying the STEP(A)M approach and the STEP(A)M components they perceived as the easiest and most challenging to integrate.

Students reported a high level of confidence in their ability to design a learning provocation based on the story (M = 4.21, SD = 0.79). This finding suggests that students generally perceived themselves as capable of using narrative as a starting point for planning integrated STEP(A)M activities. To further explore their competence in practice, students were asked to identify the STEP(A)M components they integrated most successfully, those they found most challenging, and the factors contributing to both successful integration and encountered difficulties.

Table 4. Easiest integrated STEP(A)M components

STEP(A)M component	Percent
Arts	42.4
Engineering	3.0
Mathematics	3.0
Physical Activities	7.6
Science	3.0
Multiple components	40.9

The results indicate that students most frequently integrated the Arts component (42.4%), while 40.9% reported successfully integrating multiple STEP(A)M components. The remaining individual components were selected considerably less often, suggesting that students felt more confident when working with creative and expressive activities than with individual disciplinary components. These

findings are not surprising, considering that the activities were designed around a literary narrative, which naturally encourages artistic expression and creative thinking. Moreover, narrative provides opportunities to combine several learning domains within a meaningful context, which may explain the high proportion of students who reported successfully integrating multiple STEP(A)M components.

Table 5. Most challenging STEP(A)M components

STEP(A)M component	Percent
Arts	1.5
Engineering	33.3
Mathematics	15.2
Physical Activities	3.0
Science	10.6
Technology	19.7
None	16.7

In contrast, Engineering (33.3%) was identified as the most challenging component to integrate, followed by Technology (19.7%) and Mathematics (15.2%). Interestingly, 16.7% of students reported that they did not experience difficulties integrating any STEP(A)M component. The findings suggest that students experience greater difficulty when integrating more technical and structured domains. This may reflect the fact that technical and technological domains often receive less emphasis in initial teacher education, despite being recognized as important components of integrated STEP(A)M learning (Shulman, 1987; Koehler & Mishra, 2009).

Interestingly, physical activities were rarely identified either as the easiest (7.6%) or the most challenging (3.0%) STEP(A)M component. One possible explanation is that students perceived physical activities as naturally accompanying other learning domains rather than as a separate component, which may also explain the relatively high proportion of responses indicating the successful integration of multiple STEP(A)M components. This interpretation, however, should be explored in future studies. Considering the growing emphasis on embodied learning in early childhood education (Da Cruz et al., 2025; Skulmowski & Rey, 2018; Vazou et al., 2020), further research should specifically examine how pre-service preschool teachers conceptualize and integrate physical activity within narrative-based STEP(A)M learning environments.

Students were also asked to identify the factor that contributed most to the successful integration of the selected STEP(A)M component. The nature of the activity itself was identified as the most important contributing factor (31.8%), followed by a clear connection with the narrative (24.2%) and the ease of adapting the activity to children's age and developmental level (19.7%). Prior knowledge of the STEP(A)M approach was mentioned less frequently (10.6%). These results indicate that successful integration depends primarily on meaningful instructional design rather than on students' prior knowledge alone. A coherent narrative context appears to facilitate the integration of different learning domains and supports the design of developmentally appropriate activities.

Students were also asked to identify the main reason why a particular STEP(A)M component was

difficult to integrate. The most frequently reported reasons were insufficient knowledge (25.8%), difficulty adapting the component to the activity (21.2%), and uncertainty about its implementation (19.7%). These findings indicate that students' difficulties are related primarily to a lack of methodological confidence rather than to negative attitudes toward the STEP(A)M approach. This highlights the importance of providing future preschool teachers with more opportunities to develop and practice integrated STEP(A)M activities during their initial teacher education.

Students were further asked to indicate which aspect of designing the integrated activities they found most challenging. The most common responses were integrating multiple STEP(A)M components (25.8%), identifying appropriate scientific or mathematical content (21.2%), and adapting the activities to children's age and developmental level (15.2%). Together with the previously identified reasons for difficulty, these findings indicate that designing integrated STEP(A)M activities requires both interdisciplinary thinking and pedagogical planning skills. This further supports the need to strengthen pre-service teachers' methodological competence in planning integrated learning experiences.

Students were asked to evaluate the overall difficulty of the task. The majority rated it as moderately difficult (62.1%), whereas 34.9% perceived it as easy and only 3.0% considered it difficult. Taken together with the previous findings, these results suggest that students did not perceive the task as overwhelming. Rather, they experienced it as appropriately challenging, despite encountering methodological difficulties in integrating particular STEP(A)M components. This finding further supports the potential of narrative as an effective framework for designing integrated STEP(A)M activities in pre-service teacher education.

The third research task examined differences in students' attitudes and self-assessed competence according to their prior experience working with children and prior knowledge of the STEP(A)M approach.

To examine whether students' attitudes toward the use of narrative differed according to their prior experience working with children and their prior knowledge of the STEP(A)M approach, the Shapiro–Wilk test was first applied. The results indicated that the item scores were not normally distributed across the groups. Therefore, the non-parametric Kruskal–Wallis test was used. The results of the Kruskal–Wallis test showed no statistically significant differences in students' attitudes toward narrative with respect to either their prior experience working with children or their prior knowledge of the STEP(A)M approach (Table 6).

Table 6. Differences in students' attitudes toward narrative according to prior experience working with children and prior knowledge of the STEP(A)M approach

	Prior experience in working with children			Prior knowledge of STEP(A)M approach		
Item codes	χ^2	df	p	χ^2	df	p
I1	2.170	2	0.338	0.892	2	0.640
I2	4.840	2	0.089	1.519	2	0.468
I3	1.748	2	0.417	0.251	2	0.882
I4	1.176	2	0.555	0.820	2	0.664
I5	2.281	2	0.320	1.649	2	0.439
I7	0.111	2	0.946	2.383	2	0.304

These results suggest that students perceived the pedagogical value of narrative in a similar way regardless of their previous experience working with children or their prior knowledge of the STEP(A)M approach, indicating that positive attitudes toward narrative-based integrated learning were shared across all groups.

Differences in students' self-assessed competence were examined through two indicators: perceived ability to design a learning provocation based on the story and perceived task difficulty. As the Shapiro–Wilk test indicated that both variables were not normally distributed, the Kruskal–Wallis test was again applied. The results revealed a statistically significant difference in students' confidence in their ability to design a learning provocation according to both prior experience working with children ($\chi^2 = 9.365$, $df = 2$, $p = 0.009$) and prior knowledge of the STEP(A)M approach ($\chi^2 = 6.593$, $df = 2$, $p = 0.037$). Post hoc comparisons showed that students with high prior experience working with children rated their ability to design a learning provocation significantly higher than students with low prior experience ($p = 0.007$). Likewise, students with high prior knowledge of the STEP(A)M approach reported greater confidence in designing a learning provocation than students with moderate prior knowledge. These findings suggest that confidence in designing learning provocations develops through both practical experience and prior familiarity with the STEP(A)M approach. This is consistent with the literature emphasizing that pedagogical competence is built through the integration of theoretical knowledge and authentic teaching experiences during initial teacher education (Darling-Hammond, 2006).

When perceived task difficulty was examined, no statistically significant differences were found with respect to prior experience working with children ($\chi^2 = 0.931$, $df = 2$, $p = 0.628$). In contrast, the Kruskal–Wallis test indicated a statistically significant overall difference in perceived task difficulty according to prior knowledge of the STEP(A)M approach ($\chi^2 = 6.602$, $df = 2$, $p = 0.037$). However, the subsequent Dunn post hoc test did not reveal statistically significant pairwise differences between the groups. Therefore, although the overall test suggests that differences may exist, the specific group differences could not be confirmed and these findings should be interpreted with caution. Further research involving larger samples is needed to clarify these relationships.

Overall, the results indicate that pre-service preschool teachers hold positive attitudes toward narrative as a framework for integrated STEP(A)M learning and perceive themselves as capable of applying this approach. The identified challenges were primarily associated with methodological aspects of instructional planning rather than with resistance to integrated learning. The findings highlight the importance of providing future preschool teachers with opportunities to develop interdisciplinary planning skills through authentic, narrative-based STEP(A)M activities during their initial teacher education.

Conclusion

Considering the pedagogical value of narrative as a framework for integrated STEP(A)M learning, this study sought to examine whether pre-service preschool teachers recognize its educational potential and perceive themselves as competent to apply this approach in future educational practice. Accordingly, the study focused on students' attitudes toward narrative, their self-assessed competence in applying the STEP(A)M approach, and the challenges they encountered while designing integrated activities. The findings revealed that pre-service preschool teachers generally hold very positive attitudes toward narrative-based integrated STEP(A)M learning, confirming that they recognize narrative as a meaningful pedagogical framework that supports creativity, inquiry, and the integration of different learning domains. At the same time, the results showed that technical and technological domains were perceived as the most challenging components to integrate, while the reported difficulties were primarily related to methodological aspects of instructional planning rather than to resistance toward the STEP(A)M approach. When it comes to self-assessed competence, prior experience working with children and prior familiarity with the STEP(A)M approach were associated with greater confidence in designing learning provocations based on narrative. These findings suggest that both practical experience and methodological preparation contribute to pre-service teachers' confidence in applying integrated STEP(A)M approaches. The findings further emphasize the importance of incorporating narrative-based integrated STEP(A)M learning into initial preschool teacher education and providing future preschool teachers with authentic opportunities to develop interdisciplinary planning skills and methodological competence for designing integrated learning experiences.

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DESIGNING INTERDISCIPLINARY PROJECT-BASED LEARNING FOR HETEROGENEOUS GROUPS: INSIGHTS FROM A DESIGN-BASED FRAMEWORK

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Abstract: When students from computer science, engineering, the social sciences, and the arts work together on a single project team, cross-disciplinary collaboration appears to require deliberate pedagogical support. Differences in technical vocabulary, methodological assumptions, and academic conventions can generate friction that standard Project-Based Learning (PBL) designs may not address systematically. This paper reports a design-based research study at a higher education institution in which interdisciplinary PBL (iPBL) courses form the structural core of the curriculum. Over two semesters, it documents the iterative development of a framework of ten guidelines for educators who design project courses for master's students with varied disciplinary preparation. The framework draws on Universal Design for Learning, Culturally Responsive Teaching, and research on collaborative learning. Data sources include course design documentation and student enrolment and grade records from two implementation cycles. Three design decisions seemed to matter in particular: intentional team composition along disciplinary and demographic lines, explicit articulation of assessment criteria from the outset, and differentiated scaffolding directed at discipline-specific preparation gaps. The study is limited by its single institutional context and the absence of direct outcome measures beyond grades. The findings suggest that interdisciplinary collaboration tends to depend on deliberate, combined design choices rather than on any single strategy, with implications for how educators configure assessment, grouping, and scaffolding in heterogeneous classrooms.

Keywords: *interdisciplinary project-based learning, heterogeneous groups, design-based research, higher education, collaborative learning*

Introduction

Higher education programmes are increasingly organized around interdisciplinary collaboration, which asks students from distinct academic fields to work jointly on shared problems. In programmes where interdisciplinary project work constitutes the structural core of the curriculum, students from computer science, engineering, the social sciences, and the arts are brought together within a single project module. This arrangement makes disciplinary diversity a routine feature of the learning environment and suggests that educators may need to treat differences in technical vocabulary, methodological assumptions, and epistemological orientations as design problems rather than incidental complications.

Project-Based Learning (PBL) is frequently proposed as a suitable approach for such settings, given its orientation toward authentic and complex problems that tend to benefit from multiple perspectives (Krajcik & Shin, 2014). According to Kokotsaki et al. (2016), PBL encourages collaboration, connects theoretical knowledge to applied contexts, and supports transversal competencies such as communication, critical thinking, and self-regulation. Much of the existing literature, however, addresses single-discipline contexts or assumes relatively homogeneous groups. The particular challenges of designing PBL for cross-

[20]The second author was supported by CAPES/PRINT, Edital nº 41/2017 (Award 88887.802740/2023-00).

disciplinary cohorts with varied preparation seem to remain comparatively underexplored.

In many interdisciplinary structures, an approved project proposal defines the scope and expected outcomes of a module, yet does not prescribe the content of the associated project-integrated courses. Educators are therefore left to translate broad goals into targeted competencies, learning objectives, and assessment criteria while accounting for variation in students' preparation, cultural backgrounds, and familiarity with academic conventions. On this view, the question is not only how to implement PBL, but how to configure it so that students with different forms of expertise can contribute on more equitable terms.

This paper reports on a design-based research study documenting the initial development of a framework of ten guidelines for educators implementing iPBL. The framework was refined over two semesters of PBL courses with master's students, drawing on course design documentation and student enrolment and grade records. It addresses four areas: course preparation and team formation, inclusive course design, active and collaborative learning, and communication and learner autonomy. The study examines two research questions. The first asks which design principles appear to support productive interdisciplinary collaboration for heterogeneous groups. The second asks how design adjustments between cycles reflect the principles of iterative refinement. The next section reviews the theoretical foundations, followed by the methodology, results, and conclusions.

Literature Review

The foundations of this framework draw on five bodies of research. Each contributes a set of design principles that, taken together, bear on the design of courses for heterogeneous, cross-disciplinary groups. The discussion below outlines the core claims of each tradition and how they seem to relate to these design problems.

Project-Based Learning and Interdisciplinary Collaboration

PBL may be described as an approach in which students engage in extended inquiry into complex, authentic problems and produce tangible outputs (Thomas, 2000). Its grounding lies in constructivism and experiential learning, with Dewey's account of learning through purposeful activity often cited as an early reference. In higher education, PBL has been associated with greater engagement, deeper conceptual understanding, and competencies that lecture-based instruction tends to underserve (Kokotsaki et al., 2016). When implemented across disciplines, it appears to introduce additional complexity, as students must navigate divergent frameworks for problem definition, differing standards of evidence, and distinct communication conventions. Repko (2012) describes the capacity to move between disciplinary perspectives and bring them together as integrative thinking, and suggests that this synthesis does not occur automatically; in the absence of scaffolding, teams may fragment along disciplinary lines.

Universal Design for Learning

The Universal Design for Learning (UDL) framework (CAST, 2018) offers principles for designing learning experiences that aim to be accessible from the outset rather than through later accommodation. It organises recommendations around multiple means of engagement, representation, and action and expression. In interdisciplinary PBL, UDL seems relevant because student diversity extends beyond individual preferences to different disciplinary knowledge structures. Offering content in several formats may help bridge gaps in disciplinary vocabulary, and allowing students to demonstrate competence through presentations, reports, prototypes, or portfolios acknowledges that knowledge is often expressed differently across forms of training.

Culturally Responsive Teaching

Culturally Responsive Teaching (CRT), developed by Ladson-Billings (1995) and elaborated by Gay (2010), treats students' cultural backgrounds and lived experiences as resources for learning rather than as variables to be neutralized. In practice, it involves drawing on examples from varied contexts, supporting students as they connect material to their own experience, and avoiding assumptions about shared prior knowledge. In settings that bring together students from different countries, CRT principles appear to bear on how projects are framed and how communication norms are established. Gay (2010) suggests that, when students perceive their backgrounds as assets, they tend to engage more actively.

Scaffolding

Scaffolding, grounded in Vygotsky's (1978) Zone of Proximal Development, refers to temporary, structured support that allows learners to accomplish tasks they could not yet complete alone. In PBL for heterogeneous groups, the gap between prior knowledge and project demands can be counterproductive for some students while offering insufficient challenge to others. According to Wood et al. (1976), scaffolding involves decomposing tasks into manageable phases, providing models and worked examples, and gradually withdrawing support. The form required also seems to differ: a student with a technical background may need support with collaborative communication, while a student from the humanities may need scaffolding with quantitative methods.

Collaborative Learning and Metacognition

Collaborative learning treats dialogue, shared inquiry, and collective problem-solving as central to knowledge construction (Johnson & Johnson, 2009). Oakley et al. (2004) report that intentional grouping based on academic and demographic diversity tends to produce more productive collaboration than random

assignment. However, diverse teams seem to require explicit attention to equitable participation. The development of metacognitive skills involves teaching students to reflect on, monitor, and regulate their own learning (Flavell, 1979). Tools such as reflective journals and self-assessment prompts may help students identify which strategies work for them, which appears relevant in heterogeneous groups where self-regulatory skills vary (Zimmerman, 2002). Taken together, these frameworks provide the conceptual foundation for the guidelines developed here.

Methodology

Research Design

This study adopts a design-based research (DBR) approach (Barab & Squire, 2004; McKenney & Reeves, 2012), characterised by iterative cycles of design, implementation, analysis, and redesign in authentic settings. This approach seemed appropriate because the framework was not designed in advance and then evaluated in a controlled setting; it was developed through ongoing adjustments informed by course design data from two semesters. The research proceeded through two cycles corresponding to two consecutive semesters (Winter 2025 and Summer 2026). An initial set of guidelines was derived from the theoretical foundations and applied in the first semester; the documents were then reviewed to identify what had functioned as intended and where adjustments seemed needed, and the second semester served as a cycle of refinement.

Sample

The courses enrolled 45 master's students from 21 countries, representing six broad disciplinary categories: Engineering, Computer Science and IT, Business and Management, Natural and Life Sciences, Arts, Design and Media, and the Social Sciences and Humanities (Figure 1). In the first semester, 33 students were distributed across nine teams of three to four members; in the second, 12 students worked in three teams of four. Each module is defined by an approved proposal specifying its scope and expected outcomes. At the same time, the associated courses require the research team to independently define competences, objectives, and assessment criteria, drawing on the programme's Competences Framework. The population includes domestic and international students at different stages of their academic careers, which adds variation in research experience and familiarity with collaborative work (Figure 2).

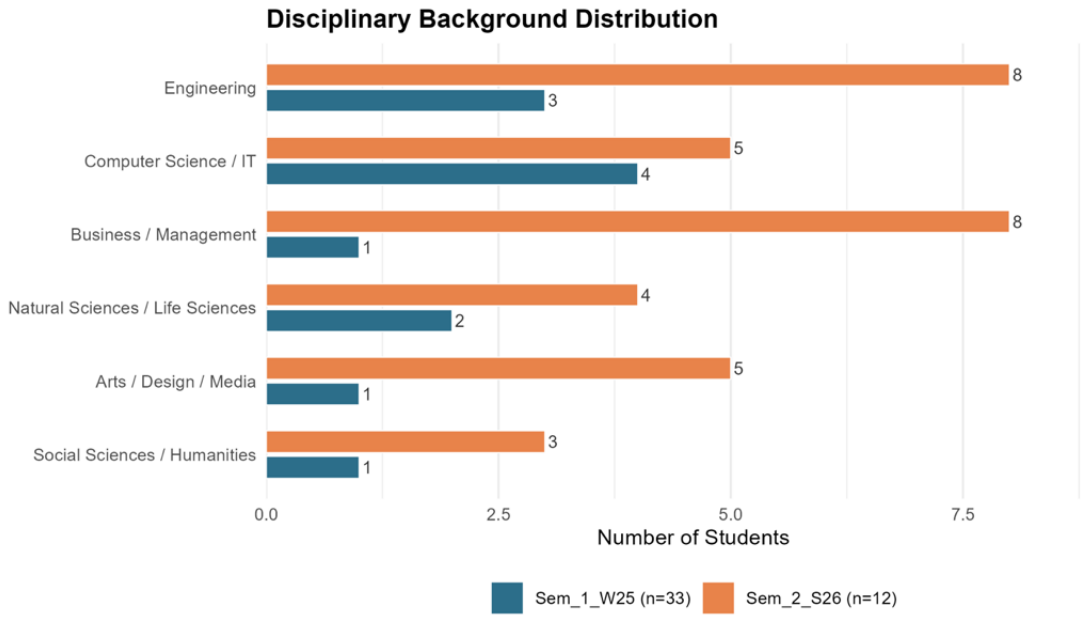

Figure 1. Disciplinary background distribution by semester (n = 45).

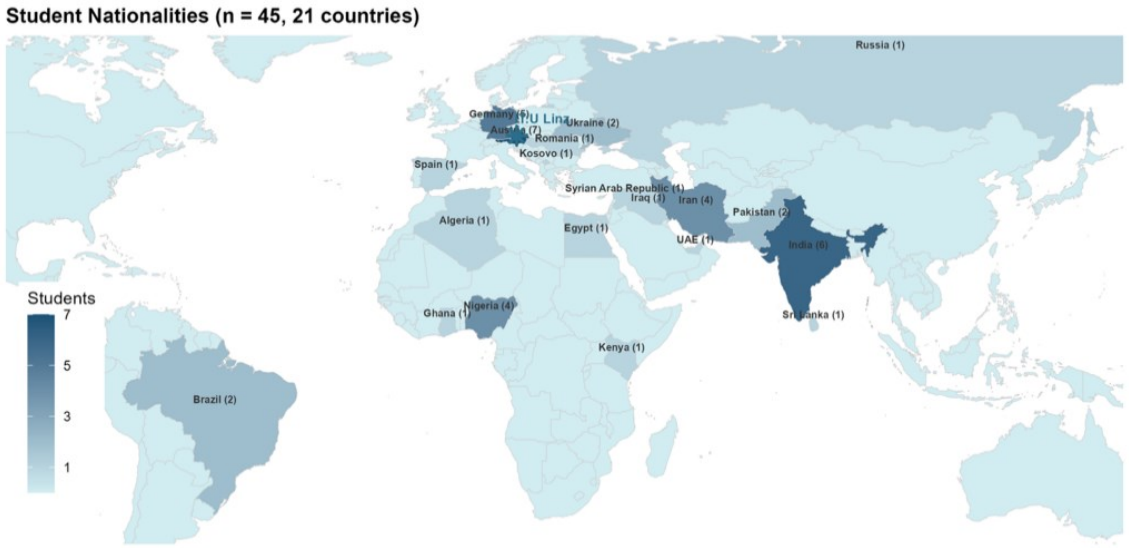

Figure 2. Student nationalities represented across both semesters (n = 45, 21 countries).

Instruments and Procedure

The guidelines emerged from the practical need to address this heterogeneity systematically across two semesters. They are summarized in Table 1.

	Guideline	Description	Key References
1	Setting the Stage	Define competences, learning objectives, outcomes, and assessment criteria before the course begins, and become familiar with students' profiles in order to adapt projects toward meaningful participation.	Krajcik & Shin (2014); Kokotsaki et al. (2016)
2	Teams & Collaborative Work	Form groups based on disciplinary and demographic diversity rather than at random.	Oakley et al. (2004). Repko (2012)
3	Intentional Course	Offer multiple means of engagement, representation,	CAST (2018)

	Guideline	Description	Key References
	Design (UDL)	and action or expression, so that varied disciplinary backgrounds can be accommodated.	
4	Transparent Assessment Design	Combine formative and summative assessment, draw on varied methods such as portfolios, peer feedback, and journals, and share rubrics and exemplars from the outset.	CAST (2018)
5	Culturally Responsive Teaching	Draw on examples from varied cultural and disciplinary contexts, connect content to students' lived experiences, and avoid assumptions about shared norms.	Ladson-Billings (1995); Gay (2010)
6	Scaffolding	Decompose tasks into phases with intermediate deliverables, provide discipline-specific worked examples, and gradually withdraw support.	Vygotsky (1978); Wood et al. (1976)
7	Active Learning	Use think–pair–share, peer instruction, and structured discussion to support participation across varying levels of disciplinary confidence.	Kokotsaki et al. (2016)
8	Collaborative Learning	Structure group work through defined roles, shared responsibilities, and an explicit framing of interdisciplinary teamwork.	Johnson & Johnson (2009); Repko (2012)
9	Inclusive Communication	Explain technical terminology, provide written summaries, and consider a flipped classroom so that students may prepare at their own pace.	OECD (2012)
10	Metacognitive Development	Address reflection, self-monitoring, and planning explicitly through reflective journals, learning logs, and self-assessment prompts.	Flavell (1979); Zimmerman (2002)

Table 1. Ten guidelines for designing iPBL for heterogeneous groups.

Data Generation and Analysis

Data were collected from two primary sources. The first was course design documentation, including course structures, module organization, assignment types, assessment rubrics, and team formation records, retrieved from the program's learning management system. The second was student enrolment data, including disciplinary backgrounds and grade records from both semesters. The analysis followed two tracks. Course design documents were compared across semesters to identify concrete changes in team formation, assignment structure, rubric design, and content delivery. Grade distributions and disciplinary composition were analyzed with non-parametric tests (Kruskal–Wallis and Mann–Whitney U) to assess whether outcomes differed across categories or between semesters. This dual-track approach related design decisions to observable patterns in performance, while acknowledging the limits of drawing causal inferences from a small sample in a single context.

Results and Discussion

The iterative process produced a framework of ten guidelines organized around four thematic areas. The discussion below presents each area with reference to the design decisions and theoretical grounding

that shaped the guidelines, addressing the two research questions.

Course Preparation and Team Formation

Examination of the documents suggested that the project proposals, while providing overall direction, did not specify which competences students should develop or how learning would be assessed. The framework, therefore, asks designers to define competences, objectives, outcomes, and assessment criteria before the project begins. Making these explicit in advance seems to matter because assumptions about what students know vary across disciplines; without it, students and instructors may operate under different implicit expectations, which can complicate assessment and raise concerns about equity. Rather than random grouping, the framework recommends intentional composition reflecting disciplinary and demographic diversity. Analysis of team composition records suggested that deliberately balanced teams tended to produce more integrative outputs, though they also required more structured onboarding to help students develop a shared vocabulary (Repko, 2012). As Figure 3 shows, first-semester teams averaged 3.2 discipline categories and 3.3 nationalities, while second-semester teams averaged 3.7 and 4.0, respectively.

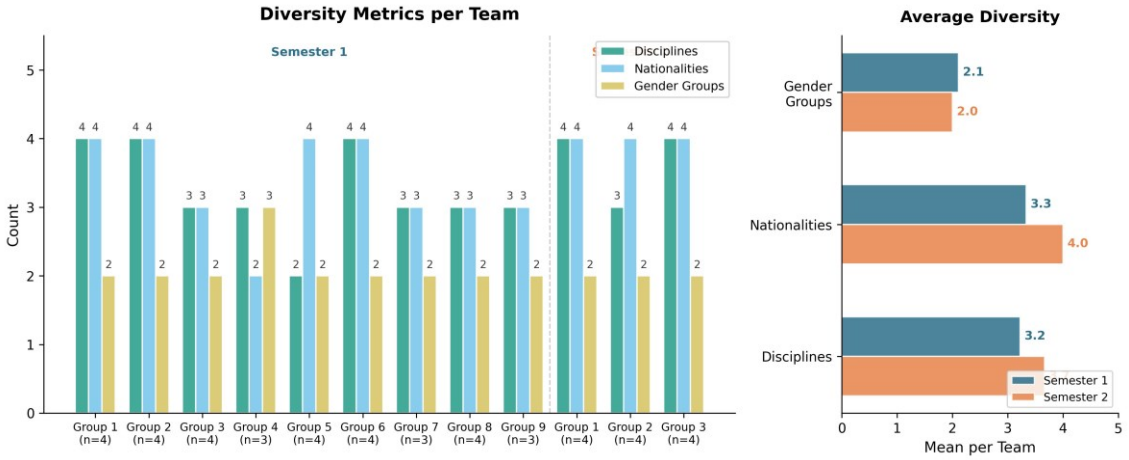

Figure 3. Team composition diversity across both semesters (12 teams, n = 45).

Inclusive Course Design

Three guidelines bear on inclusive design. The first applies UDL principles so that content is accessible through several formats from the outset. The documents indicate that combining video, written text, and visual representations was built into the course structure as a response to asymmetric prior knowledge. Statistical methods familiar to social science students, for instance, were introduced with explicit visual scaffolding for design students, while design thinking was given a structured written introduction for engineering students. A second element concerns assessment transparency: criteria, rubrics, and exemplars were made available from the start. Comparison across semesters showed a gradual move toward greater explicitness, particularly in the dimensions assessing interdisciplinary integration, where conventions appear to diverge most. The third element applies CRT principles, drawing on examples from

varied contexts and structuring opportunities for students to connect work to their own experience; this was extended between semesters in response to patterns of unequal participation in the records.

Active and Collaborative Learning

The sixth guideline addresses differentiated scaffolding calibrated to different starting points. The documents suggest that the more productive configuration decomposed tasks into phases with intermediate deliverables, provided discipline-specific worked examples alongside interdisciplinary models, and included structured checkpoints before each transition. Active learning strategies, including think-pair-share, peer instruction, and structured discussion, were incorporated to support participation across varying levels of disciplinary confidence. Collaborative learning was structured through defined tasks, shared responsibilities, and an explicit framing of interdisciplinary teamwork. Without this structure, the first-semester documentation indicated that teams tended to divide work along disciplinary lines rather than integrate perspectives, which seemed to run counter to the project's purpose (Repko, 2012). This observation informed the restructuring of collaborative tasks in the second semester.

Communication, Autonomy, and Overall Patterns

In multilingual, cross-disciplinary classrooms, specialized terminology and uneven familiarity with academic register may act as barriers to participation. The ninth guideline recommends explaining terminology, providing written summaries, and considering strategies such as the flipped classroom and the tenth addresses metacognition through reflective questionnaires and learning journals. A recurrent observation was that no single guideline seemed sufficient on its own; the value of the framework appears to derive from combining transparent assessment, intentional composition, differentiated scaffolding, and metacognitive tools. A Kruskal–Wallis test indicated no statistically significant difference in final grades across the six disciplinary categories ($H = 1.76$, $p = 0.882$), nor across levels of computer skill ($H = 2.05$, $p = 0.358$), as shown in Figure 4. This may suggest that the design did not systematically advantage any particular background.



Figure 4. Final grade distribution by discipline category (left) and computer skill level (right).

When grade distributions are compared across semesters (Figure 5), the proportion of students receiving the highest grade rose from 45% in Semester 1 to 67% in Semester 2, and no student in Semester 2 received a grade below Good. Given the small sample and single context, these figures are best read as descriptive rather than as evidence of an effect attributable to the framework.

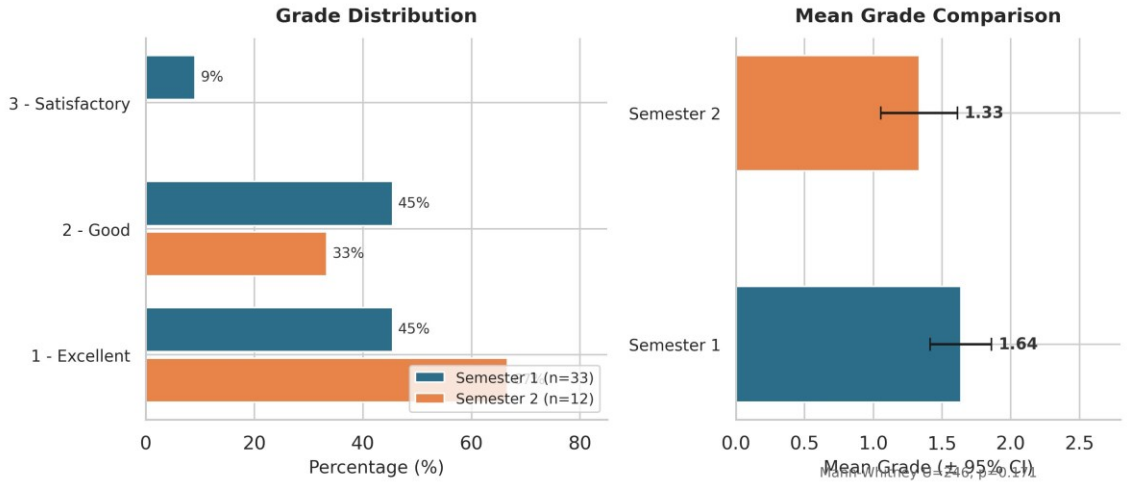

Figure 5. Grade distribution by semester (left) and mean grade comparison with 95% confidence interval (right).

Conclusions

This study reported a design-based research process through which a practical framework for interdisciplinary PBL was developed and refined over two semesters. The ten guidelines, applied with 45 master's students from 21 countries and 6 discipline categories, address a gap in the literature by focusing on the design problems that arise when students from different backgrounds work together without the shared conventions that ordinarily support collaboration within a single field. The findings suggest that productive collaboration tends to depend on deliberate design across several dimensions, and that the interdisciplinary context appears to make each dimension more consequential rather than less.

Several limitations should be noted. The study was conducted in a single, recently established programme with a distinctive structure, which may limit transferability. The data draw on course design documentation and grade records rather than direct measures of learning processes. The value of the framework is therefore supported by documented design decisions and two cycles of refinement rather than by controlled experimental evidence, and the longer-term effects of the guidelines remain unknown.

Several directions for future work follow. Incorporating student perspectives through interviews or surveys would provide evidence on how the guidelines are experienced. Analysis of richer outcome data could provide more direct evidence on whether these outcomes support equitable learning across categories. The framework might also be tested in programmes with different structures to assess whether the guidelines transfer or require adaptation. As an implication for practice, institutions developing new interdisciplinary programmes may find the framework useful as a starting point, particularly within

integrative models such as STEPAM. In contrast, established programmes may draw on it to identify areas where current design could be strengthened. The guidelines are intended to be adapted rather than applied prescriptively.

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https://doi.org/10.46793/STEPAM26.130T
Udk: 37.091.3::811.111-053.4

FROM HEAD TO TOE: A DAY OF MOVEMENT AND DISCOVERY IN EARLY CHILDHOOD LANGUAGE LEARNING

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Abstract: The STEPAM paradigm – which integrates Physical Education – combined with Montessori principles and Content and Language Integrated Learning (CLIL) provides a holistic framework for early childhood language education. This case study investigates a one-day English language intervention with six preschool children aged 3–6 years. Four participants had prior language exposure from diverse contexts. Data were collected through observational notes, informal questioning, and a pre-test administered prior to the intervention, and a post-test conducted one week later. Results indicate that participants improved their understanding of the topic "Senses," acquiring between five and fifteen new English vocabulary items. Instances of creative thinking and emerging reasoning in English and Serbian were observed in all children. The findings suggest that young learners benefit from active, play-based, movement-oriented learning combined with hands-on exploration. The study is limited by its small sample, short duration, and focus on short-term outcomes; therefore, the findings cannot be generalised beyond this specific context.

Keywords: STEPAM, Montessori Method, CLIL, English language learning, early childhood education

Introduction

The growing need for individuals equipped with 21st century skills and advanced English language proficiency places increasing pressure on educators to develop innovative teaching approaches. Although numerous instructional models support the development of these competencies, a unified educational framework that simultaneously fosters language development and higher-order thinking skills has yet to be fully established.

The present research draws on complementary theoretical perspectives to address the developmental, cognitive, and linguistic needs of young learners in a public preschool setting (Lillard, 1996; Cameron, 2001; Nikolov & Mihaljević Đigunović, 2011). Montessori principles shaped the pedagogical context, CLIL connected content and language objectives, STEPAM incorporated movement and interdisciplinary learning, and the 5E model organized the activities. The intervention focused on the topic "Senses." Particular attention was given to English vocabulary development and to observable manifestations of creative and age-appropriate reasoning during the activities. Informal questioning and observational notes provided contextual qualitative information for interpreting the results.

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Theoretical background

Montessori Principles

The Montessori Method is a holistic educational approach that addresses children's physical, cognitive, social, and emotional development. Montessori principles shape both the organisation of the learning environment and pedagogical interaction, emphasising child autonomy, sensorial learning, and the use of structured hands-on materials (Lillard, 1996; Montessori, 1967).

Mixed-age groups further support peer learning, as younger children observe and learn from older peers, while older children reinforce their understanding through guidance and collaboration (Montessori, 1967). Within the prepared environment, the teacher acts primarily as a guide and facilitator rather than a direct instructor, encouraging exploration and the gradual development of independence and confidence (Montessori, 1949).

Montessori education also provides children with opportunities to make choices within a prepared environment according to their interests and developmental readiness. Movement and sensory exploration are considered important dimensions of children's interaction with their environment and broader development (Montessori, 1967). These principles informed the present intervention, particularly the use of hands-on materials, sensory activities, movement, choice, and mixed-age interaction.

Content and Language Integrated Learning (CLIL)

CLIL integrates content and language learning by engaging learners with meaningful subject matter while developing language through that engagement (Coyle et al., 2010). Its 4Cs framework—Content, Communication, Cognition, and Culture—emphasises the interconnected development of these dimensions through appropriately designed learning experiences.

In lower primary grades, CLIL practices in multi-grade classrooms can foster individual learning through peer interactions (Bradonjić, 2023), reflecting Montessori principles that emphasise collaboration and learning within mixed-age groups.

Recent research further suggests that appropriately implemented CLIL can support foreign language development without necessarily compromising content learning, particularly when instruction is purposeful, contextualised, and cognitively engaging (Escudero et al., 2025; Lefterov & Mantovani, 2025).

Vocabulary Enrichment Through Movement

Movement-based approaches have been widely used in early foreign language education. Total Physical Response (TPR), for example, connects language input with physical action and can be particularly appropriate for young learners who are still developing the ability to sustain attention during conventional verbal instruction.

Kandić Najić (2023) investigated the role of listening and TPR activities in the development of young learners' speaking skills. The author reported that the experimental TPR group improved from an initial proportional mean score of 0.07 in the pre-test to 0.57 five days after instruction, whereas the control group reached only 0.16, demonstrating stronger vocabulary retention and oral production in the TPR condition. The author also indicates that such approaches increase motivation, comprehension, and active participation.

Similarly, Kalaycıoğlu (2011) found that combining picture vocabulary games with TPR produced better vocabulary outcomes than TPR alone. These findings suggest that movement combined with visual, auditory, and contextual support can facilitate vocabulary learning.

The present intervention extended this principle by combining movement with sensory exploration, experimentation, creative expression, and interdisciplinary content.

Higher-order Thinking Skills

Creative thinking is commonly associated with divergent thinking, particularly through the dimensions of fluency, flexibility, originality, and elaboration (Torrance, 1974). Critical thinking involves processes such as interpretation, analysis, evaluation, inference, explanation, and self-regulation (Facione, 1990). In early childhood, imaginative questions, storytelling, experimentation, and collaborative activities can provide opportunities for children to generate ideas and make connections (Wu & Derakhshan, 2026).

STEAM, STREAM, and STEPAM

STEM education has progressively expanded into interdisciplinary approaches such as STEAM and STREAM, incorporating arts, literacy, and other dimensions of learning. These approaches aim to develop problem-solving, creativity, collaboration, communication, and experiential learning through interdisciplinary activities (Wai Leng, 2023).

The Recreation component of the STREAM educational framework, or one of its interpretations, has likewise been associated with physical, psychological, and cognitive benefits (Donnelly et al., 2013; Lambourne & Donnelly, 2016; Lees & Hopkins, 2013; Reiner et al., 2013). Da Cruz et al. (2025) highlight the potential of embodied and movement-based learning for creativity, critical thinking, well-being, and academic engagement, positioning STEPAM as a framework connecting Physical Education and movement with interdisciplinary learning.

In the present study, STEPAM was operationalised through movement, games, outdoor physical activities, sensory exploration, and interdisciplinary tasks.

5E Lesson Model

The 5E instructional model is an inquiry-based framework comprising five phases: Engage,

Explore, Explain, Elaborate, and Evaluate. Originally developed within science education, it promotes active learning through hands-on experience, collaboration, reflection, and knowledge construction (Bybee et al., 2006; Bybee, 2015). In the present study, sensory experiments, movement activities, songs, and creative tasks were distributed across the five phases (see Appendix 1).

Integrative Framework

The integrative model represents a form of principled eclecticism in which each component fulfils a distinct but complementary role: Montessori principles shaped the learning context and interactional patterns; STEPAM operationalised movement-based and exploratory learning; CLIL connected language and content objectives; and the 5E model organised the instructional process (see Figure 1).

The rationale for combining these educational approaches is further supported by previous research conducted in early childhood English language learning contexts. In a case study examining the development of creative and critical thinking through STEAM projects, Tasić (2025) found that interdisciplinary, inquiry-based activities encouraged young learners to generate original ideas, make connections across domains, justify their reasoning, and engage actively in English language use.

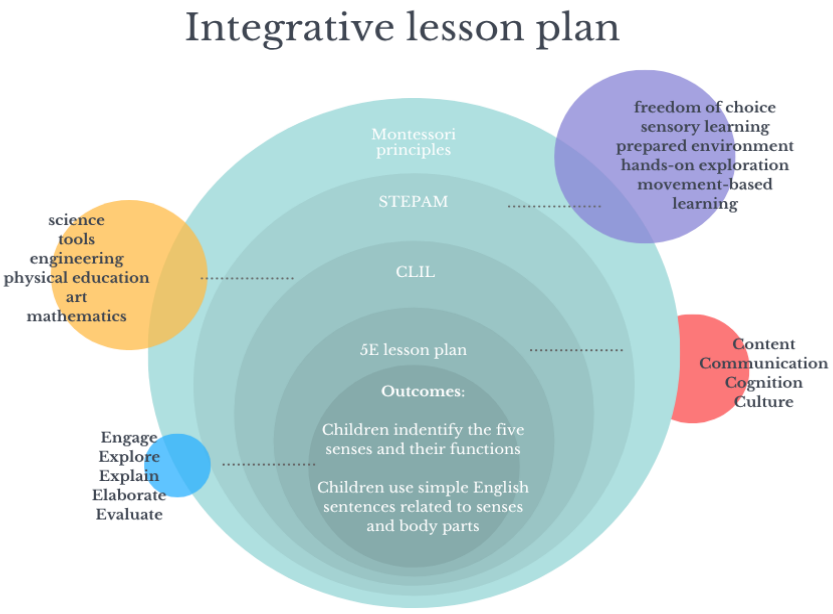

Figure 1. *Integrative lesson plan framework combining Montessori principles, STEPAM, CLIL, and the 5E instructional model*

Note. Figure created by the researcher using Canva

Methodology

Research Design and Purpose

The study employed an exploratory mixed-methods case study design, combining descriptive quantitative data from a researcher-developed pre-test and delayed post-test with qualitative data obtained through informal questioning and observational notes.

The case study design was selected because it enabled an in-depth and context-sensitive examination of children's English language production, participation, and spontaneous cognitive responses within their natural preschool environment. A case study was particularly appropriate given the small number of participants, the one-day intervention, and the exploratory purpose of the research.

The quantitative component was descriptive rather than inferential. Pre- and post-intervention scores were compared to identify observable changes in vocabulary knowledge. The qualitative component provided contextual information about children's participation, language use, creative responses, and age-appropriate reasoning during the intervention.

The purpose was therefore not to establish causal effectiveness but to explore what linguistic and behavioural changes could be observed following the implementation of the integrative teaching model.

Research question and objectives

The main research question was:

1. What changes in English vocabulary knowledge were observed following the one-day integrative intervention among children aged 3–6?

The study also had two exploratory objectives:

- to examine observable manifestations of creative thinking and age-appropriate reasoning expressed in Serbian and English during the intervention;
- to explore whether children's previous English language exposure appeared to be associated with their language use and participation during the intervention.

Participants

The participants were six preschool children aged 3–6 attending a local public preschool institution. The group consisted of one girl aged 3, three boys aged 4, and two children aged 6 (one boy and one girl).

The participants formed a mixed-age group, which was compatible with the study's Montessori principles implemented. Because of the very small sample and the case-study design, the participants were not intended to represent the wider preschool population.

Intervention Design

The intervention incorporated the previously described Montessori-inspired, CLIL, STEPAM, and

5E principles. Activities included sensory experiments, movement activities, songs, games, outdoor physical activities, and creative tasks.

Before implementation, written parental consent was obtained and official approval was received from the preschool principal.

Instruments

Pre-test and delayed post-test

A researcher-developed vocabulary assessment was administered immediately before the intervention and again one week later. The assessment consisted of 22 vocabulary items distributed across four categories:

- eight body-part items;
- ten numbers;
- two colours;
- two verbs.

The same vocabulary was assessed in the delayed post-test to examine changes in children's performance and short-term retention. Assessment tasks included pointing to body parts, counting with fingers to elicit number vocabulary, and using a song “Red Light, Stop; Green Light, Go” to elicit colour and verb vocabulary.

The assessment was designed to match the participants' developmental level and relied on age-appropriate recognition and production tasks rather than formal written testing.

Informal questioning

Informal questioning was used to explore children's previous experience with English and to identify their existing language knowledge. These interactions were conducted naturally before and during the intervention rather than as formal interviews.

Observational notes

Observational notes documented children's verbal and non-verbal responses, participation, interaction, language use, and spontaneous cognitive responses. Particular attention was given to behaviours that could be interpreted as manifestations of creative thinking and emerging reasoning. The analysis focused on observable indicators such as generating unusual or multiple ideas, making associations and connections with prior experience, elaborating on an initial idea, considering alternatives or different perspectives, and explaining or comparing observations.

These indicators were informed by the conceptualisations of creative thinking and critical thinking proposed by Torrance (1974) and Facione (1990). The study did not use a standardised creativity or critical-

thinking test; consequently, these observations were interpreted as qualitative indicators of cognitive engagement rather than measurements of children's creative or critical-thinking abilities.

Both Serbian and English responses were retained because limiting observation to English would have underestimated the children's ability to express their ideas at their developmental level.

Results

Table 1. Pre-test Results of English Vocabulary Knowledge

A child/age	Body parts (/8)	Numbers (/10)	Colours (/2)	Verbs (/2)	Total score (/22)	Mean
Child A/3	0/8	3/10	0/2	0/2	3/22	**0.14**
Child B/4	8/8	10/10	2/2	2/2	22/22	**1.00**
Child C/4	0/8	3/10	0/2	0/2	3/22	**0.14**
Child D/4	0/8	10/10	0/2	0/2	10/22	**0.45**
Child E/6	8/8	10/10	2/2	2/2	22/22	**1.00**
Child F/6	0/8	10/10	0/2	0/2	10/22	**0.45**
Total	**16/48**	**46/60**	**4/12**	**4/12**	**70/132**	**0.53**

Note. Body parts vocabulary included: head, shoulders, knees, toes, eyes, ears, mouth, and nose. Colours included: red and green. Verbs included: stop and go.

The overall mean proportion of correct responses on the pre-test was 0.53. Two participants (Children B and E) achieved maximum scores across all tested vocabulary categories. Both children regularly used English at home. When their results were excluded, the mean proportion of correct responses among the remaining four participants was 0.29.

The difference illustrates the importance of considering previous language exposure when interpreting the overall group score.

Table 2. Post-test Results of English Vocabulary Retention

A child/age	Body parts (/8)	Numbers (/10)	Colours (/2)	Verbs (/2)	Total score (/22)	Mean
Child A/3	5/8	10/10	2/2	1/2	18/22	**0.81**
Child B/4	8/8	10/10	2/2	2/2	22/22	**1.00**
Child C/4	1/8	10/10	1/2	2/2	14/22	**0.64**
Child D/4	1/8	10/10	2/2	2/2	15/22	**0.68**
Child E/6	8/8	10/10	2/2	2/2	22/22	**1.00**
Child F/6	5/8	10/10	2/2	1/2	18/22	**0.81**
Total	**28/48**	**60/60**	**11/12**	**10/12**	**109/132**	**0.83**

The overall mean proportion of correct responses increased from 0.53 on the pre-test to 0.83 on the delayed post-test. Among the four participants without regular bilingual English exposure, the mean increased from 0.29 to 0.74.

The largest individual increase was observed for the youngest Child A, who gained 15 vocabulary items between the pre-test and delayed post-test.

Among participants without regular bilingual English exposure, gains ranged from 5 to 15 items.

Although performance improved substantially, the design does not permit causal attribution to the intervention alone.

Creative Responses and Emerging Reasoning

Since the children showed a preference for experiential and engaging outdoor activities that provided opportunities for communication through intentional questioning, children's creative productions and emerging reasoning were selected from their responses during these activities.

Examples included:

- Child B: “It looks like slime.” (English)
- Child D: “It looks like Coca-Cola.” (Serbian)
- Child E: “It looks like raindrops. Raindrops are falling down. It smells like orange. And it tickles my hand.” (English)

Child F: “It looks like the sea.” (Serbian)

The responses illustrate associative thinking, connection with prior experience, and elaboration of sensory observations. Child E additionally incorporated movement, smell, and tactile sensation into the description.

During the final activity in the Elaborate phase, children discussed chalk drawings representing the five senses and connected them with personal experiences:

- Child A: “Those are flowers. I can smell the flowers.” (Serbian)
- Child B: “It's an insect. I can see insects. And I can touch them!” (English)
- Child C: “It's a ladybug. I can touch it.” (Serbian)
- Child D: “It's a marshmallow. I melt it on the fire. I can eat it.” (Serbian)
- Child E: “I can smell the flowers. I can eat honey from the beehive. I can see the plane, neeeeow!” (English)
- Child F: “I can see the sun and I can eat strawberries.” (Serbian)

The responses further demonstrate association, elaboration, and imaginative interpretation, particularly in Child D's extension of a visual association into a sequence involving melting and eating.

Engagement, Choice, and Participation

Throughout the intervention, the children demonstrated cooperation, patience, and sustained engagement. They generally waited for their turns and showed enthusiasm for participating in the different activity stations.

Opportunities for choice appeared to support engagement. Children were allowed to select materials and colours during creative activities and to choose combinations of food coloring during sensory experiments. Some participants chose to remain longer at a particular station even after the rest of the group had moved to another activity.

For example, Child F remained engaged in the "Rainbow Magic Potions" activity while the other children participated in the "Traffic Light Song." Child D initially chose not to participate in the "Head, Shoulders, Knees, and Toes" activity. Nevertheless, both children subsequently participated actively in other components of the intervention.

The observations therefore suggest that participation did not necessarily require uniform engagement in every activity. Rather, providing opportunities for choice appeared to support flexible participation while allowing children to remain involved in the broader learning experience.

Language Choice During Interaction

Four children had previous exposure to English through different informal contexts, including interaction with an older school-aged sibling and engagement with video games, while two children regularly communicated in English at home and demonstrated bilingual language use.

Although most children had some previous contact with English, spontaneous English production varied considerably. The children generally appeared more willing to express their ideas in Serbian when they lacked confidence in English vocabulary. The two children who regularly used English at home were more likely to initiate English-language responses spontaneously and appeared to provide a linguistic model for their peers.

Discussion

The findings provide preliminary support for the potential value of movement-based, multisensory, and play-oriented activities in early childhood English language learning. The improvement remained substantial when the two children with regular bilingual English exposure were excluded, indicating that participants with more limited prior exposure also showed notable improvement.

These findings are broadly consistent with previous research indicating that movement, games, and TPR can facilitate vocabulary learning and oral language development among young learners (Kalaycıoğlu, 2011; Kandić Najić, 2023). The present study extends these observations by embedding movement within a broader interdisciplinary framework that also incorporated sensory exploration, experimentation, creative expression, and content-based language learning.

The findings cannot be interpreted causally because the study lacked a control group and could not separate intervention effects from prior knowledge, repeated exposure, individual differences, or outside exposure to English.

The children's spontaneous responses demonstrated associative thinking, elaboration, and connections with prior experience, providing examples of cognitive engagement consistent with dimensions of creative thinking (Torrance, 1974). Some responses also involved explanation, comparison, and justification, which may represent emerging forms of reasoning (Facione, 1990). However, because no formal creativity or critical-thinking measures were used, these observations should not be interpreted as evidence of developed or measured abilities.

The high engagement observed during sensory experimentation and outdoor games is consistent with the movement-based and interdisciplinary rationale of STEPAM (Da Cruz et al., 2025). However, because the components were implemented simultaneously, their individual contributions cannot be isolated.

From a CLIL perspective, children encountered English while moving, experimenting, observing, comparing, creating, and communicating rather than learning vocabulary in isolation. Visual, physical, sensory, and contextual cues may have provided additional support for comprehension during the activities.

The findings are also consistent with Tasić's (2025) case study, which demonstrated that interdisciplinary STEAM activities facilitated young learners' generation of ideas, making connections, and meaningful use of English. The present study extends this work by incorporating a stronger movement-based STEPAM dimension.

Previous English exposure was associated with both initial vocabulary performance and willingness to use English. Nevertheless, participants with limited prior exposure also showed substantial gains, suggesting that movement, visual cues, sensory experience, repetition, and contextualized interaction may support participation at lower proficiency levels.

The stronger English production of bilingual participants also highlights the potential role of peer interaction, as more proficient children appeared to provide additional linguistic models for their peers, consistent with research on peer learning in CLIL contexts (Bradonjić, 2023).

Conclusion

The one-day intervention was followed by substantial short-term improvement in the targeted English vocabulary among the most of the preschool participants. Observational data additionally indicated engagement, cooperation, associative thinking, elaboration, and age-appropriate reasoning during sensory, movement-based, and interdisciplinary activities.

Previous English exposure appeared to be associated with initial vocabulary knowledge and spontaneous English production, while participants with more limited exposure also demonstrated meaningful gains. The findings therefore provide preliminary support for the feasibility of combining Montessori principles; STEPAM, CLIL, and the 5E model in early childhood English language education.

The study does not establish causal effectiveness of the integrative model or any individual component. Future research should employ larger samples, comparison or control groups, validated language measures, repeated interventions, and longer follow-up periods to examine the contribution of movement, sensory exploration, peer learning, and content-based instruction more systematically.

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Appendix 1. *Lesson plan "Senses"*

<table>
<tr><td>STEPAM DAY
Kindergarten (age 3-6)</td><td colspan="2">SENSES</td><td>Date
May, 2025</td></tr>
<tr><td colspan="2">Materials Needed:
Food coloring
Water
Vegetable oil
Effervescent tablet
Light source
Worksheet
Stickers
Chalk
Sports' equipments</td><td colspan="2">Lesson Outcomes:
1.Make observations based on sensory evidence
2.Develop collaborative, creative, and critical-thinking skills
3.Identify the five senses and their functions
4. Understand the importance of each sense in gathering information
5. Distinguish between the role of the senses in real-life learning and in virtual entertainment experiences
6. Use simple English sentences related to senses and body parts
7.Enrich English vocabulary with content specific words and expressions (eyes, ears, mouth, nose, head, shoulders, knees, toes; red light – stop, green light – go; I (can) hear with my ears, and so on.)</td></tr>
<tr><td>Engage

20 min.</td><td colspan="3">• The teacher evaluates children's vocabulary in English related to body parts and senses.
• Sing and dance to the song "Head, Shoulders, Knees, and Toes", which gradually accelerates in tempo – https://www.youtube.com/watch?v=WX8HmogNyCY
• Ask questions: What was the song about? (Body parts.) What did we do with our body parts? (We moved our hands to point at body parts.)
• We can move our hands, shoulders, knees, and toes. Can we move our eyes, ears, mouth, and nose? Children look in the mirror and attempt to move their eyes, ears, mouth, and nose.
• Teacher scaffolds: Turn your eyes left and right, up and down, and in a circular motion. Try the same with your nose and mouth. What about your ears? Try moving them together with your head.
• Why do we move these body parts in real life? (Demonstrate touching, placing a hand above the eyes, behind one ear, taking a deep inhale, and chewing food)
• We move our hands so we can...touch.
We move our eyes so we can...see.
We move our ears so we can...hear.
We move our nose so we can...smell.
We move our mouth and tongue so we can...taste.</td></tr>
</table>

	These are the five senses: touch, sight, hearing, smell, and taste.
Explore 40 min.	• **Rainbow Magic Potions** Ingredients: 2-3 drops of food coloring in primary colors (red, yellow, blue) 1/5 water 4/5 vegetable oil 1 effervescent tablet A source of light 1. Experimenting with color: • Add drops of one color and then drops of another color. • Give children the opportunity to choose which colours they would like to mix. • Mix the potion and record the color combinations on a piece of paper. • Place the paper in front of the corresponding potion (Scribble in one color, add a + sign, scribble in the second color, add an = sign, then scribble the resulting secondary color). • If children can write, they can also write the color names. • Allow children to independently experiment with the number of color drops and color shades they create. • After the teacher demonstrates the activity, children participate one by one in an organized sequence. 2. Observe the reaction: • Drop the effervescent tablet into the potion and observe what happens. • Place a hand above the potion. • Encourage them to describe what they see, hear, smell, and feel. 3. Creating a magical effect: • After making the colorful potions, place them on a light source (mobile's flashlight). • Discuss their observations. 4. Discussion: How do our senses help us experience our surroundings? • We used our eyes to see colors in the light and daytime. • We used our ears to hear the fizzy sound. • We used our hands to feel the bubbling potion. What else do our senses tell us about the potion? Is it safe to drink? Why or why not? Do water and oil mix? Why and why not? Do heavier objects always sink? Encourage children to connect their new understanding of density with prior experiences, such as throwing rocks and leaves into a river.
Explain 60 min.	• Watch and listen to the video of the song “I Can Hear with My Ears” – https://www.youtube.com/watch?v=3ahpruY9eYM • Children should reinforce their prior understanding that we use senses to experience our surrounding and that each sense helps us gather information. • Help children make connections between the five senses and their everyday experiences. Ask guiding questions to encourage more specific answers and conclude. • **Virtual barbershop**: Children wear blindfolds and headphones for a few minutes and then discuss their overall experience: What did you hear? How did you feel in virtual reality? Were your senses tricked? – https://www.youtube.com/watch?v=IUDTlvagjJA&t=32s • **Senses and feelings**: Sounds used in the entertainment media, such as in cartoons, play an important role in enhancing enjoyment and emotional engagement. • The audio experience should lead to the conclusion that sometimes, even when relying on only one sense, such as hearing, we can gather significant information about our environment. Objects like plastic bag, scissors, and

	doors have distinct sounds, and a person's voice can reveal whether they are a man or a woman. • **Traffic light**: The children will make the traffic light for pedestrians, red – stop and green – go. Children will use their traffic lights while dancing to a video without sound. After the video is finished, they will look at it again, but this time with the sound on. What was the difference? Was it easier when we used just one sense (sight) or more (sight and hearing)? What do they think and why? • **Interconnected senses**: Conclude that relying on only one sense is sometimes insufficient for fully understanding our environment. That is why it is important to use multiple senses, to fully experience our surroundings and survive, like animals do – both predator and prey.
Elaborate 90 min	• **Outdoor game: "What's the time, Mr. Wolf?"** (A description with a video demonstration can be found in the app *365 Games*) • There will be one modification to the game. Instead of the wolf chasing the children after saying, "It's dinner time!", the wolf will turn around, observe the children's positions for a couple of seconds, put on a blindfold, and try to find them while they remain standing in their positions. Upon reaching a child, the wolf touches the child's face and clothes and asks, "Who are you?" The child must always respond with, "It's me!", after which the wolf guesses the child's name. If the guess is incorrect, the wolf moves onto the next child until the correct guess is made. The child whose name is guessed correctly becomes the next wolf. • This game helps children understand how we use all our senses in real life and how they assist us in gathering information and surviving – just like animals in the wild, whether as predators or prey, like early humans, or even in modern society, such as in traffic. For example, we see positions with our eyes, recognize voices and sounds with our ears, and feel textures and shapes with our hands. • **Hide and Seek**: The well-known game demonstrates how interconnected senses contribute to play and enjoyment – I seek using my ears (I hear you move) and my eyes (I see you run). A description and video demonstration can be found in the app *365 Games*. • **Let's do it**: In collaboration with school-aged children, parents, and teachers, various sports activities, such as football, volleyball, basketball, and tennis are organised. All children choose and participate in activities that require them to use sensory information while engaging in sports. • **Draw with chalk outside**: Draw something we that can be seen, heard, touched, smelled, or tasted. • Children can draw real or imaginary objects, be creative, and explain their drawings to demonstrate understanding of the functions of the five senses.
Evaluate 30 min	• Children collaborate on a worksheet with pictures and sense stickers. Each picture has multiple possible answers allowing them to experiment with different combinations and explain their choices. • The teacher observes their communication, takes notes for each child, and then listens to their answers and explanations. • The teacher evaluates children's vocabulary use and understanding of the five senses in English.

https://doi.org/10.46793/STEPAM26.144L
Udk: 37.091.3:331

DEVELOPING RELEVANT PSYCHOLOGICAL COMPETENCIES FOR THE WORKPLACE THROUGH STEAM EDUCATION

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Abstract: In the context of rapid technological change, the digitalization of work, and growing labour-market demands for non-cognitive competencies, this paper examines the significance of STEAM education for the development of psychological capacities relevant to contemporary workplaces. The aim of the paper was to identify, on the basis of the available literature, the key psychological competencies fostered by STEAM approaches and to conceptually relate them to constructs in business psychology. The sample consisted of relevant empirical and review studies in STEAM education, educational psychology, and business psychology, collected through a narrative, theoretically driven literature review. The methods applied included content analysis, thematic synthesis, and conceptual mapping of findings. The results indicate that STEAM environments, particularly those grounded in interdisciplinary and project-based learning, foster creativity, critical thinking, collaboration, adaptability, resilience, self-efficacy, and engagement. The findings further highlight the importance of educational settings that encourage autonomy, experimentation, and team-based learning, especially through open-ended project tasks. It is concluded that STEAM education has substantial potential to strengthen young people's psychological readiness for work and that its integration with business psychology may improve curriculum design, outcome assessment, and the alignment of education with organizational needs in both practice and policy.

Keywords: *STEAM education, psychological competencies, business psychology, workplace skills, psychological capital*

Introduction

Rapid technological change, globalization, and the digitalization of work have transformed the structure of occupations and the nature of organizational life. Alongside technical and digital skills, contemporary organizations increasingly value psychological competencies such as creativity, critical thinking, adaptability, resilience, collaboration, and communication (OECD, 2018; World Economic Forum, 2020). These competencies are conceptualized in business psychology through constructs like psychological capital, growth mindset, psychological safety, and innovative work behavior, all of which predict performance, well-being, and employability in dynamic work environments (Luthans et al., 2007; Edmondson, 1999; Dweck, 2006).

At the same time, educational systems seek models that can respond to these changing labor market needs. STEAM education, which extends traditional STEM (Science, Technology, Engineering, Mathematics) by incorporating the Arts, emphasizes creativity, design thinking, and integrative problem solving (Yakman, 2008; Perignat & Katz-Buonincontro, 2019). STEAM approaches are usually realized through project-based, interdisciplinary learning that engages students in authentic, often collaborative

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tasks with open-ended outcomes. Such learning environments are assumed to foster a combination of cognitive, social, and emotional skills that are highly relevant for future work roles (Conradty & Bogner, 2019).

Despite the growing popularity of STEAM initiatives, there is still limited integration between research on STEAM learning outcomes and theoretical constructs of business psychology. Many studies examine creativity, engagement, or attitudes towards STEM/STEAM fields, but rarely explicitly connect these outcomes to psychological competencies that predict functioning in organizational settings, such as self-efficacy at work, resilience under pressure, or readiness for innovation (Henriksen, 2014; Madani, 2019). This gap hinders the systematic use of STEAM pedagogy as a deliberate strategy for the development of workplace-relevant psychological competencies.

The primary aim of this paper is to analyze and synthesize existing literature to determine how STEAM education contributes to psychological competencies that are important for the workplace and how these competencies can be conceptually mapped onto constructs in business psychology. The paper focuses on: (1) identifying core psychological competencies fostered in STEAM contexts; (2) relating these competencies to established constructs in business psychology; and (3) discussing implications for curriculum design and organizational practices such as recruitment, selection, and employee development.

In doing so, the paper seeks to contribute to a more coherent framework that connects pedagogical approaches in STEAM with the requirements of contemporary organizations. Such a framework can support educators in designing learning experiences that prepare students not only for content knowledge but also for psychological readiness for work, and can help organizations better understand and value STEAM-based competencies in talent management processes.

Methodology

Approach

The paper is based on a narrative, theoretically driven review of literature at the intersection of STEAM education and business psychology. Rather than conducting a fully systematic review with strict inclusion and exclusion criteria, this approach aims to identify key themes, constructs, and conceptual linkages that illuminate how STEAM-related learning outcomes can be translated into workplace-relevant psychological competencies (Baumeister & Leary, 1997).

Search Strategy

Relevant literature was searched in databases such as Web of Science, Scopus, ERIC, and PsycINFO, as well as in Google Scholar, using combinations of the following keywords: “STEAM education”, “STEM and Arts integration”, “project-based learning”, “creativity”, “21st century skills”, “psychological competencies”, “business psychology”, “psychological capital”, “growth mindset”, “psychological safety”,

"employability skills", and "workplace skills".

Priority was given to empirical and review studies published in the last 15-20 years, as this period corresponds with the intensification of discourse on 21st-century skills and STEAM approaches. However, foundational theoretical works in business psychology and educational psychology were also included, regardless of publication year, when they provided key conceptual frameworks (e.g., Luthans et al., 2007; Dweck, 2006; Edmondson, 1999).

Inclusion Focus

The review focused on three categories of studies:

-Research on STEAM education that reports psychological and behavioral outcomes (e.g., creativity, collaboration, self-efficacy, resilience, engagement, problem-solving).

-Studies on 21st-century skills and employability that align educational outcomes with labor market expectations.

-Research in business and organizational psychology that conceptualizes and operationalizes constructs such as psychological capital, growth mindset, psychological safety, innovative work behavior, adaptability, and resilience in organizational contexts.

Articles that exclusively focused on content knowledge in STEM without discussion of psychological, social, or affective outcomes were not central to the analysis.

Analytical Procedure

The analysis proceeded in three steps:

-Identification of recurring psychological competencies reported as outcomes of STEAM education (e.g., creativity, critical thinking, collaboration, adaptability, resilience, self-efficacy).

-Conceptual mapping of these competencies onto related constructs in business psychology (e.g., creativity is innovative work behavior; self-efficacy & optimism are psychological capital; openness to learning and growth mindset; safe collaborative environments are psychological safety).

-Synthesis of implications for the design of educational programs and for organizational practices in recruitment, selection, and employee development.

This methodology allows for an integrative perspective that connects educational and organizational literatures, with the aim of formulating a coherent argument about the potential of STEAM education for developing psychological competencies relevant to the workplace.

Results

Psychological Competencies Fostered in STEAM Education

Across the reviewed studies, several psychological competencies consistently emerged as outcomes of STEAM-based learning:

Creativity and divergent thinking.

STEAM projects, which often involve open-ended tasks, design challenges, and the integration of artistic expression with scientific and technical concepts, are associated with increased creative thinking, fluency of ideas, and originality (Henriksen, 2014; Conradty & Bogner, 2019). Students are encouraged to explore multiple solutions, experiment, and take intellectual risks.

Critical thinking and problem-solving.

Interdisciplinary STEAM tasks require students to analyze complex problems, integrate knowledge from different domains, and evaluate possible solutions (Bybee, 2013). This environment supports the development of higher-order thinking skills, including reasoning, argumentation, and evidence-based decision-making.

Collaboration and communication.

Many STEAM initiatives rely on team-based projects where learners must coordinate, negotiate roles, and present their outcomes to peers or external audiences (Yakman, 2008). Such settings foster social skills, including active listening, constructive feedback, and conflict resolution.

Adaptability and resilience.

Project-based learning in STEAM frequently involves ambiguity, setbacks, and iterative prototyping. Students need to cope with failure, revise their ideas, and persist in the face of challenges (Madani, 2019). This supports the development of adaptability, perseverance, and tolerance for uncertainty.

Self-efficacy and engagement.

Participation in meaningful, authentic projects that connect with real-world issues can increase students' sense of competence and agency (Bandura, 1997; Perignat & Katz-Buonincontro, 2019). Positive experiences with problem-solving and creative expression in STEAM contexts are linked with higher academic self-efficacy and sustained engagement.

Interdisciplinary thinking and systems perspective.

Integrating arts with science, technology, engineering, and mathematics encourages students to perceive problems as parts of broader systems, linking technical knowledge with human, social, and ethical dimensions. This systemic perspective is closely aligned with complex problem-solving requirements in modern organizations.

Mapping STEAM Outcomes to Business Psychology Constructs

The identified competencies can be meaningfully connected to established constructs in business psychology:

Psychological capital (PsyCap) - defined as a positive psychological state characterized by self-efficacy, optimism, hope, and resilience (Luthans et al., 2007) is supported by STEAM experiences that foster confidence in problem-solving, persistence in the face of failure, and positive expectations about one's ability to influence outcomes.

Growth mindset the belief that abilities can be developed through effort and learning (Dweck, 2006) is congruent with STEAM pedagogies that normalize iteration, emphasize learning from mistakes, and reward experimentation rather than only correct answers.

Psychological safety a shared belief that the team is safe for interpersonal risk-taking (Edmondson, 1999) is mirrored in collaborative STEAM environments where students are encouraged to share ideas, ask questions, and express doubts without fear of ridicule or punishment. Such climates are crucial for innovation in organizations.

Innovative work behavior the generation, promotion, and realization of new ideas in a work role (Janssen, 2000) is conceptually related to creativity, divergent thinking, and problem-solving skills developed in STEAM projects.

Adaptability and learning agility central for functioning in dynamic, uncertain organizational contexts are fostered through exposure to complex, ill-defined problems in STEAM tasks that require flexibility, continuous learning, and rapid adjustment of strategies.

Relevance for Workplace Readiness

The competencies cultivated through STEAM education overlap substantially with those that employers identify as critical for employability and success in the 21st-century workplace (OECD, 2018; World Economic Forum, 2020). These include:

-Creativity and innovation

-Critical thinking and problem-solving

-Collaboration and communication

-Adaptability, resilience, and stress tolerance

-Lifelong learning orientation

Although many STEAM studies focus on educational outcomes, the underlying psychological constructs are directly relevant to organizational life. For instance, increased creative confidence and tolerance for ambiguity in STEAM learners can translate into greater willingness to propose novel ideas and engage in creative problem-solving at work. Similarly, collaboration skills developed in interdisciplinary teams during education can facilitate effective teamwork and cross-functional cooperation in organizations.

However, the literature also suggests that the transfer of competencies from educational to organizational

contexts is not automatic. Factors such as organizational culture, leadership style, and the design of work tasks can either support or hinder the expression of these competencies (Saks, 2019). This highlights the importance of alignment between educational practices and organizational environments.

Discussion

STEAM as a Framework for Developing Psychological Competencies

The findings of this review indicate that STEAM education can be understood not only as a strategy for improving interest and achievement in STEM fields, but also as a broader framework for developing psychological competencies relevant for the workplace. Through integrative, project-based, and often inquiry-oriented pedagogy, STEAM creates learning conditions that resemble complex, collaborative work environments.

From the perspective of business psychology, such learning environments provide early experiences of behaviors and mindsets that later support effective functioning in organizations: setting and pursuing challenging goals, working in diverse teams, facing and overcoming setbacks, and communicating ideas to different audiences. This alignment suggests that STEAM education can be intentionally designed to develop components of psychological capital, growth mindset, and capacity for innovative work behavior.

Implications for Curriculum Design

The integration of business psychology constructs into STEAM curriculum design offers several advantages:

Clearer learning outcomes.

By explicitly formulating psychological competencies (e.g., resilience, collaborative skills, creative self-efficacy) as learning goals, educators can design tasks, assessments, and feedback processes that systematically support their development.

Alignment with labor market needs.

Connecting STEAM outcomes with constructs recognized in organizational research facilitates communication with employers and policymakers. It becomes easier to demonstrate how STEAM programs contribute to employability and organizational effectiveness.

More comprehensive assessment.

Traditional assessments that focus on content knowledge do not capture changes in psychological competencies. Incorporating self-report scales, behavioral observations, and reflective tasks related to constructs like psychological capital or growth mindset can offer a more holistic picture of student development.

Implications for Organizational Practice

From the organizational side, recognizing the value of STEAM-based competencies has implications for the following:

Recruitment and selection.

Employers can include experiences with STEAM projects, interdisciplinary teamwork, and creative problem-solving as relevant indicators of candidates' potential for innovative and adaptable performance.

Onboarding and development.

Organizations can build on STEAM-related strengths of new employees by offering opportunities for further development of psychological capital, collaborative skills, and creative thinking through coaching, mentoring, and project assignments.

Organizational culture.

To ensure that competencies developed in education can be expressed, organizations need cultures that promote psychological safety, experimentation, and continuous learning conditions already modeled in high-quality STEAM classrooms.

Limitations and Future Directions

The present review is limited by its narrative character and by the heterogeneity of studies on STEAM education. Many studies use small samples, short interventions or non-standardized outcome measures which makes it difficult to draw firm causal conclusions about the development of psychological competencies. Additionally, relatively few studies explicitly connect STEAM outcomes with constructs from business psychology, which required conceptual rather than strictly empirical mapping.

Future research should aim to:

-Conduct longitudinal studies that follow STEAM learners into higher education and the workplace, examining the persistence and transfer of psychological competencies.

-Use validated measures from business and organizational psychology (e.g., psychological capital scales, measures of growth mindset or psychological safety) within STEAM research.

-Explore how specific elements of STEAM pedagogy (e.g., degree of autonomy, feedback style, interdisciplinary level) differentially contribute to distinct psychological competencies.

Conclusion

In contemporary organizations, psychological competencies such as creativity, adaptability, resilience, collaboration, and critical thinking are as important as technical knowledge. STEAM education, through its integrative and project-based character, offers a promising framework for developing these competencies already in formal education.

This paper has argued that the psychological outcomes of STEAM education can be fruitfully

mapped onto key constructs in business psychology, including psychological capital, growth mindset, psychological safety, and innovative work behavior. Such mapping helps to clarify the relevance of STEAM for workplace readiness and enables stronger alignment between educational practices and organizational needs.

For educators, this perspective supports the intentional design of STEAM curricula that cultivate not only disciplinary understanding but also psychological preparedness for work. For organizations, it highlights the importance of recognizing and valuing competencies gained through STEAM education in recruitment, selection, and employee development. Strengthening the dialogue between education and business psychology can ultimately contribute to more adaptive, innovative, and psychologically healthy workplaces in the 21st century.

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https://doi.org/10.46793/STEPAM26.152P
Udk: 316.774-053.2

BETWEEN SCREENS AND MOVEMENT: THE ROLE OF MASS MEDIA IN SHAPING YOUTH PHYSICAL ACTIVITY IN LEISURE TIME

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Abstract: Leisure time represents a key context for the development of healthy lifestyles, especially among children and adolescents, where habits related to physical activity (PA), social interaction, and well-being are established. In modern society, mass media plays a significant role in shaping daily routines, behaviors, and attitudes, potentially influencing the quality of leisure time and levels of PA among youth. However, increased media consumption is often associated with sedentary behavior, raising concerns about its long-term effects on health and well-being. The aim of this study was to examine the influence of mass media on PA levels and the quality of leisure time among youth, as well as to explore their perceptions and attitudes regarding media use and active lifestyle engagement. The study included a sample of 206 respondents aged 15 years and older. Data were collected using a specially designed questionnaire, administered online under the supervision of the research team. The study was conducted in period between September and October 2025. The questionnaire included socio-demographic variables (age, gender, place of residence, education level, and access to mass media) and closed-ended items measured on a Likert-type scale assessing agreement and satisfaction with statements related to media use and physical activity. All responses were collected anonymously to ensure confidentiality. Data were analyzed using SPSS software. Descriptive statistics were applied to summarize the data. Findings indicate that mass media plays a significant role in shaping youth leisure-time behavior, with notable associations between media exposure and reduced PA levels. The study emphasizes the need for educational and preventive strategies aimed at promoting balanced media consumption and encouraging more active and health-oriented leisure time among young people.

Keywords: *Physical Activity; Leisure Time; Lifestyle; Media Influence*

Introduction

Physical activity is widely recognized as one of the essential determinants of physical, mental, and social well-being among young people. According to the recommendations of the World Health Organization (WHO) (2020), children and adolescents should engage in at least 60 minutes of moderate-to-vigorous physical activity daily. However, rapid technological development and increased access to digital media have substantially changed the way young people spend their leisure time.

Mass media have become an integral part of everyday life. Mass media consumption has become one of the defining characteristics of childhood and adolescence in the digital era. Children and adolescents spend an increasing proportion of their leisure time engaging with television, smartphones, computers, tablets, social media, online gaming, and streaming platforms. Consequently, media influence has become one of the strongest environmental factors affecting physical activity habits. In contemporary society, sedentary leisure-time behaviors among youth have accelerated parallel to the proliferation of digital mass media. While traditional media (e.g., television) historically initiated the debate on physical inactivity, modern algorithmic platforms like Instagram and TikTok have fundamentally restructured youth routines.

While these technologies provide opportunities for learning, entertainment, and social interaction, they have also transformed leisure behaviors by replacing many traditional forms of physical activity (PA) and recreation. The relationship between modern technology, mass media and PA is complex rather than purely negative. Mass media can both encourage and discourage PA, depending on the type of media content, duration of exposure, and the way young people engage with digital technologies. Therefore, understanding the relationship between mass media and PA is essential for developing effective health promotion strategies and design of public health interventions. Understanding this relationship is also essential for educators, parents, healthcare professionals, and policymakers seeking to promote healthy lifestyles among children and adolescents. In addition, researchers have devoted considerable attention to understand the relationship between media consumption and physical activity levels among young people.

The influence of mass media in leisure time

Mass media has become one of the most influential factors shaping how young people spend their leisure time. The rapid development of digital technologies, the internet, social networks, streaming platforms, and mobile devices has transformed traditional patterns of recreation among children and adolescents. Leisure time, which was previously dominated by outdoor play, sports, and face-to-face social activities, is increasingly characterized by media-based activities such as watching television, browsing social networks, playing video games, and consuming online content.

Today, in contemporary society, during leisure time, young people are increasingly exposed to various forms of media, including television, social media platforms, online videos, streaming services, and digital gaming. This widespread media consumption has raised concerns about its potential impact on PA levels, as prolonged screen time is often associated with sedentary behavior and reduced participation in recreational and sports activities.

Constant exposure to media can significantly affect a teenager's physical, emotional, psychological, and social growth (Jakka, 2026). The influence of mass media on youth leisure behavior can have both **positive and negative effects.** On the positive side, media provides opportunities for education, communication, creativity, and access to information. Social media platforms and online communities can encourage young people to participate in physical activities by sharing exercise programs, sports challenges, motivational content, and health-related information. Digital platforms also allow young people to follow athletes, learn new skills, and become inspired to engage in recreational and organized sports activities (Maher, et al.,2014).

Research has demonstrated a complex relationship between mass media consumption and PA among children and adolescents. On one hand, excessive exposure to entertainment media may contribute to

physical inactivity by replacing time that could otherwise be devoted to active play or exercise. On the other hand, mass media can also serve as a valuable tool for promoting healthy lifestyles by providing access to fitness content, educational campaigns, sports events, and motivational messages that encourage participation in PA (Tremblay at al., 2011) .

Research demonstrates a complex and potentially bidirectional relationship between digital media use and PA among children and young people. On the one hand, high levels of recreational screen-based media use may contribute to greater sedentary time and can coexist with insufficient PA, raising concerns about increasingly sedentary lifestyles. However, screen time and physical inactivity should not be considered interchangeable, as reducing screen-based sedentary behaviors does not necessarily result in corresponding increases in PA (Feng et al., 2024). On the other hand, digital and social media can provide valuable opportunities to promote active lifestyles through access to exercise information and demonstrations, motivational content, social support, fitness challenges, and other interactive resources. Systematic reviews indicate that social media and other online interventions have the potential to support PA engagement and positive health-related behavior change, although effects vary according to the type of intervention and patterns of engagement (Goodyear et al., 2021, Goodyear et al., 2023). Thus, digital media may function both as a source of sedentary behavior and as a potential resource for PA promotion, depending on how, why, and for how long they are used.

However, excessive consumption of mass media during leisure time is often associated with increased sedentary behavior. Long periods spent using screens may replace time that could be devoted to physical activity, outdoor play, and social interaction. Studies has shown that higher levels of screen-based media use among children and adolescents are related to lower levels of PA and increased sedentary lifestyles (Tremblay et al., 2011; Stiglic & Viner, 2019). This is particularly important because insufficient PA during childhood and adolescence may negatively affect physical health, psychological well-being, and the development of healthy lifestyle habits.

The relationship between media use and PA is influenced by several factors, including the type of media consumed, the duration of exposure, individual motivation, parental supervision, socioeconomic status, and peer influence. While passive media consumption, such as prolonged television viewing or non-interactive screen use, may contribute to inactivity, active and purposeful media use can support learning, motivation, and participation in physical activity. Consequently, understanding how different forms of mass media affect PA behaviors during leisure time is essential for developing effective health promotion strategies aimed at increasing PA and reducing sedentary lifestyles among young people.

Therefore, mass media should not be viewed only as a risk factor but also as a potential resource for promoting healthy leisure habits. Educators, parents, and health professionals should encourage balanced media use, where digital technologies complement rather than replace physical activity, social interaction,

and active forms of recreation (Council on Communications and Media, 2016)

Examining this relationship provides important insights for educators, parents, healthcare professionals, and policymakers seeking to maximize the positive potential of mass media while minimizing its negative effects on children's and adolescents' physical and psychological well-being. The use of mass media and other different types of activities, including PA, significantly impact the quality leisure time, both in positive or negative direction. On the other hand, quality leisure time is crucial for the holistic development and overall well-being of every individual, especially young people and children. Having this in mind, the aim of this study is to examine the influence of mass media on PA levels and the quality of leisure time among adolescents and youth, as well as to explore their perceptions and attitudes regarding media use and active lifestyle engagement.

Method of work

Subject of research

The subject of our research are the opinions of young people aged 15 years and above about their perspectives on leisure time utilization and how mass media consumption reflects on their PA levels and quality of their lives.

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The sample included 206 respondents aged 15 and older, students at secondary school and at Univeristy “Goce Delcev” in Stip, North Macedonia. From the total sample, 75.5% participants were between 15–18 years old and 23% were young adults aged 19–24 years (20%). The vast majority of the participants (82,5%) are residents in urban environments (cities), with the remaining 17,5% lives in rural areas (villages). In terms of educational attainment, 81% are secondary school students, and the rest 19% are university students.

The study was conducted using questioner that was specially designed for the purposes of this study. The questioner was administrated online. It was conducted individually under the supervision of the research team. Data collection was done between September/ October, 2025. The findings presented here are part of a larger, comprehensive study investigating the impact of mass media on youth attitudes, PA engagement, movement habits, and the overall factors dictating leisure time quality.

Beside general data (age, gender, place of residence, education, access to mas medium), it also contains closed-ended questions applied as a scale of assessment where examiners determine the degree of agreement and satisfaction in the offered claims.

Ethical Considerations.

Data collection was strictly anonymous to safeguard respondent identities.

Statistical Analysis.

Data processing and analysis were conducted using SPSS software. Descriptive statistics were computed to summarize the baseline distribution. For better overview of the results, they were also presented in Graphics.

Results and discussion

Media Accessibility and Habits

To understand the foundational landscape of youth media consumption, it is critical to evaluate the environmental availability of these platforms. To establish this baseline, respondents were asked about access to media. The obtained answers confirm near-ubiquitous digital connectivity among youth nowadays, confirming that all 206 participants have access to a mobile phone, 95% have access to television and 91% have access to laptops or desktop computers. Access to tablets is significantly lower as only38% has this. These figures underscore that in the contemporary era of digitalization, digital device ownership or access is nearly universal among school-aged youth and young adults. The overview of the answers is presented at Figure 1.

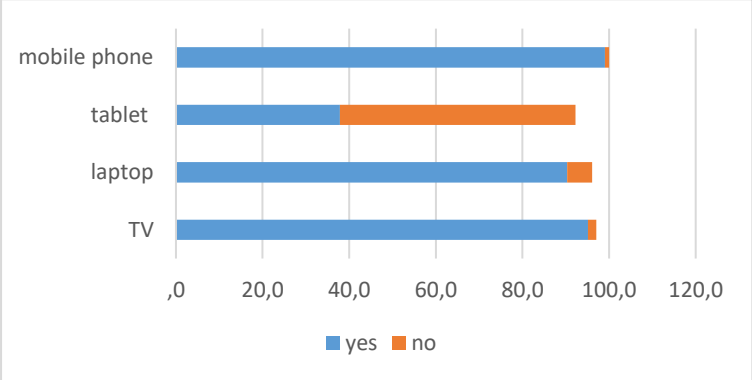

Figure 1: Access to media

The access to social media tools and accounts suggest that they are an integral part of adolescents' daily lives, shaping communication, information access, leisure time, and peer interaction. Their use varies according to factors such as age, gender, socioeconomic circumstances, family environment, technology access, and individual interests. They play a significant role in the daily life of modern people, and for that purpose, we attempted to determine which habits young people have established regarding the use of mass media in their everyday lives. Although excessive media use has been associated with lower physical activity, evidence regarding social media specifically remains mixed (Purba et al., 2023). Social media may displace time spent being active, but they can also provide social support, health information, and motivation for active lifestyles. Examining both behaviours may therefore clarify how they coexist in adolescents'

everyday lives.

Following question refers to the frequency of mass media use in youngsters' everyday lives, aiming to identify the amount of time per day spend using different media. Several media platforms were offered for this question (Instagram, TikTok, Facebook, YouTube etc), and for each of them, respondents had the opportunity to choose the frequency of their use. Following the responses, the platforms such Instagram and TikTok are among the most widely used among young people (Figure 2 and Table 1). **Instagram** functions as the most widely used social media platform among adolescents. Cultivates the highest engagement, with 57.3% of youth utilizing it for 1–3 hours daily, 19.4% for 3–5 hours, and 12% exceeding 5 hours per day. **TikTok** shows similar trend of usage having 38.8% of respondents that spends 1–3 hours daily on the app, 23.3% engage with it for 3–5 hours, and 11% use it for over 5 hours daily. The least used media, specifically for less than one hour per day, are Facebook (85%), browsing websites (77%), watching TV (69%), and playing online games (65%).

Conversely, traditional platforms and specialized digital behaviors require less time commitment. The majority of respondents spend less than one hour per day on Facebook (85%), general web browsing (77%), watching television (69%), and playing online video games (65%).

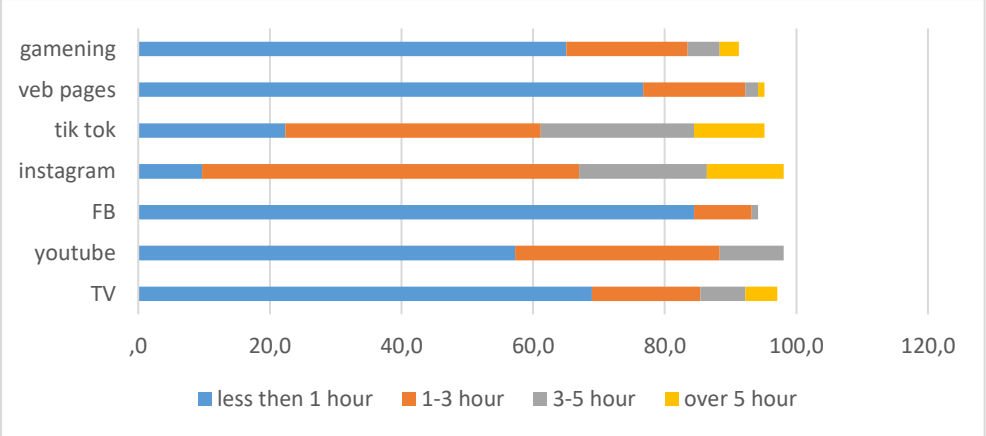

Figure 2: How much time per day do you spend using the following media?

Table 1: Daily Time Distribution Across Varied Mass Media Formats

ı Platform Type	Daily Volume ours)	rate Daily Volum Hours)	Daily Volume (<1	Hory Behavioral fication
ram	ɔ	ɔ	ɔ*	ry Interactive Medium
ɔk	ɔ	ɔ	ɔ*	Density Entertainment
e Gaming			ɔ	Peripheral Activity
ision (TV)			ɔ	ual Traditional Mediur
Browsing			ɔ	ional Information Sear
ook			ɔ	dary/Declining Mediu

Note: Incomplete values are statistically grouped or inferred within the remaining sample distributions (Sample N = 206).

Similarly to results in our study, recent evidence indicates that Instagram and TikTok are among the most widely used social media platforms among adolescents. Large-scale surveys show that approximately six in ten adolescents use Instagram and TikTok, with use being particularly prevalent among older adolescents and girls (Faverio & Sidoti, 2024). Similarly, a large study of more than 10,000 adolescents found TikTok (67.1%) and Instagram (66.0%) to be among the most commonly used social media platforms (Nagata et al., 2025). These findings highlight the prominent role of visually oriented and short-form video platforms in contemporary adolescents' media consumption habits.

Purpose and Context of Media Consumption

The motivations underlying media consumption vary considerably according to the type of media and platform used (Figure 3). In the present study, information seeking and entertainment emerged as the two dominant purposes of media consumption, although their relative importance differed across platforms. This pattern is consistent with recent research showing that young people use social media to satisfy multiple needs, including entertainment, information and content exploration, social interaction, inspiration, and self-expression (Wong & McLellan, 2024; van der Wal., Valkenburg & van Driel., 2024; Thorell et al, 2024).

Web browsing emerged as the main source of information, reported by 60.1% of participants, followed by Facebook (45%). In comparison, only 21% reported using television for this purpose. These findings point to a shift from traditional toward digital and social-media-based sources of information among young people. Contemporary research similarly indicates that adolescents increasingly encounter and actively seek information through social media, including content related to current events, personal interests, sports, and other areas relevant to their everyday lives (van der Wal et al., 2024; Wong & McLellan, 2024; Thorell et al., 2024).

Entertainment was particularly prominent in the use of online gaming (57%), TikTok (30%), and YouTube (27%). The strong entertainment orientation of TikTok and YouTube is consistent with recent research identifying entertainment and distraction as important motivations for adolescents' social media use (Wong & McLellan, 2024; van der Wal et al., 2024).

The findings also demonstrate that information and entertainment should not necessarily be considered mutually exclusive motives. Instagram showed a particularly strong dual-purpose pattern, with 35% of participants reporting using it for both information and entertainment. A similar overlap was evident for YouTube (29%) and TikTok (26.2%), suggesting that these platforms can combine entertainment with information seeking and informal learning. This corresponds with recent research showing that young people use social media not only for entertainment but also to explore topics of interest, obtain information, develop skills, and find inspiration (Wong & McLellan, 2024; van der Wal et al., 2024).

Taken together, these findings illustrate the increasingly multifunctional nature of young people's media consumption. Rather than using individual platforms exclusively for either information or entertainment, young people move between—and often combine—these purposes within the same digital environment. This is particularly evident for visually oriented platforms such as Instagram, TikTok, and YouTube, where entertainment, information, inspiration, and learning increasingly intersect.

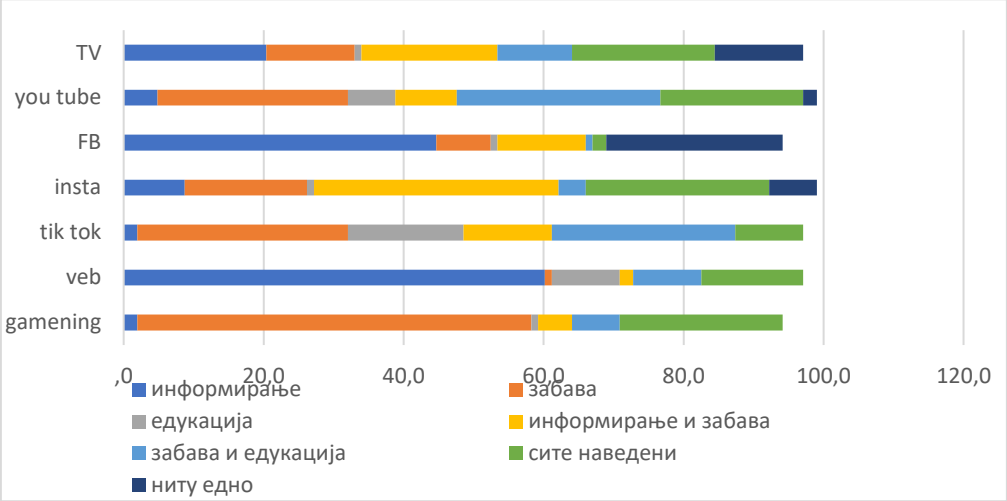

Figure 3: Purpose and Context of Media Consumption

A critical finding regarding physical health is *the physical posture* assumed during media consumption. More than half of the respondents (52%) report that they are *sitting or lying down* while using media. Another 46.6% utilize a *combination* of stationary and mobile postures, while a marginal 2% remain exclusively *in motion*.

The predominantly sedentary nature of screen-based media consumption suggests that high levels of media use may contribute substantially to the time young people spend sitting or reclining with low energy expenditure. Recreational screen time is commonly recognized as an important component of sedentary behavior, and prolonged screen exposure has been associated with lower habitual PA and a range of adverse health outcomes among adolescents (Shao & Zhou, 2023; Wilhite et al., 2023). These findings raise concerns that high levels of recreational media consumption, particularly when accumulated over extended periods and not balanced by sufficient physical activity, may contribute to an increasingly sedentary lifestyle.

Youth Physical Activity and Leisure Time

PA is an essential component of a healthy lifestyle, contributing to a better quality of life and proper overall development from an early age. Keeping this in mind, we sought to examine the PA levels among young people in an era where mass media dominates their leisure time. Despite high screen times, the data

reveals a substantial commitment to PA during leisure time.

Thus, in response to the question: *How often are you physically active during your leisure time?*, 35% of respondents reported being active 3–4 times per week, 31% indicated a frequency of 1–2 times per week, while 16.6% stated that they are physically active every day (Figure 4).

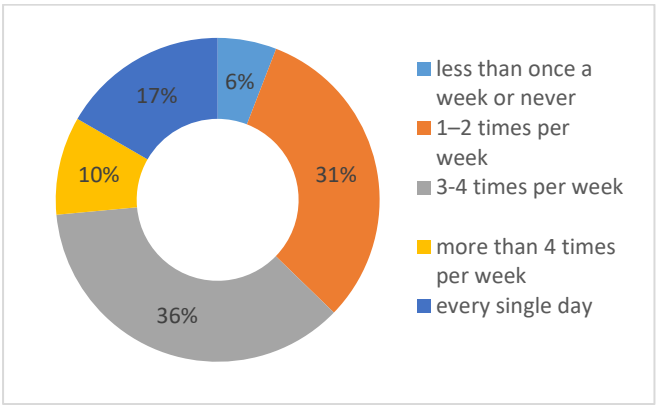

Figure 4: Frequency of engagement in physical activity during leisure time

In terms of type of PA in which our respondents were engaged, our findings indicate strong preference for accessible, recreational, and unstructured forms of exercise over highly organized or institutionalized sports. The distribution of activities reflects a behavioral pattern heavily influenced by contemporary lifestyle constraints and peer-driven socialization:

In particular, **walking** is almost universally practiced and chosen by 83.5% of participants in our study. Organized sports (such as football, basketball, etc.) are practiced regularly by 38%, while running and gym training are each favored by 27%. On an occasional basis, respondents participate in running (37%, hiking/mountaineering (28%), and cycling (23%) (Figure 5).

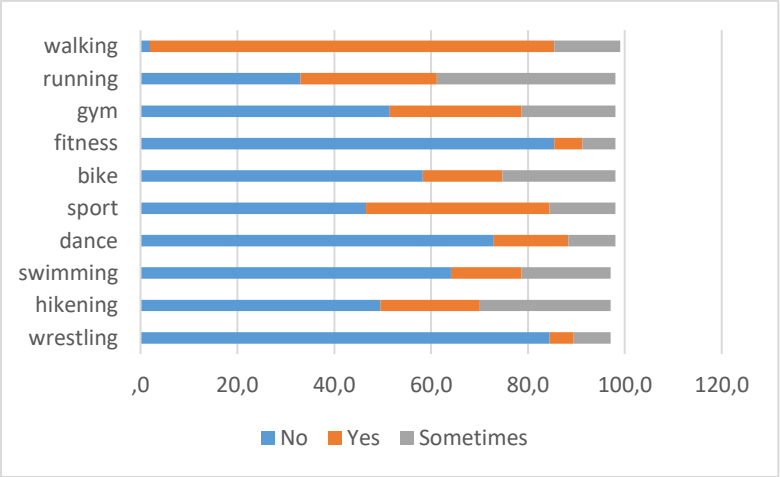

Figure 5: Types of physical activity practice in leisure time

Motivation for Physical Activity

Motivation for PA serves as the foundation for a healthy and active lifestyle, playing a critical role

in both initiating and sustaining regular exercise. Through a structured approach, a positive mindset, and environmental support, individuals can successfully internalize PA habits and reap long-term physiological benefits. This is particularly vital for children and adolescents, as consistent physical movement directly guides proper anatomical growth and holistic development.

To better understand the factors underlying PA participation, respondents were asked, "What motivates you to be physically active?" with possibility to select multiple factors from a predefined checklist (Figure 6). The findings reveal a clear predominance of health, fitness, and socially oriented motives, while external pressures and media-related influences were considerably less prominent.

Health and physical fitness are identified as dominant motives. Improving physical fitness emerged as the strongest reported motivation, selected by 97% of respondents, while 94% identified improving and maintaining their health as an important reason for being physically active. These findings indicate that young people predominantly associate PA with personally valued benefits related to physical condition and health. This pattern is broadly consistent with research emphasizing the importance of autonomous and personally meaningful motives for engagement in PA and the development of sustained active lifestyles (Tapia-Serrano et al., 2023).

Social interaction is another source of motivation. Socialization was reported as motivational factor by 76.7% of participants. For a substantial proportion of respondents, PA therefore appears to represent not only a health-enhancing behavior but also an opportunity to spend time with peers and participate in shared social experiences. This finding aligns with evidence demonstrating the importance of peer relationships, social support, and relatedness for young people's PA participation (Barbarosa et al., 2024; Thorell et al., 2024). Recent systematic-review evidence also indicates that peers and social norms can meaningfully influence PA behaviors among young people (Müller, Fallucchi & Suhrcke, 2024).

In contrast, externally driven motives were considerably less influential. Following social trends ("because everyone else is doing it") was not identified as a motivation by 74% of respondents, while 60% reported that media and online influencers did not motivate them to be physically active. Similarly, 58% did not identify pressure from their social environment to maintain a particular physical appearance as a motivating factor. Advice or encouragement from parents and teachers was also not perceived as a motivation by 46% of participants.

Taken together, these findings suggest that PA participation among the young people in this study is more strongly associated with personally valued health and fitness outcomes and opportunities for social interaction than with perceived external pressure, social trends, or direct media influence. This pattern is consistent with contemporary motivational perspectives that distinguish more autonomous forms of motivation from externally controlled motives and highlight the importance of autonomy, competence, and relatedness in supporting sustained engagement in physical activity (Tapia-Serrano et al., 2023).

Nevertheless, the relatively low self-reported influence of media and influencers should be interpreted cautiously. Young people's perceptions that social media do not directly motivate their PA do not necessarily imply an absence of media influence. Social media and influencers may shape attitudes toward health, fitness, appearance, and body ideals in less direct ways, and current evidence indicates that influencers have become important sources of health-related information for young people (Engel et al., 2024). Thus, the present findings may indicate that participants perceive health, fitness, and social interaction as their immediate motivations for physical activity, while media-related influences may operate more indirectly.

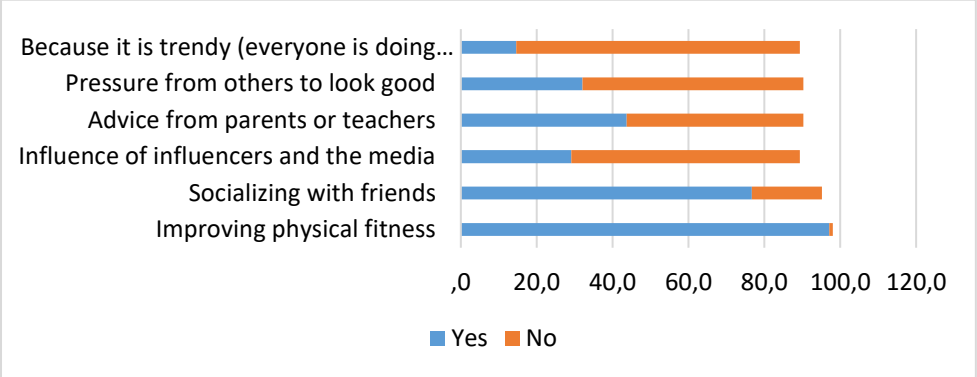

Figure 6: Motives for engagement in physical activity

Although social media are strongly embedded in the everyday lives of the young people in this study, 60% of respondents did not identify media or online influencers as factors motivating them to be physically active. Instead, physical fitness (97%), health improvement and maintenance (94%), and social interaction (76.7%) were reported as substantially more important motives. This suggests that frequent exposure to social media should not necessarily be interpreted as a directly perceived source of motivation for PA. At the same time, the absence of a consciously perceived influence does not necessarily imply that social media have no role in shaping young people's attitudes toward physical activity. Exposure to fitness-related content may similarly contribute to the construction of ideas about what it means to be physically fit, healthy, or physically attractive, even when users do not explicitly identify such content as a reason for exercising.

The present findings therefore point to an important distinction between perceived direct motivation and potential indirect media influence. Young people may primarily understand their participation in PA in terms of personally meaningful benefits, particularly health, physical fitness, and social interaction, while social media may form part of the broader sociocultural environment in which these values and perceptions are developed. Consequently, high social media exposure and low self-reported media motivation for PA should not necessarily be viewed as contradictory findings. Rather, they highlight the complexity of the relationship between social media consumption and PA and suggest that future research should consider not only the amount of social media use, but also the type of content consumed and the ways in which young people engage with health-, fitness-, sport-, and appearance-related content.

The Dual Role of Social Media in Physical Activity

Social media constitute an increasingly important part of young people's everyday environment and may contribute to shaping their knowledge, attitudes, motivation, and behaviors related to health and PA. Importantly, their influence is not necessarily unidirectional. Social media can provide access to health information, exercise ideas, role models, peer support, and motivational content, while excessive or inappropriate use may also contribute to sedentary behavior, social comparison, unrealistic body ideals, and other potentially negative outcomes. Consequently, understanding not only how frequently young people use social media, but also what type of content they engage with, is important when examining the relationship between social media use and physical activity.

To explore engagement with health and PA related digital content, participants were asked whether they followed social media content or profiles related to PA, fitness, sport, nutrition, and health. More than one-third (37.7%) reported following such content regularly, while a further 50.0% indicated that they did so occasionally. Thus, almost nine out of ten participants reported at least some exposure to health, sport, or PA-related social media content.

A similar pattern emerged when participants were asked how frequently they watched videos, posts, or podcasts concerning PA, sport, exercise, or nutrition. One-quarter (25%) engaged with such content daily, while a further 39% did so several times per week. Taken together, these results indicate that PA and health-related digital content forms a relatively common component of participants' social media consumption. This is relevant given evidence that social media can provide opportunities for delivering health information and promoting physical activity, particularly through accessible, relatable, and interactive content (Goodyear et al., 2021; Aschwanden & Messner, 2024).

Participants' perceptions of the influence of social media provide further insight into this relationship. When asked whether social media encouraged or discouraged them from being physically active, 60% perceived social media as encouraging their PA, whereas 38% reported no perceived influence. This suggests that, for a substantial proportion of the sample, social media are perceived not merely as a source of entertainment but also as a potentially supportive environment for PA.

These findings are consistent with emerging evidence regarding the potential of digital and social media to support active lifestyles. Systematic-review evidence suggests that appropriately designed social-media interventions can contribute to positive changes in PA and other health-related behaviors, although the strength and consistency of these effects vary considerably across studies (Goodyear et al., 2021). Similarly, Aschwanden and Messner (2024) demonstrated that social media influencers can positively affect adolescents' enjoyment of and readiness for PA, particularly when the content presents authentic, relatable, and achievable forms of activity. Evidence among university students also suggests that social media and

mobile technologies can provide useful channels for PA promotion among young adults (Buja et al., 2024).

Nevertheless, the present results should be interpreted as perceived influence rather than evidence of a causal effect. Following fitness, sport, or health-related content does not necessarily lead to higher levels of PA, and the effects of such exposure are likely to depend on the nature of the content, the way users engage with it, and individual characteristics. The findings nevertheless demonstrate that social media occupy a potentially important position within the broader physical activity environment of young people and highlight their potential as a channel for delivering credible, engaging, and age-appropriate messages promoting active and healthy lifestyles.

Patterns of Engagement with Physical Activity and Health-Related Social Media Content

To further explore how young people engage with PA and health-related social media content, participants reported the frequency with which they used social media for four specific purposes: exercise instruction, nutrition and healthy lifestyle information, participation in fitness challenges, and motivational or inspirational content (Figure 7). Across all four categories, “sometimes” was the most frequently reported response, suggesting that engagement with such content is primarily occasional and purpose-driven rather than an established daily routine (Table 2).

Exercise videos and tutorials represented the most common form of engagement, with 67.7% of participants reporting that they sometimes used digital video content for exercise instruction. This finding indicates that social media may function as an accessible source of practical guidance, providing young people with exercise demonstrations, workout ideas, and information that can potentially be transferred into their own physical activity practices.

Nutrition and healthy lifestyle information was another important area of engagement, with 50.5% of respondents reporting that they sometimes used social media to access dietary advice or healthy lifestyle recommendations. This finding reflects the increasingly prominent role of social media as a source of health-related information among adolescents and young adults (Engel et al., 2024). However, the accessibility of such information should be considered alongside concerns regarding its credibility. Recent research examining nutrition-related content on TikTok found considerable variation in its quality and accuracy, highlighting the need for critical digital and health literacy when young people use social media as a source of nutrition advice.

Participation in digital fitness challenges was somewhat less frequent, although 42.7% of participants reported occasionally engaging in activities such as TikTok dance challenges, exercise challenges, or step-counting goals. Such interactive formats illustrate the potential of social media to move beyond passive content consumption by encouraging users to translate digital engagement into physical

participation. Nevertheless, evidence concerning the effectiveness of social-media fitness content in producing sustained changes in PA remains mixed, and engagement with online fitness content should not automatically be equated with increased PA (Nuss et al., 2024).

Finally, 36.6% of participants reported sometimes engaging with motivational or inspirational messages related to PA and healthy lifestyles. Although this was the least frequently reported of the four categories, motivational content may still play a supportive role for some young people.

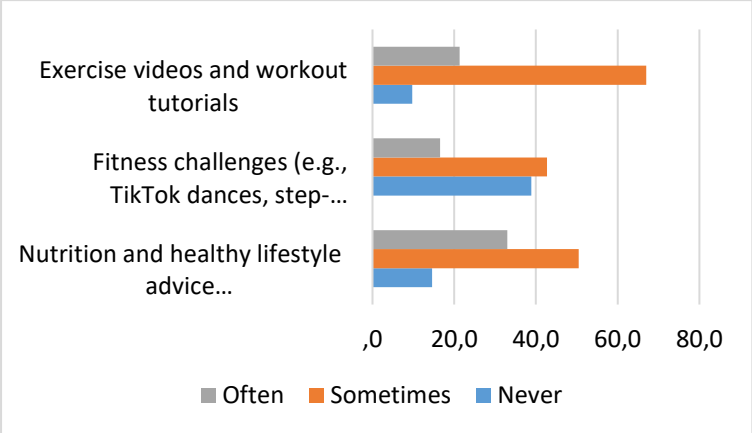

Figure 7: Use of social for improvement of physical activity and healthy lifestyle

Table 2: Frequency of use of Social Media Content for Lifestyle Optimization

Content Category Type	inant Metric Respomple Percentage ('		Behavioral Implication
ise Videos & Tutorials	*Sometimes*	67.7%	h operational utility for independ training.
ion & Wellness Advice	*Sometimes*	50.5%	lerate reliance for dietary and hea choices.
ctive Fitness Challenges	*Sometimes*	42.7%	merging peer-driven algorithmic engagement.
ational Content / Speeches	*Sometimes*	36.6%	liary psychological and motivati support.

Regarding the question: Has an influencer, YouTuber, or public figure motivated you to start a physical activity?, the respondents expresed a highly polarized distribution of opinions. A slight majority of 51% stated that public digital figures had no impact on their decision to initiate physical training. Remaining 49% responded affirmatively, indicating that these digital media personalities served as a direct catalyst for starting some form of PA.

Overall, the findings suggest that social media may function as a supportive resource for PA rather than as a primary motivational driver. The relatively high engagement with exercise videos and tutorials indicates that young people use social media to access workout ideas, practical guidance, and inspiration. This is consistent with research showing that fitness-related social media can provide exercise ideas and

enhance motivation, particularly when activities are perceived as realistic, relatable, and achievable (Aschwanden & Messner, 2024). However, exposure to fitness-related content should not automatically be interpreted as increased PA, as evidence regarding its translation into sustained behavioral change remains inconsistent (Nuss et al., 2024).

The use of social media for nutrition and healthy lifestyle information further demonstrates its growing role as a source of health-related content. While such platforms can provide accessible information and support healthy behaviors, concerns remain regarding content credibility, social comparison, unrealistic body ideals, and the quality of nutrition and fitness advice provided by influencers (Engel et al., 2024). These findings highlight the importance of digital health literacy and suggest that the potential of social media to support active and healthy lifestyles depends not only on the frequency of use, but also on the quality and type of content consumed and how young people engage with it.

Personal Perspectives and Subjective Assessments

To optimize social media utilization, young people must develop strong media literacy and critical thinking skills, enabling them to evaluate the profound impacts of these platforms on both physical and mental health. When approached with intentionality and moderation, social media serves as a powerful catalyst for an active and healthy lifestyle. Conversely, excessive and uncritical consumption triggers a significant reduction in PA, yielding adverse physical and psychological consequences for children and adolescents.

To evaluate these personal perspectives and systemic attitudes, respondents assessed their level of agreement with four specific perceptual claims (Figure 8) using a 5-point Likert scale, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). More than half of respondents (52.0%) agreed or strongly agreed that social media helps them *learn new exercises*. This suggests that digital platforms represent a relevant source of practical exercise information for many young people. An even larger proportion (60.0%) agreed or strongly agreed that they felt motivated to engage in physical activity after viewing social media posts or videos. Attitudes toward the statement *I prefer passive activities (social media, gaming) over physical activity* are highly polarized. While a large segment of the participants in the study e rejects this claim, a substantial minority affirms a baseline preference for passive digital leisure over physically demanding pursuits. This variation highlights the complex relationship between digital media consumption and PA and suggests that these behaviors should not necessarily be viewed as mutually exclusive. Rather, social media may function as either a sedentary leisure activity or a resource supporting PA, depending on the content consumed and the way individuals engage with it.

Regarding the statement *Social media can replace traditional learning methods for physical exercise (e.g., from teachers, coaches, and instructors)*, the collective sentiment is distinctly negative. This suggests that, despite recognizing the instructional and motivational potential of social media, respondents continue

to value direct professional guidance when learning physical activities. Current research similarly suggests that digital technologies can enhance PA and health-related learning through video feedback, apps, online resources, and other tools, but their value is greatest when they are meaningfully integrated into pedagogical processes rather than treated simply as replacements for professional instruction (Teutemacher et al., 2024).

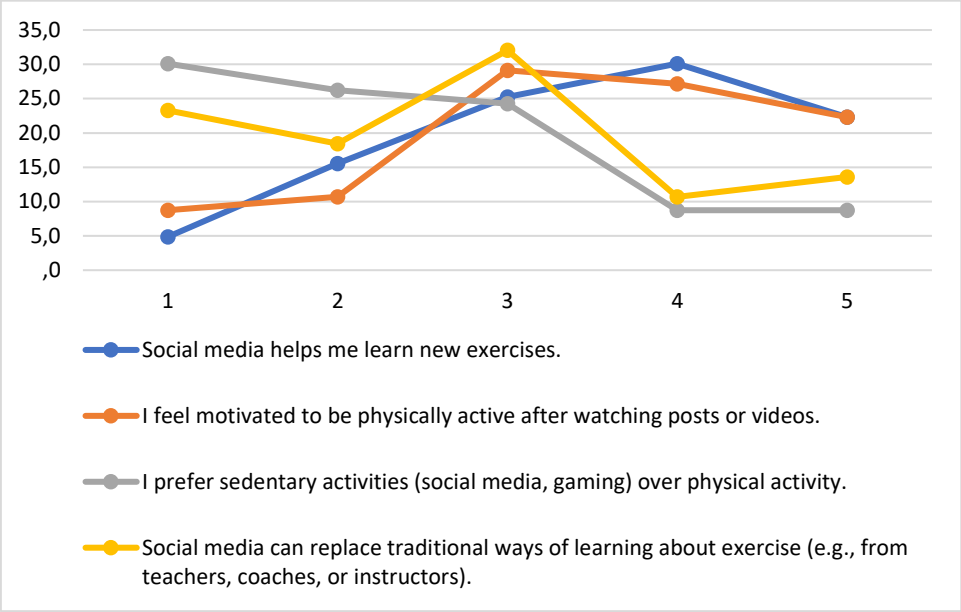

Figure 8: Perspectives of social media and their effects

The findings distinguish between the motivational and instructional roles of social media. More than half of participants found social media useful for learning new exercises, and 60% reported increased motivation to be physically active after viewing related content. This supports evidence that relatable social media content can enhance PA motivation and that digital technologies can support learning in physical education (Knoke, Woll & Wagner, 2024; Teutemacher et al., 2024). However, participants did not view social media as a replacement for teachers, coaches, or instructors. Instead, social media may provide ideas, demonstrations, and motivation, while professionals offer structured guidance, feedback, and individual support. Concerns about the credibility of online health information further highlight the importance of digital health literacy (Freeman et al., 2023; Engel et al., 2024). Thus, social media should be considered a complement to, rather than a substitute for, professional physical activity and physical education support.

Conclusion

The findings of this study highlight the complex and multifaceted relationship between social media use and PA among young people aged 15–24. Social media are deeply embedded in their everyday lives, serving not only as sources of entertainment but also as platforms for information, learning, social interaction, and engagement with health, sport, and fitness-related content. While excessive screen-based

media use may contribute to sedentary lifestyles, social media also offer opportunities to promote active and healthy behaviors through accessible information, exercise resources, motivation, and inspiration.

Despite high levels of social media exposure, participants did not perceive media or influencers as primary reasons for being physically active. Instead, physical fitness, health, and social interaction emerged as the strongest motives for PA. At the same time, many participants reported that social media encouraged them to be active, helped them learn new exercises, and provided access to fitness and health-related content. These findings suggest an important distinction between primary motivation and supportive influence: social media may not determine why young people choose to be physically active but can provide resources, ideas, and encouragement that support their active lifestyles.

Importantly, participants generally did not perceive social media as a replacement for teachers, coaches, or instructors. Social media may therefore be most valuable as a complementary resource that provides digital inspiration alongside professional instruction and structured PA opportunities. Its influence should not be considered simply positive or negative, but in relation to the amount and purpose of use, the type and quality of content consumed, and how digital engagement translates into everyday behavior. Concerns related to misinformation, unrealistic body ideals, social comparison, and the credibility of online health information further emphasize the importance of digital health and media literacy

These findings underline the potential for educators, coaches, health professionals, and youth organizations to use social media more intentionally to promote active and healthy lifestyles through credible, relatable, inclusive, and practically applicable content. Rather than positioning digital media and PA as competing aspects of young people's lives, the challenge is to harness the motivational and educational potential of social media while promoting balanced screen use and critical engagement with digital content. Future research should therefore move beyond overall measures of social media use and examine how specific platforms, types of content, and patterns of engagement relate to PA behaviors among different groups of young people.

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THE EFFECTS OF GAMIFICATION AND EXERGAMING IN PHYSICAL EDUCATION IN PRIMARY SCHOOL - REVIEW ARTICLE

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Abstract: The aim of this study was to review and critically examine the existing evidence on the effects of gamification and exergaming in physical education in primary school. A systematic search was conducted in PubMed and Web of Science for studies published between 2010 to 2025. Seven studies met the eligibility criteria and were included in the final synthesis, comprising a total of 985 participants of both sexes aged 6 to 14 years. The included studies varied considerably in design, sample size, intervention duration and frequency, program content, and outcome measures. Overall, the analyzed studies suggest that gamification and exergaming may have positive effects on students' intrinsic motivation, enjoyment, engagement, and selected educational outcomes in physical education classes. In several studies, these approaches were also associated with improvements in basic psychological needs, flow, and academic performance, although the sustainability of these effects appears to depend on the quality and duration of implementation. Despite the generally promising findings, methodological heterogeneity and practical limitations such as resource availability and teacher workload should be taken into account when interpreting the results. It can be concluded that gamification and exergaming represent potentially valuable pedagogical strategies in primary school physical education, but further methodologically robust research is needed to clarify their long-term educational effectiveness.
Key words: *motivation, physical activity, active learning*

Introduction

Physical and sports activities positively influence an individual's health (Martins et al., 2018). For this reason, Physical Education (PE) plays a fundamental role in childhood, as a large proportion of children come into contact with it only through this subject (Hernaiz-Sanchez & Bader-Gilabert, 2023). Physical education, as a school subject, has an extended role and special responsibility, which is reflected by the fact that the content of the PE course deals with many contemporary issues in the educational process in addition to the characteristics that cannot be provided by any other school subject or learning content (Radisavljević & Milanović, 2019). Physical Education helps to develop motor skills, coordination, flexibility, and endurance, contributing to an active and healthy lifestyle (Strong et al., 2005). Physical Education lessons also provide opportunities for teamwork and social and physical interaction with peers (Bailey, 2006). This helps them understand the importance of respecting others' limitations, while fostering empathy and

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inclusion in and out of the classroom (Bailey, 2006). In addition, authors (Strong et al., 2005) point out that physical activity during school hours helps combat stress and improve concentration, simultaneously improving focus and health.

Within the area of PE, games have traditionally been used, since any motor, popular, traditional or sport game that is proposed in class is configured as the foundation from which to structure the entire teaching–learning process of the curricular contents (Extremera & Montero, 2016). Currently, education is characterised in general terms by the absence of student motivation, lack of interest and lack of effort and discipline to achieve new knowledge and skills (Ruano, Martínez, Valero & Martínez, 2021). However, the emerging methodological approach of gamification is even more transformative, since it proposes that the class itself, taking advantage of the fact that we are immersed in a digital society, really transforms itself into an active game with digital elements, based on role-playing games and in video games, within which both teachers and students have the opportunity to grow (Fernandez-Rio, De Las Heras, González, Trillo & Palomares, 2020; Ferriz-Valero, Østerlie, Martínez & García-Jaén, 2020). Effective gamification orients students toward intrinsic motivation, where they enjoy the process, as opposed to extrinsic motivation, where the aim is to obtain external rewards, or to stop the process to avoid failure (Soriano-Pascual, Ferriz-Valero, García-Martínez & Baena-Morales, 2022).

Exergaming refers to digitally mediated games that require bodily movement to play, thereby combining entertainment with physical activity. In educational contexts, exergaming has been increasingly recognized as a potentially useful strategy for promoting movement participation, enjoyment, and motivation among children (Sun, 2012; Sun, 2013). Research suggests that exergaming can increase physical activity engagement and situational interest, particularly in school-based settings, although its motivational effects may decline over time if the activities are not pedagogically varied and meaningfully integrated into instruction (Chen et al., 2023). Accordingly, exergaming should not be viewed merely as a technological novelty, but rather as a pedagogical tool whose effectiveness depends on thoughtful implementation, task design, and alignment with educational objectives.

As a whole, traditional PE is neither interesting nor motivating for schoolchildren in this digital period. Currently, no systematic reviews have been found that focus solely on elementary school children. Therefore, the aim of this study was to review and critically examine the existing evidence on the effects of gamification on PE on the motivation of younger school-aged children.

Method

The study was conducted and reviewed following the PRISMA guidelines as outlined by Page et al. (2021). A comprehensive search was conducted in PubMed and Web of Science to identify studies examining the

effects of gamification on children's motivation. PubMed was specifically chosen for its focus on biomedical literature, providing access to high-quality studies on children's motivation and physical activity, while Web of Science was used to capture broader, multidisciplinary research and to track citations. The search was performed in March 2026 and was limited to studies published in the last 15 years (2010–2025). The search strategy was developed around three core concepts: gamification, PE motivation, and children. The research search strategy is detailed in Figure 1.

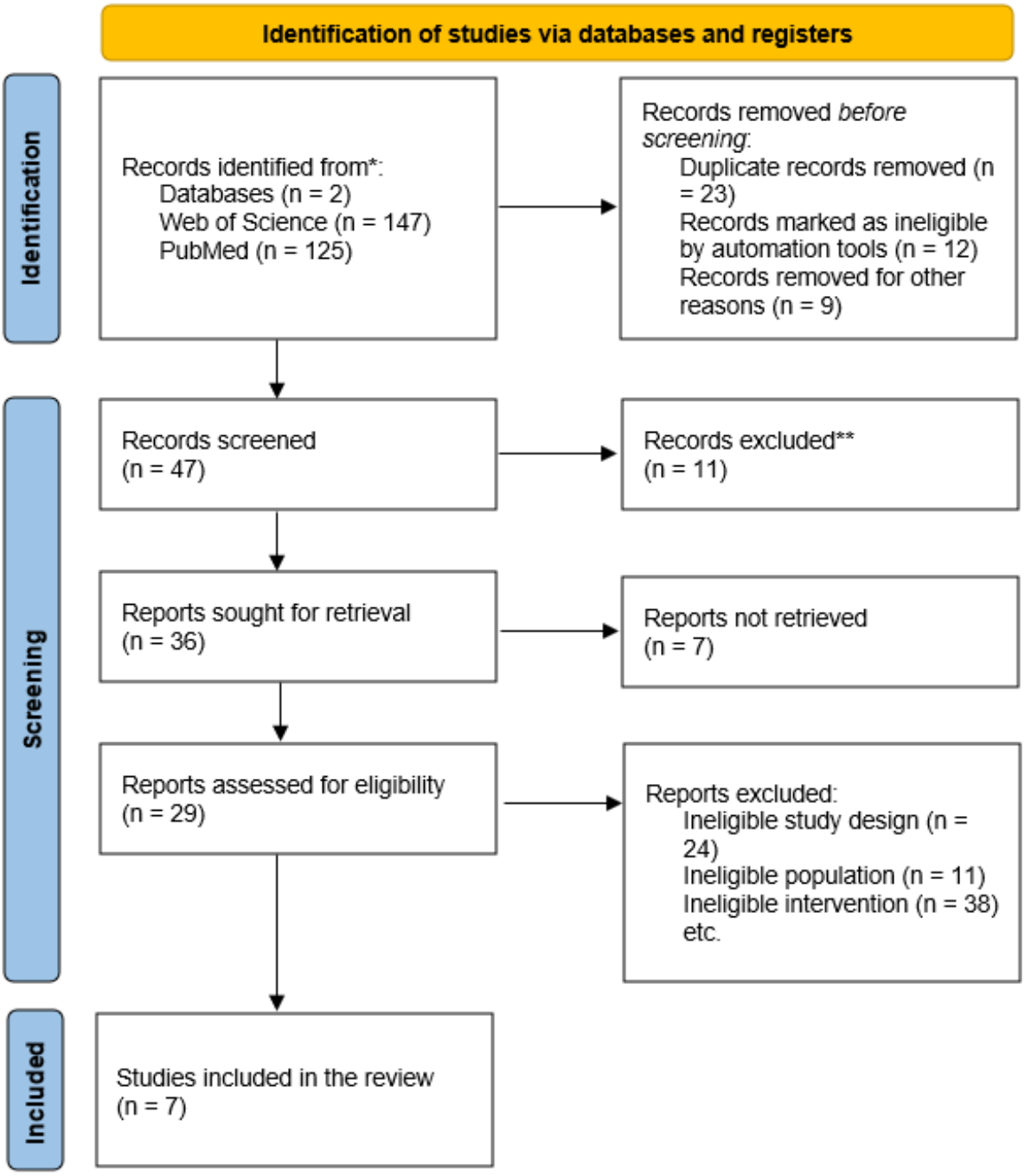

Figure 1. *PRISMA flow diagram*

2.2. Inclusion criteria

For inclusion in the final analysis, studies were required to investigate the effects of gamification PE on the motivation of children aged 6 to 12 years. Eligible studies had to employ an experimental design, including randomized controlled trials or single-group pre-post interventions, with a clearly defined gamification program. Interventions were required to have a minimum duration of 6 weeks. Studies were required to assess motivation using validated tests or surveys for all outcomes. While controlled trials were preferred, studies without a control group were also included due to the limited number of studies available in this area, ensuring a more comprehensive review of the existing evidence.

2.3. Exclusion criteria

Studies were excluded from the final analysis if they did not examine the effects of a gamification PE program on motivation, involved participants outside the age range of 6 to 12 years, or included children with health conditions or disabilities. Studies that did not employ an experimental design, such as randomized controlled trials or single-group pre-post interventions, or that lacked a clearly defined protocol were also excluded. Additionally, studies were excluded if the intervention lasted less than 6 weeks, if motor abilities were assessed using non-validated or unreliable tests, or if insufficient detail about the intervention or outcome data was provided. Non-original research articles, such as reviews or meta-analyses; publications in languages other than English; duplicate publications; and studies with overlapping samples were also excluded.

Results

The quality assessment of the studies was performed based on the total number of studies included in the quantitative synthesis, and the individual scores each study obtained are provided in Table 1.

Table 1. *Analysis of the articles that provide scientific evidence on gamification in PE in Elementary School.*

First author and year of publication	**Sample of participants**				**Scientific Evidence Evaluation Instrument**	**Experimental program**		**Gamification elements**	**Results**
	Control Group		*Experimental Group*			*Duration (weeks)*	*Frequency and duration (weekly)*		
	Number	*Age*	*Number*	*Age*					
Sun, H. 2013	/	/	n=70 F=40 M=30	9 to 12	Interest Scale Elementary School	Two semesters	2 per week 30 min each	Two Cateye gamebikes, one Xavix boxing, one 3-kick, two Dog fight flight simulators, two Nintendo Wiis, two stations of four DDRs, two Gamercize activities, and two XrBoards	The results indicated that students' situational interest dropped dramatically over two semesters, but their PA intensity increased over time. The results showed that boys and girls were equally active in the exergaming lessons, but boys perceived their gaming experiences more enjoyable than girls did.
Fernández-Río et al., 2020.	/	/	n=290 F=138 M=152	6–7 (n=126) 11–12 (n=57) 12–14 (n=107)	Questionnaire (The subscale Intrinsic Motivation of the Spanish validated version of the Revised Perceived Locus of Causality Scale), discussion group, portfolio (for teachers), and drawings (only in 6–7-year-old students).	30 sessions 15 weeks	2 per week 50 min each	/	Increased the intrinsic motivation of children.

Quintás-Hijós et al. 2020a.	191 F=101 M=90	11.1 ± 1.7	n=226 F=121 M=105	11.1 ± 1.5	Ad hoc questionnaire and validated questionnaires (Perceived Locus of Causality Scale; Dispositional Flow Scale-2; and Basic Psychological Needs in Exercise Scale).	1 month 12 sessions	3per week 60 min each	Traditional didactic intervention vs. a gamified exergaming intervention.	Improvement in basic psychological needs, academic performance, and students' motivation and disposition to learn.
Quintás-Hijós et al. 2020b.	191 F=101 M=90	11.1 ± 1.7	n=226 F=121 M=105	11.1 ± 1.5	Fieldnotes, ad hoc open-ended questionnaire, semi-structured individual interviews, and focus group interviews.	1 month 12 sessions	3per week 60 min each	Traditional didactic intervention vs. a gamified exergaming intervention.	The facilitator was the realismo fits didactic design and its adaptability to different educational contexts. The main barriers were materials and facilities.
Serrano Durá et al., 2021.	17 F=11 M=6	12 to 13	n=19 F=8 M=11	12 to 13	The COSACUES and COSACUESAEF questionnaires and the physical tests: Bering–Sørensen Test, SideBridge Test, and Prone Forearm Plank Test. To measure motivation, the Feeling Scale was used, and perceived effort was measured with the OMNI Scale.	6 sessions	/	/	It was found that the girls assimilated the contents better with the gamified methodology. A greater perception of effort and greater motivation was also confirmed with the gamified intervention.

Parra González et al. (2021)	/	/	n=100	9 to 10	Data collection was carried out through an ad hoc questionnaire.	/	/	gamification and flipped learning	Gamification was better valued by Primary and Secondary Education students compared to Baccalaureate students, who preferred the flipped classroom. Higher scores were obtained in different variables such as student–student relationship,autonomy, or collaboration.
Sotos-Martínez et al. 2023.	35 F=16 M=21	9 to 11	n=37 F=18 M=17	9 to 11	A questionnaire, "Motivation Questionnaire in Physical Education" (CMEF-EP)	6 weeks 10 sessions	/	Traditional didactic intervention vs. a gamified intervention using a technology app called ClassDojo.	A significant interaction effect over time was observed only for intrinsic motivation between the gamified and control groups. The results show the efficacy of gamification to increase the motivation of elementary physical education students. However, it does not decrease amotivation.

Note: *n: Number; F: Female; M: Male*

An initial search of electronic databases yielded 974 studies. After duplicates were removed, 512 records were screened. Of these, 209 studies were excluded based on the predefined inclusion criteria. The remaining 112 articles were assessed for eligibility, but the full text of one article was unavailable, leaving 71 studies for full-text review. Following this thorough evaluation, 7studies met all criteria and were included in the final analysis.

Table 1 presents previous studies, including the first author and year of publication, participant sample (gender and age), the motivation survey used, the experimental program (duration and frequency), and the study results.

Disccusion

The aim of this study was to review and critically examine the existing evidence on the effects of gamification on PE on the motivation of younger school-aged children. A total of 7 studies were analyzed, which aimed to examine the effects of a gamification PE program on motivation in younger school-aged children. Although most studies report positive outcomes, interpreting these findings requires caution due to substantial heterogeneity in study designs, intervention characteristics, and outcome measures. Overall, motivation improved among elementary school children. However, the magnitude and consistency of these effects varied considerably between studies.

The findings of the present study, considered in light of previous research, support the view that gamification and exergaming may represent effective pedagogical approaches for enhancing students' experiences in PE, particularly in relation to motivation, enjoyment, and engagement. The analyzed studies consistently indicate that game-based methodologies can positively influence intrinsic motivation and classroom participation, especially among younger children, which is in line with reports by Fernandez-Rio et al. (2020), Quintas (2020a), and Sotos-Martínez et al. (2023), who observed improvements in motivation and selected educational outcomes following gamified interventions. Moreover, the combination of gamification and exergaming appears to provide broader benefits, including improvements in basic psychological needs, flow, and academic performance, suggesting that these approaches may contribute not only to children's affective involvement but also to the overall quality of learning in PE. However, the evidence also suggests that such positive effects should be interpreted with caution, as their sustainability may depend on the quality of implementation, variation of activities, and contextual relevance. In this regard, Sun (2013) demonstrated that although exergaming increased physical activity intensity, children's situational interest declined over time, indicating that the motivational appeal of these interventions may weaken if the novelty effect is not supported by an appropriate pedagogical design. In addition, the reviewed literature suggests that the effectiveness of these methodologies may vary according to age, gender, and educational stage, with younger children generally responding more positively to gamification and some

evidence showing more favorable outcomes for girls in specific contexts. Despite these promising findings, practical limitations such as teacher workload, technological requirements, and infrastructural constraints remain important barriers to implementation in school settings. Therefore, gamification and exergaming should not be viewed merely as attractive alternatives to traditional instruction, but as pedagogical tools whose educational value depends on their purposeful, developmentally appropriate, and context-sensitive integration into PE teaching practice. Furthermore, the reviewed literature indicates that the effectiveness of gamification and exergaming may not be uniform across all child populations, but rather influenced by factors such as age, gender, and educational stage. Previous studies have shown that younger children tend to respond more positively to gamified content, while some findings also suggest that girls may benefit more from such interventions in specific educational contexts. These observations highlight the importance of adapting innovative teaching methods to the developmental and motivational characteristics of learners. At the same time, practical barriers such as teacher workload, limited access to technological resources, and infrastructural constraints remain important challenges for implementation in school settings. Therefore, gamification and exergaming should not be regarded merely as attractive alternatives to traditional instruction, but as pedagogical tools whose effectiveness depends on their purposeful, developmentally appropriate, and context-sensitive integration into PE teaching practice. In that sense, their value lies not only in increasing children's short-term interest but also in their potential to support a more child-centered, engaging, and educationally meaningful learning environment.

Conclusion

Based on the analyzed studies, it can be concluded that gamification and exergaming represent valuable pedagogical approaches in PE, with the potential to enhance children’s motivation, enjoyment, engagement, and selected educational outcomes. Although the reviewed evidence generally supports their positive effects, these approaches should not be considered universally effective, as their impact appears to depend on the quality of implementation, children’s developmental characteristics, and the educational context. Therefore, the successful application of gamification and exergaming in PE requires thoughtful pedagogical planning, adequate resources, and adaptation to children’s needs. Overall, these methodologies may help create a more engaging, child-centered, and educationally meaningful PE environment, while future research should further examine their long-term effectiveness and practical applicability in school settings.

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https://doi.org/10.46793/STEPAM26.182CJ
Udk: 355.233.2:796/799-053.5

PRIMARY SCHOOL STUDENTS PERCEPTIONS AND ATTITUDES TOWARD STEPAM APPROACH?

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Abstract: Physical inactivity among children has become a major global public health concern, with more than 80% of adolescents failing to meet recommended physical activity guidelines. Schools provide one of the few structured settings for promoting regular physical activity; however, physical education often represents the only organized form of activity during school hours and remains limited in duration. At the same time, concerns have emerged regarding low achievement and participation in STEM-related fields, creating a need for innovative educational approaches. Integrated STEM/STEAM learning has been recognized as a promising strategy for developing key competencies and increasing student engagement. While previous studies have explored children's attitudes toward physical activity, limited research has examined perceptions of interdisciplinary approaches combining STEM and movement. Therefore, this study aimed to examine primary school students' perceptions and attitudes toward STEPAM activities. The research was conducted in 2025 and included a sample of 79 fourth-grade primary school students from Jagodina, Serbia. Students completed a questionnaire evaluating their experiences with STEPAM lessons. The results revealed generally positive perceptions of the implemented activities, with mean scores ranging from4.08 to 4.47 on a five-point scale, indicating a high level of agreement with positive statements. The highest score was recorded for inquiry-based activities (M = 4.47, SD = 0.60), while similarly high ratings were observed for enjoyment and engagement-related items (M = 4.37, SD = 0.77). Overall, students evaluated STEPAM lessons very positively.

Keywords: *Physical Activity; STEAM Education; Student Engagement*

Introduction

Physical inactivity among children has become a major global public health concern. Contemporary lifestyles characterized by reduced outdoor play and various sedentary leisure behaviours, including increased screen exposure, have contributed to declining daily movement levels across school-aged populations. Global estimates indicate that more than 80% of adolescents do not meet recommended physical activity guidelines, prompting urgent calls for systemic action (World Health Organization, 2024). Recently, Culková and Dušková (2025) found that many elementary school children did not achieve recommended levels of physical activity during the school day. Their findings emphasized the significant role of school-related factors, particularly environmental conditions such as school size and access to sports facilities, as well as structured opportunities including organized activity breaks and outdoor learning. Interestingly, family lifestyle variables did not show a significant direct influence on school-day physical activity levels.

It is widely discussed and accepted that insufficient physical activity is associated not only with adverse health outcomes, including obesity and cardio metabolic risk, but also with lower motor

[24]

competence and reduced overall functional capacity. A systematic review conducted by Janssen and LeBlanc (2010) demonstrated that regular physical activity in school-aged children is strongly associated with improved body composition, cardiometabolic health, musculoskeletal fitness, and psychological well-being.

Schools represent one of the few structured environments in which regular physical activity can be systematically promoted; however, despite this potential, many educational systems struggle to provide adequate movement opportunities within the school day. It is estimated that for more than 80% of children, physical education represents the only structured physical activity they engage in during the school day (European Commission, 2015). Physical education is formally included as a compulsory subject across all European curricula; however, the proportion of instructional time allocated to it remains relatively limited. On average, P.E. accounts for approximately 10% of total curriculum time, while in some countries it constitutes less than 5%, even at the primary level. The allocation becomes even more restricted in secondary education, where many systems dedicate a smaller share of instructional time to physical education (EACEA/Eurydice, 2013). Simmilarly, in Serbia, physical education is generally delivered three to four times per week in primary schools, yet despite this relatively stable provision, the overall weekly allocation remains insufficient to ensure that children meet recommended daily physical activity levels.

Also, in the same time, the situation in Serbia indicates a stagnating number of students pursuing science, technology, and mathematics in secondary and higher education. Although Serbian students achieved slightly above-average results in TIMSS 2019 in mathematics and science (Đerić et al., 2020), the country remains significantly behind leading systems such as Singapore, Japan, and Finland. Similarly, PISA results show that Serbian students perform below the OECD average in mathematics and science, with recent cycles confirming this trend (Pavlović Babić & Baucal, 2013; Schleicher, 2019).

STEM represents an interdisciplinary educational framework that integrates science, technology, engineering, and mathematics through purposeful alignment of curriculum objectives, learning standards, assessment strategies, and instructional design. Latest EU reports show low student proficiency levels, shortages of qualified STEM teachers, widening talent gaps, and the urgent need for additional policy actions and research to evaluate integrated STEAM approaches (European Commission, 2025) and persistent gender and regional gaps in STEAM participation, and calls for integrated and inclusive STEAM learning to foster key competences like critical thinking, problem-solving, and digital skills (European Commission, 2025b).

Rather than treating these disciplines as isolated subjects, the STEM approach emphasises meaningful connections across domains to support deeper learning. STEM literacy, therefore, encompasses an understanding of the role these fields play in contemporary society, familiarity with key foundational concepts within each discipline, and the ability to apply this knowledge in practical contexts. This includes critically interpreting scientific and technological information, solving everyday technical problems, and

using mathematical reasoning in real-life situations (Margot & Kettler, 2019).

Against this backdrop of policy emphasis on integrated STEAM learning and the development of key competences, as well as the positive attitudes of teacher (Mihajlovic, A., Cekic-Jovanovic, O., & Ignjativic, A. 2026), it becomes essential to consider how children themselves perceive and experience such interdisciplinary approaches, particularly when they are implemented through physically active learning contexts.

Various research has increasingly examined children's attitudes toward physical activity and physical education, demonstrating that positive perceptions are strongly associated with higher motivation, stronger intentions to be active, and greater engagement in regular physical activity (Mercier et al., 2023). Research has also explored children's attitudes toward specific forms of physical training, with Kocić and Ignjatović (2018) finding that young pupils generally hold positive perceptions of different types of resistance training as part of their physical activity experiences, which may influence their motivation and engagement in diverse movement opportunities. However, there are limited research regarding children attitudes toward interdisciplinary approach including STEM and Physical activity.

Research methodology

The main aim of the study was to examine primary school students' perceptions and attitudes toward STEPAM activities.

Based on this aim, two research questions were formulated:

1. Do students have positive perceptions of the STEPAM activities in which they participated?
2. Do students have positive attitudes toward the integration of physical activities with Science and Mathematics content?

Participants and Procedure

The research was conducted in 2025 and included a sample of 79 fourth-grade primary school students from central Serbia. All students attended two STEPAM classes prior to data collection. The questionnaire was administered after the completion of these classes.

A detailed description of the implemented STEPAM lessons is presented in Table 1.

Table 1. Description of STEPAM classes

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No.	Teaching unit	Integrated subjects	Main activities	Learning goals
1	**Balloons**	Science, Technology, Engineering, PE, Art, Mathematics	Investigating air, pressure and surface tension; testing bubble solutions; designing bubble-making tools; balloon games; measuring bubble size, distance and duration; creating bubble artwork.	Understand how air, pressure and surface tension influence bubbles and balloons; apply measurement and data analysis; develop coordination, teamwork, creativity and engineering-design skills.
2	**Forces Game**	Science, PE, Art, Mathematics	Push-and-pull activities in pairs; rope-pull game; comparing movement on different surfaces and with different body masses; using force arrows.	Understand force as a push or pull and explore how magnitude, direction, mass and friction affect movement.
3	**Re-cycle Balance**	Science, Technology, Engineering, PE, Art, Mathematics	Balance activities; measuring and comparing mass; sorting recyclable materials; constructing balance scales from recycled materials; balance testing and group presentation.	Understand balance, mass distribution and measurement; connect physical balance with recycling and environmental responsibility; develop coordination, cooperation and design skills.
4	**Materials Box Challenge**	Science, Technology, Engineering, PE, Art, Mathematics	Observing everyday objects and geometric forms; collecting materials through movement; comparing material properties; constructing geometric models; adapting and presenting designs.	Explore relationships between geometric form, material properties and function; develop spatial reasoning, construction, creativity, coordination and collaborative problem-solving.
5	**Natural Ecosystems & Habitats**	Science, Technology, Engineering, PE, Art, Mathematics	Investigating terrestrial and aquatic habitats; habitat posters and collages; camouflage design; digital 3D habitat models; predator–prey movement activities.	Understand habitats, biodiversity and adaptations; recognise the importance of ecosystem conservation; apply geometry and creative design to environmental concepts.
6	**Force & Power**	Science, Technology, Engineering, PE, Art, Mathematics	Exploring renewable and non-renewable energy sources; constructing and testing model cars powered by different energy sources; measuring distance and time; energy-themed movement games.	Understand energy, force and power and their relationship with movement; compare energy sources; develop engineering, measurement, data-analysis and sustainability skills.
7	**Balloons**	Science, Technology, Engineering, PE, Art, Mathematics	Investigation of balloons and bubbles; bubble experiments; balloon games; engineering design; measurement and digital documentation; bubble art.	Investigate air, pressure and surface tension through experimentation and movement; apply measurement, observation, creativity and teamwork.
8	**Oxygen & Gases**	Science, Technology, Engineering, PE, Art, Mathematics	Investigating air composition and oxygen; candle/combustion experiment; water-cycle activities; breathing-rate measurements; movement activities; data analysis.	Understand the role of oxygen in life, respiration and combustion; explore air composition and the water cycle; relate physical activity to oxygen demand and breathing.
9	**Human Body**	Science, Technology, Engineering, PE, Art, Mathematics	Exploring skeletal, muscular, circulatory, respiratory and nervous systems; human-body relay; constructing life-sized body models; measuring heart rate and relay times.	Understand the structure and interaction of major body systems; connect physical activity with body functions; develop health literacy, teamwork and data-analysis skills.
10	**Coding in Action**	Science, Technology, Engineering, PE, Art, Mathematics	Creating and testing algorithms; Bee-Bot/coding activities; movement-based coding games; maze navigation; grid-based algorithm drawings; debugging.	Develop algorithmic and computational thinking; understand sequencing, repetition and conditional logic; develop spatial reasoning, problem-solving, precision and perseverance.
11	**Hop to Grid**	Science, Technology, Engineering, PE, Art, Mathematics	Designing settlements on coordinate grids; rural/urban settlement activities; human-grid navigation by hopping and jumping; Google Maps route exploration; spatial games.	Understand spatial relationships, coordinates, directions and settlement organisation; develop navigation, spatial awareness, movement, mathematical reasoning and design skills.
12	**Step by Step**	Science, Technology, Engineering, PE, Art, Mathematics	Observing motion and stillness; movement games; measuring movement; creating visual and digital representations of motion; analysing simple movement data.	Distinguish motion from static positions; observe, measure and represent movement; connect physical experience with mathematical, artistic and digital representation.

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No.	Teaching unit	Integrated subjects	Main activities	Learning goals
13	**Static Electricity**	Science, Technology, Engineering, PE, Art, Mathematics	Experiments with charged materials; investigating attraction and repulsion; constructing a simple static-electricity apparatus; movement games; recording and interpreting data.	Understand electric charges, attraction, repulsion and static electricity; investigate charge through experimentation and develop data-analysis, engineering and teamwork skills.
14	**Mapping, Magnets, and Movement**	Science, Technology, Engineering, PE, Art, Mathematics	Magnet experiments; exploring attraction and repulsion; magnetometer measurements; mapping and navigation; movement games; construction challenges.	Understand magnetic forces and their effects; collect and analyse data; use technology for measurement and navigation; develop coordination, spatial awareness and collaborative problem-solving.
15	**Shadow in Motion**	Science, Technology, Engineering, PE, Art, Mathematics	Investigating light and shadows; changing light distance and angle; creating shadow-theatre models; movement activities; recording and representing observations.	Understand how shadows are formed and how light, distance and angle affect them; explore geometry and spatial relationships through movement, experimentation and creative design.
16	**Time**	Science, Technology, Engineering, PE, Art, Mathematics	Reading and measuring time; movement and timed challenges; exploring clock mechanisms; constructing clock models; calculating elapsed time and converting units.	Understand time as a measurable quantity; read clocks, calculate elapsed time and convert units; connect duration with movement and everyday activities.
17	**A Journey Through Time – Transformers**	Science, Technology, Engineering, PE, Art, Mathematics	Creating historical timelines; sequencing inventions; relay activities with invention cards; researching technological development; designing future inventions.	Understand decades, centuries and millennia; organise events chronologically; recognise technological change and develop creative ideas for future innovation.
18	**Liquids**	Science, Technology, Engineering, PE, Art, Mathematics	Investigating density and solubility; floating/sinking experiments; Rainbow Jar; model-submarine engineering challenge; water-themed cooperative games; mathematical comparisons.	Understand liquid properties, density, solubility and buoyancy; investigate why objects float or sink; apply mathematical comparison and engineering design.
19	**Don't Eat Me**	Science, Technology, Engineering, PE, Art, Mathematics	Investigating food chains and ecological relationships; predator–prey movement games; constructing habitats; analysing food requirements; creating ecosystem representations.	Understand interdependence among living organisms, food chains and ecosystem balance; develop environmental awareness, cooperation and mathematical representation of ecological data.
20	**Electricity**	Science, Technology, Engineering, PE, Art, Mathematics	Investigating conductors and insulators; building simple circuits; circuit-themed movement games; using Makey Makey; measuring wire length and circuit dimensions; designing paper circuits.	Understand electric current and closed circuits; distinguish conductors and insulators; design, construct and improve simple electrical systems.
21	**Symmetry Around Us**	Science, Technology, Engineering, PE, Art, Mathematics	Identifying symmetry in nature and the human body; symmetrical movement; mirror activities; digital pattern creation; designing symmetrical patterns.	Understand symmetry and lines of symmetry; recognise symmetry in nature, the body and design; develop coordination, spatial reasoning and creative expression.
22	**Aggregate Condition**	Science, Technology, Engineering, PE, Art, Mathematics	Investigating solids, liquids and gases; observing density and phase changes; Rainbow Jar; matter-discovery stations; mathematical representation and 3D models.	Distinguish the three states of matter; understand their properties, density and phase changes; collect, compare and represent scientific data.
23	**Be Fit**	Science, Technology, Engineering, PE, Art, Mathematics	Fitness stations; pulse measurement before and after exercise; endurance games; health-data graphs; designing fitness routines; creating health comics.	Understand healthy lifestyle habits and the body's response to exercise; measure and interpret pulse data; promote physical activity, healthy nutrition, rest and well-being.

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No.	Teaching unit	Integrated subjects	Main activities	Learning goals
25	**The Water Cycle**	Science, Technology, Engineering, PE, Art, Mathematics	Exploring the water cycle through diagrams/models; investigating evaporation, condensation and precipitation; movement-based activities; modelling and data interpretation.	Understand the stages of the water cycle and their relationships; represent natural processes through models, movement and visualisation; connect scientific concepts with measurement and environmental awareness.

Instrument

The data were collected using a questionnaire developed by [author(s)]. The instrument consisted of two parts. The first part included five five-point Likert-type items related to students' perceived experience of the STEPAM lessons and activities in which they participated (see Table 2). The second part consisted of nine five-point Likert-type items assessing students' general attitudes toward the integration of physical education activities into Science and Mathematics content. Conceptually, items A1, A2, A3, and A6 reflected affective attitudes toward integration, whereas items A4, A5, A8, and A9 reflected perceived cognitive difficulty. This distinction was made on a conceptual basis, differentiating between students' emotional responses to integrated learning (e.g., whether they liked such integration or found it interesting) and their perceptions of cognitive effort and understanding (e.g., whether they perceived the activities and content as difficult or helpful for understanding).

For all items, students indicated the extent to which they agreed with each statement on a five-point scale ranging from 1 (strongly disagree) to 5 (strongly agree). In interpreting the mean scores, the classification proposed by Narli (2010) was applied, whereby the following intervals were used: [1.00–1.80) very low level of agreement; [1.80–2.60) low; [2.60–3.40) moderate; [3.40–4.20) high; and [4.20–5.00] very high. Although reliability analysis was conducted, the internal consistency coefficients were not sufficient to justify forming composite scales; therefore, all items were analyzed individually.

Table 2. Items assessing students' perceived experience of STEPAM lessons

Item code	Item
PE1	I liked the lesson in which *Science*, Mathematics, and Physical Education were connected.
PE2	I really liked the activities during the STEPAM project lessons.
PE3	The physical exercises during Science and Mathematics lessons were fun.
PE4	I liked the inquiry-based activities during the STEPAM Science lesson.
PE5	I would like to have STEPAM lessons more often.

Table 3. Items assessing students' attitudes toward integrated STEPAM learning

Item code	Item
A1	It is fun when we do activities at school that connect science, mathematics, and physical education.
A2	It is interesting when the teacher gives us tasks to explore science and mathematics through physical exercise and games.
A3	I like learning mathematics through interesting physical activities.
A4	It is very difficult when we connect several school subjects while learning about natural laws.

A5	It is very difficult for me to understand everything when we learn science, mathematics, and physical education together.
A6	I like exploring science and mathematics topics on my own through physical activity when I am not at school.
A7	I do not have enough time to do physical exercise because I prefer to sit and study mathematics and science.
A8	When we have different subjects combined in one lesson (science, mathematics, physical education), I understand the material better.
A9	I understand the material better when we combine Science and Physical Education in class.

The statistical analysis was conducted using SPSS for Windows, version 23.0. For the quantitative data analysis, descriptive statistical measures were calculated, including percentages, means, standard deviations, and the coefficient of variation (CV).

Results

The first research question examined whether students had positive perceptions of the STEPAM activities in which they participated. Descriptive statistics for these items are presented in Table 4.

Table 4. Descriptive statistics for students' perceived experience of STEPAM lessons

Items	N	Response (%)					M	SD	CV
		1	2	3	4	5			
PE1	79	1.3	1.3	12.7	58.2	26.6	4.08	0.75	18.31
PE2	79	0	3.8	6.3	39.2	50.6	4.37	0.77	17.64
PE3	76	1.3	2.5	3.8	50.6	38.0	4.26	0.77	18.12
PE4	76	0	1.3	1.3	44.3	49.4	4.47	0.60	13.40
PE5	76	0	1.3	5.1	45.6	44.3	4.37	0.77	17.64

Note. Values under 1–5 represent percentages of responses.

Students' responses indicate generally positive perceptions of the implemented STEPAM lessons. The mean values ranged from 4.08 to 4.47 on a five-point scale, suggesting a high level of agreement with positive statements about the lessons.

The highest mean score was observed for item PE4 (M = 4.47, SD = 0.60), indicating that students particularly appreciated the inquiry-based activities. Similarly high ratings were observed for PE2 and PE5 (M = 4.37, SD = 0.77). Overall, the findings suggest that students evaluated the STEPAM lessons very positively.

The second research question examined students' general attitudes toward the integration of physical activities with Science and Mathematics content. Descriptive statistics are presented in Table 5.

Table 5. Descriptive statistics for students' attitudes toward integrated STEPAM learning

Items	N	Response (%)					M	SD	CV
		1	2	3	4	5			
A1	78	0	1.3	5.1	60.8	31.6	4.24	0.61	14.32
A2	79	1.3	5.1	8.9	51.9	32.9	4.10	0.86	20.88
A3	79	2.5	7.6	13.9	43.0	32.9	3.96	1.01	25.40
A4	79	1.3	57.0	25.3	11.4	5.1	2.62	0.90	34.20
A5	79	1.3	57.0	25.3	11.4	5.1	2.62	0.90	34.20
A6	79	1.3	1.3	12.7	58.2	26.6	4.08	0.75	18.31
A7	76	0	0	0	31.6	64.6	4.67	0.47	10.13
A8	76	0	1.3	0	43.0	51.9	4.51	0.58	12.79
A9	77	1.3	12.7	11.4	44.3	27.8	3.87	1.02	26.30

Note. Values under 1–5 represent percentages of responses.

Overall, students expressed positive affective attitudes toward integrated learning. Items reflecting affective attitudes (A1, A2, A3, and A6) showed relatively high mean values (ranging from 3.96 to 4.24), indicating agreement with positive statements about learning through integrated physical activities.

Items reflecting perceived cognitive difficulty (A4 and A5) showed mean values slightly below the midpoint (M = 2.62), indicating that students generally did not perceive integrated learning as highly difficult, although some variability in responses was observed.

For item A7, the high mean value (M = 4.67) indicates that many students agreed (64.6% strongly agreed and 31.6% agreed) with the statement that they tend to prefer sitting and studying over engaging in physical exercise, suggesting a potential imbalance between academic and physical activities.

Items A8 and A9 indicated that students generally perceived improved understanding when subjects were integrated, particularly for item A8 (M = 4.51), which had the highest mean value among all items in this section (more than 90% of students selected "agree" or "strongly agree" for item A8).

In terms of response dispersion, the lowest relative variability was observed for item A7 (C_V = 10.1%), indicating a high level of consensus among students, whereas items A4 and A5 showed the highest variability (C_V = 34.2%), suggesting more diverse perceptions regarding cognitive difficulty.

Disscusion

The findings of this study indicate that primary school students generally perceive the STEPAM approach positively and show favourable attitudes toward the integration of physical activity with Science and Mathematics learning. These findings are particularly relevant in the context of the growing need to provide children with more opportunities for physical activity during the school day and, at the same time, to promote interdisciplinary learning that connects academic knowledge with meaningful and active

learning experiences. The theoretical framework of the study emphasised that schools represent an important structured environment for promoting physical activity, while contemporary STEM/STEAM approaches increasingly advocate the integration of different disciplinary domains rather than treating them as isolated areas of knowledge.

The results related to students' perceptions of the STEPAM lessons provide a particularly strong indication of the acceptability of this approach. All five items assessing students' experiences of the implemented lessons had high mean values, ranging from 4.08 to 4.47. The highest score was obtained for the item referring to inquiry-based activities (PE4, M = 4.47), suggesting that students especially appreciated opportunities to explore and investigate within the Science lessons. Similarly, students expressed high levels of agreement that they liked the activities implemented during the STEPAM lessons (PE2, M = 4.37) and that they would like to participate in STEPAM lessons more often (PE5, M = 4.37). These results suggest that the integration of physical activity with Science and Mathematics did not reduce students' enjoyment of learning; rather, the active and inquiry-oriented character of the lessons appears to have contributed to a positive learning experience.

This finding is consistent with the theoretical perspective presented in the introduction, according to which meaningful connections among disciplines can support deeper learning and the application of knowledge in practical contexts. STEM literacy is not limited to the acquisition of isolated disciplinary knowledge, but also involves the ability to use scientific, technological and mathematical knowledge in meaningful real-life situations. The positive responses to the STEPAM lessons therefore suggest that physical activity can provide an additional context through which such interdisciplinary connections become more concrete and accessible to primary school students.

The findings concerning students' general attitudes toward integrated STEPAM learning provide further support for this interpretation. The affective items (A1, A2, A3 and A6) produced relatively high mean values, ranging from 3.96 to 4.24. Students generally agreed that connecting Science, Mathematics and Physical Education was fun and interesting and that they liked learning through physical activities. This is important because previous research has shown that positive attitudes toward physical activity and physical education are associated with greater motivation, stronger intentions to be physically active and greater engagement in physical activity.

At the same time, the results for A4 and A5 suggest that students did not generally perceive integrated learning as highly difficult. Both items had a mean value of 2.62, which is below the midpoint of the five-point scale. This indicates that, despite the simultaneous engagement with several subject areas, students did not predominantly experience the integrated activities as cognitively demanding. However, the relatively high coefficients of variation for these two items (CV = 34.20%) indicate greater diversity in students' perceptions of difficulty. This suggests that although integrated learning was generally acceptable, individual students may differ in the extent to which they perceive interdisciplinary tasks as cognitively

demanding. Such variation should be taken into account when designing future STEPAM activities, particularly with regard to task complexity, pacing and the level of scaffolding provided by the teacher.

One of the most interesting findings concerns item A7. The mean score of 4.67, with 64.6% of students strongly agreeing and a further 31.6% agreeing, indicates a pronounced preference for sitting and studying Science and Mathematics rather than engaging in physical exercise. This result deserves particular attention because it appears to contrast with the generally positive attitudes toward STEPAM activities. In other words, students may enjoy physical activity when it is embedded in academic learning, while simultaneously maintaining a general preference for sedentary forms of studying. The low coefficient of variation for A7 (CV = 10.13%) further indicates a high degree of consensus among students. This finding may be particularly important in relation to the problem of insufficient physical activity among children discussed in the theoretical framework. Previous research cited in this study indicates that many children do not achieve recommended levels of physical activity during the school day and that schools therefore have an important role in creating additional opportunities for movement. The present results suggest that STEPAM could represent one possible way of addressing this challenge without necessarily requiring additional curriculum time exclusively devoted to Physical Education. Instead, physical activity may be embedded within Science and Mathematics learning, thereby creating opportunities for movement while simultaneously pursuing academic learning goals.

Particularly noteworthy are the findings for A8 and A9, which indicate that students perceive benefits for their understanding of learning content when subjects are integrated. A8 had a very high mean score (M = 4.51), with more than 90% of students selecting either “agree” or “strongly agree.” A9 also received a positive mean score (M = 3.87). These findings suggest that students do not perceive physical activity merely as a recreational addition to academic lessons. Rather, they may recognise movement as contributing to their understanding of Science and Mathematics content. This supports the broader theoretical premise of integrated education that knowledge can become more meaningful when learners are able to establish connections between different domains of experience.

Taken together, the findings provide a positive answer to both research questions. First, students demonstrated positive perceptions of the STEPAM activities in which they participated. Second, they expressed generally positive attitudes toward integrating physical activities with Science and Mathematics content. The particularly high ratings of inquiry-based activities, enjoyment, willingness to participate in more STEPAM lessons, and perceived improvement in understanding suggest that the approach has considerable potential from the students’ perspective. However, the results also indicate that positive experiences with integrated activities do not automatically eliminate students’ broader preference for sedentary academic behaviour. This distinction is important and suggests that STEPAM should be viewed not as a complete solution to physical inactivity, but as one pedagogical strategy that can increase opportunities for meaningful movement within academic learning.

The findings should nevertheless be interpreted with caution. The study involved 79 fourth-grade students from central Serbia, all of whom participated in two STEPAM lessons before completing the questionnaire. Consequently, the findings primarily reflect students' perceptions of a short-term learning experience and cannot be interpreted as evidence of long-term changes in attitudes or physical activity behaviour. Furthermore, because the internal consistency coefficients were not sufficient to justify the formation of composite scales, the items were analysed individually. This approach provides useful information about specific aspects of students' perceptions but limits the possibility of making broader claims about a single underlying attitude construct.

Future research should therefore involve larger and more diverse samples, a greater number of STEPAM lessons and, where possible, longitudinal or quasi-experimental designs. It would also be valuable to examine whether repeated exposure to integrated, physically active learning can influence not only students' perceptions but also their motivation, physical activity levels, academic achievement and retention of Science and Mathematics knowledge. Further research could additionally investigate differences according to age, gender, prior academic achievement and students' initial attitudes toward physical activity.

Conclusion

The present study provides evidence that primary school students have predominantly positive perceptions and attitudes toward the STEPAM approach. Students evaluated the implemented STEPAM lessons highly positively, particularly the inquiry-based activities, and expressed a desire to participate in such lessons more frequently. They also generally reported that connecting Science, Mathematics and Physical Education was interesting and enjoyable and that integrated learning could help them understand the learning content better.

An important contribution of the study is the finding that physical activity can be perceived by students not only as an independent educational objective but also as a meaningful component of academic learning. Integrating movement into Science and Mathematics lessons may therefore provide an opportunity to increase students' exposure to physical activity while simultaneously supporting interdisciplinary learning. This is particularly relevant given the limited amount of time allocated to Physical Education in many educational systems and the continuing concern about insufficient physical activity among children.

At the same time, the high agreement with the statement indicating a preference for sitting and studying rather than exercising demonstrates that positive attitudes toward STEPAM activities should not be equated with a general preference for physical activity. This finding highlights the importance of designing learning environments in which movement is naturally and meaningfully incorporated into everyday academic learning rather than treated as an occasional addition.

Overall, the results suggest that STEPAM represents a promising pedagogical approach for connecting physical activity with Science and Mathematics learning in primary education. Its potential lies particularly in combining inquiry, interdisciplinary learning and movement in ways that students perceive as enjoyable and supportive of their understanding. Further research is needed to determine whether these positive perceptions can be sustained over longer periods and whether regular implementation of STEPAM can contribute to measurable improvements in students' learning, motivation and physical activity behaviour.

Acknowledgment

This research was conducted within the framework of the STEPAM project, co-funded by the European Union under the Erasmus+ Programme, Cooperation Partnerships in Higher Education. Grant No. 2023-1-RS01-KA220-HED-000166894. Project title: Teacher Training in Physical Activities and Embodied Learning through STEAM Education – STE(PA)M.

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https://doi.org/10.46793/STEPAM26.196S
Udk: 81`232:78-053.4

LANGUAGE ACQUISITION THROUGH MUSIC AND MOVEMENT

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Abstract: The preschool period is the most intensive phase of children's language and musical development. These two aspects of development occur in parallel, suggesting the application of related content and approaches in early education. Building on findings that the earliest forms of children's singing precede the speech period, and on numerous analogies between language and music, this paper explores the possibilities for language acquisition through music and movement. Movement, in this context, serves as a didactic tool that mediates between music and language, facilitates the integration of diverse areas, content, and abilities, and promotes rapid and effortless language acquisition.

Key words: *language development, music, movement, integration, preschool age.*

Introduction

In the programme design for the early childhood education and care in the contemporary educational landscape, the importance of a holistic approach is emphasised as the most appropriate strategy for working with preschool-aged children, whose „intellectual, emotional, sensomotor, social and speech development are mutually conditioned and intertwined“(*Preschool Education Program Framework – Years of Ascent*, 2018, p. 5).

Instead of focusing on individual knowledge of each methodology, the emphasis is on an integrated approach to learning, within which educators model a relationship of inquiry and collaboration (Krnjaja, 2015, p. 196). The main characteristic of learning in the preschool period is that it appears through holistic child development. The preschool period is the most intensive phase of speech and musical development, which is why timely stimulation through various content, training, and pedagogical interventions is essential; any potential shortcomings are difficult to make up for. Based on the finding that the earliest forms of children's singing precede the speech period (Voglar, 1997), by numerous analogies between language and music, this paper explores the possibilities of language acquisition through musical content and activities. At an early age, the most obvious, spontaneous examples of music and language integration are based on movement. Movement, in this context, serves as a didactic tool that mediates between music and language, enables the integration of different content and abilities, and promotes the rapid and easy acquisition of language.

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The influence of music on speech development

The influence of musical stimulation on speech development has been the subject of numerous recent studies (François et al., 2013; Knight & Rabon, 2017; Papadimitriou et al., 2021; Politimou et al., 2022). Assessments of the musical and speech abilities of preschool-aged children show that rhythmic and synchronisation skills are a significant predictor of developed phonological awareness (awareness of sounds and syllables), and that a developed ability to perceive melody is linked to the development of grammar (Politimou et al., 2022). Developed musical abilities also correlate with the ability of speech segmentation, i.e., with language comprehension (François et al., 2013).

Listening to, perceiving, and processing sounds and musical structures influences the development of speech prosody, and rhythmic and prosodic abilities play a very significant role in language acquisition (Groß et al., 2010). By learning the lyrics and melody of a nursery rhyme with the children, the educator promotes the reproduction of phonological and prosodic structures, thereby significantly enhancing the children's language skills. It is the children's song, in which musical and literary content are combined, that is most often the link for integrating these two areas. It is applied in various areas of music education – listening to music, composition, playing an instrument, and performing musical games – but in educational practice, as well as in research on the early stages of language and musical development, the singing of nursery rhymes is the most prevalent. Singing a song is often, but not always, complemented by other musical activities.

Through singing songs and mastering singing techniques, we improve breathing and muscle control, stimulate vocalisation, develop receptive and expressive speech, and improve the ability to articulate sounds correctly (Geist et al., 2008, p. 311). Relaxation exercises, breathing and vocalisation exercises that precede singing, matching the rhythm of speech and music, and expanding a child's vocabulary and their ability to understand lyrics all contribute to both speech and musical development.

Integrative music therapy, in the form of singing and playing percussion instruments and the piano, even for a short period of time, leads to a significant improvement in various aspects of speech development in children with delayed speech development, primarily to the development of speech comprehension, speech production (application of morphological rules) and the development of phonological short-term memory (echolalic recall of nonsense syllables) (Groß et al., 2010). At the same time, playing musical instruments improves the fine motor skills of the hand and fingers (Baklanova & Novikova, 2016), which is very significant for speech development. The findings of recent research confirm the positive impact of playing a particular instrument on the individual components of children's language development and abilities, even into their school years (Song, 2023).

In spontaneous creative expression by preschool children, whether verbal or musical, there is often a meaningful integration of the sense of hearing, motor skills, and the verbal expression of feelings (Groß

et al., 2010). Creative singing, as the first, spontaneous form of singing and creative expression, can manifest in two forms. The first is the invention of melody and rhythm, in which the words play a secondary role and may be reduced to individual sounds or groups of words. The second type of singing creativity is narrative invention prompted by the child's current activities, thoughts, or memories, in which the melody is subordinate to the words (Voglar, 1997, p. 15). All forms of creative singing, although spontaneous, unrepeatable, simple, and/or formless, are the first step towards a later conscious acquaintance with the principles of the poem's creation, "based on the musical transposition of the expressive means of speech" (Petrović, 2014, p. 15). The educator's role is to support the creation of spontaneously made-up lyrics that a child has sung in the same tune, and to encourage the use of movement or instruments such as bells, rattles, the clavichord, or xylophone as part of the spontaneously initiated creative process. An integrative approach to the development of children's speech and musical creativity activates their creative potential, particularly in children with delayed speech development who are not accustomed to symbolic expression, inventing fantastical stories, and sound play (Groß et al., 2010).

The development of correct diction in a child's expressive speech involves mastering a series of speech elements, which include the rhythm and tempo of speech, word accent, pauses in speech, sentence melody, intonation, and correct breathing. Mastering the aforementioned elements of diction also contributes to the development of singing skills, so the entire series of exercises provides both verbal and musical stimulation. Such exercises include breathing exercises, listening exercises, articulation gymnastics, and oral-motor exercises. Breathing exercises help to strengthen the diaphragm and increase lung capacity, and at the same time, we practise correct posture with the children, i.e., the singing stance. It should be noted that other exercises, such as rhythmic improvisations to music, "help to develop coordination and flexibility, promote the proper formation of the body's muscular and skeletal systems, and the development of balance" (Baklanova & Novikova, 2016, p. 3).

The development of auditory attention leads to the development of receptive speech, as well as musical abilities. Given the temporal nature of musical content, attention and concentration are a prerequisite for the successful realisation of all forms of musical activity. The educator leads the exercise by making a sound while the children, with their eyes closed, guess where the sound is coming from. This exercise also encourages the discrimination of sound characteristics: duration, timbre, and intensity. In a second variation of the exercise, the educator speaks quietly, and the children, one by one, repeat what they have heard. The game Chinese Whispers / Telephone helps to develop auditory attention and draws attention to the importance of clear and loud pronunciation when passing on a message.

Articulation exercises, or oral praxis exercises, involve drills to increase the suppleness of the moving parts of the speech apparatus. We warm up the tongue, lips, and facial muscles through play, whilst ensuring we maintain an upright posture and relaxed shoulders. In addition to developing the speech apparatus, the exercises are also important for the development of the vocal apparatus (Bratić & Filipović,

2001).

Oral-motor exercises contribute to mastering the correct position of the speech apparatus when pronouncing sounds. The correct pronunciation of vowels contributes to speech intelligibility, as well as to the development of vocal diction. To begin with, oral-motor exercises should be practised when pronouncing vowels. When vowels are pronounced, the opening of the mouth is at its widest, the tip of the tongue is positioned low in the oral cavity, and the airflow exits unimpeded (Đurković-Pantelić, 1998, p. 84–85). After the children correctly position the parts of the speech apparatus, they repeat with the teacher the lengthened pronunciation of the "a" sound.

For the correct pronunciation of the "e" sound, it is important that the children stretch their lips into a smile, with a small gap between their teeth; when pronouncing "i", the lips are also stretched, but the opening is smaller than for the "e" vowel. The oral-motor exercise for the vowel "o" begins with shaping the lips into a circle (the educator demonstrates and invites the children to repeat the lip movements after them), while for "u", the lips remain rounded, but the opening is smaller than for "o". Articulation exercises for the critical consonants being developed in preschool children should be accompanied by illustrations of the positions of the articulatory organs (Spasić, 2023, p. 55–61).

Movement, as part of various exercises for pronouncing vowels and consonants, contributes to the development of speech and singing diction, but its role is not limited to these aspects of a child's development. In the process of acquiring language and musical content, movement acts as a cognitive tool that enables the transfer of auditory information to the internal mental plane (Vukićević & Petrović, 2020) and helps in familiarising oneself with and understanding new concepts. In doing so, children are further motivated and engaged, and the entire learning process takes place in a positive socio-emotional climate.

Movement as a link between the integration of speech and musical development

Music, or musical activities, has a stimulating effect on all aspects of children's development, with previous research most often highlighting the positive effects of music on the development of mathematical-logical abilities, verbal memory, reading ability, and more accurate pronunciation of a second (foreign) language, musical abilities, social skills and later academic achievements (Miendlarzewska & Trost, 2014; Rašković & Popović, 2021).

The musical content and activities for children used in educational work are aligned with the stages of musical development, and the selection of content is, in this respect, made according to age and the critical period for acquiring specific knowledge and skills in various domains. When we speak of early learning and development, the most frequent way a child expresses and learns is through movement. The use of movement in the learning process is in keeping with children's natural need to move, and music, with its expressive means, further encourages them to be active.

A children's song, sung while illustrating its lyrical content with movements, becomes a singing game; listening to a composition, whose character or melody is brought to life through movement, transforms into a type of game – a game with instrumental music. Movement is an indispensable part of performing the counting-out rhyme, which enriches it but also aids its precise execution and develops a child's sense of rhythm, their perception of rhythmic pulsation, and the stressed and unstressed parts of a bar. Due to its clear and distinct rhythm, or the rhythmic pronunciation of its syllables, the counting-out rhyme is suitable for practising lip mobility and contributes to the correct and clear pronunciation of consonants and vowels. (Bratić & Filipović, 2001, p. 83).

The movement also plays a significant role in integrative activities, as it brings together different educational and developmental areas. We will provide a few examples. As we have previously noted, musical content suitable for integrating speech development and musical education primarily includes all types of songs in which the literary content is the basis and the music is a descriptive means (Ivanović, 1981, p. 147). These include folk songs and songs composed to the verses of well-known authors for children, such as J. Jovanović Zmaj, D. Erić, Lj. Ršumović or M. Antić. After familiarising themselves with the text of the song, this is followed by a vocal reproduction of the song, and the simplicity, rhythm, and other characteristics of the songs covered at preschool age encourage children to perform most of them with movement. In terms of genre, performing the song with movement can take the form of a folk dance, be through a choreographed routine, or the children can be given the freedom to find their own dance expression in keeping with the dominant mood they recognise in the song.

In addition to singing, listening to songs can also be a cornerstone for integrating speech and musical education. This is done by recording a listened-to song using word symbols or hand gestures, thereby fostering symbolic and non-verbal communication skills. To introduce the children to these forms of communication, the educator will first record the song lyrics themselves using word symbols (pictures which will be used to record common nouns with a concrete meaning from the song's text), and will also use hand gestures where possible to represent the actions in the song. After presenting various songs to the children in this way several times, the educator will encourage the children to present the songs themselves using pictographic writing and/or by changing the hand movements.

In a wide range of different musical games (Sudzilovski & Ivanović, 2015), music games with lyrical content are particularly suitable for an integrative approach. A music game is the most spontaneous way for a child to express their musical abilities, sense of rhythm, and their perception of melody and lyrics, and in performing it, they bring out their creativity. (Ivanović, 1981, p. 15). During musical games, in which children are free from the pressure to speak, but do so spontaneously, a child with delayed speech development or a child with speech difficulties often speaks more, because they feel more relaxed (Pitt, 2020, p. 69). Children's musical play, as a form of open-ended play, promotes communicative abilities, and the educator's role is to observe the children's musical games, participate in them as a co-player, and observe

the communication process during play (Pitt, 2020, p. 72). During the performance of the musical game, a young pre-school child communicates by expressing their emotional state through laughter, vocalisation, gestures, rhythmic activity that accompanies the lyrics of the song they are listening to, as well as through singing self-composed songs, which often have a complex melodic contour (Pitt, 2020, p. 75).

The application of the kamishibai technique in an integrated approach provides a unique opportunity for the development of children's narrative skills. According to Dušica Bojović, kamishibai is not just storytelling with pictures, but a kind of "theatre in miniature" that activates attention and imagination (Bojović, 2018). In order to integrate speech, music, and movement, kamishibai is used as a visual trigger for speech, where children, while observing illustrations of a fairy tale (e.g., "The Three Little Pigs"), simultaneously listen to musical accents that accompany the action. In this way, syncretism is encouraged – the child connects the visual stimulus (the picture), the auditory (the music), and the verbal (their own speech), which significantly accelerates the acquisition of new words and correct sentence structure. Additionally, through movement, children show the action and the characters' movements in a dance dramatisation, in which the educator, in the role of a narrator, tells the plot of the fairy tale, and the children independently devise the appropriate dance expression (Kamenov, 2007: 230). By imitating characters and actions through role-play or imaginative and improvisational games, children are introduced to dramatic creativity (Milovanović, 2019: 190).

Shared thematic content across different areas is the fundamental starting point for integration, which must be built upon with other structural methods of connection. Thematic proximity between literary and musical content, even in the title of a work, encourages integrative activities and assists educators in their creation and implementation. For example, after introducing the text of the fable The Hare and the Tortoise through a dramatisation, such as kamishibai or a puppet show, the children can be taught the rhyme The Tortoise and the Hare. In the introductory part, the educator leads a discussion with the children about types of animals, with an emphasis on recognising the speed at which they move. At the educator's prompt, the children imitate the movements of the hare and the tortoise and act out their race through drama. In the final part, the children perform the rhyme "The Hare and the Tortoise". Depending on the text at a particular point, the educator plays rhythmic motifs quickly or slowly, and the children imitate the rabbit and the tortoise in keeping with the tempo.

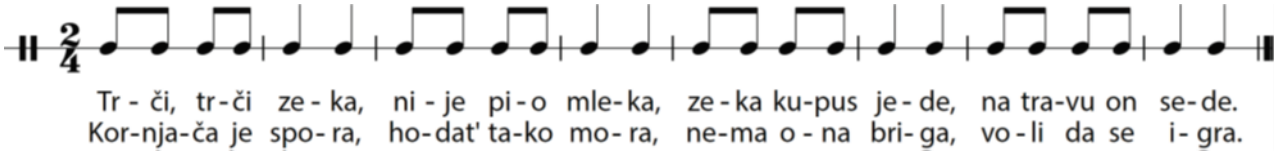

Figure 1. The 'Hare and the Tortoise' counting rhyme

When working on a nursery rhyme, integration can also be established in the introductory part of the integrated activity, as in the following example of working on the nursery rhyme “At Grandma's”. In the introductory part, the breathing exercise is accompanied by a oral-motor exercise for the “l” sound, which can be used with older and preschool-age children.

‘Children, we said that in this picture we see a house. Grandma lives in this house, and I have to reveal something to you. Grandma has prepared something very tasty, and it's… "palačinka”[26] (I show the illustration.) I say the word “palačinka ” (eng. pancake) emphasising the correct pronunciation of the “l” sound and invite the children to repeat after me. I show the children an illustration for the articulation of the “l” sound and say: 'Let's open our mouths and roll our tongues up like a pancake, so that the tip of the tongue goes behind the upper front teeth.' I touch the alveolar ridge with a spatula and say that the tip of the tongue goes on the bump. The tongue remains in that position, and we all say the “l” sound. Then, we say the other words: leaf, school. ‘Now we're going to imagine we're setting off to Grandma's. As we skip, we hum la-la-la-la-la-la.’ We link the “l” sound with the other vowels through movement. In this way, the oral-motor exercise is transformed into breathing exercises, shaped according to the rhythmic patterns in the nursery rhyme or performed with dynamic nuance.

The integrated exercises described constitute a system that simultaneously promotes the development of both speech and musical abilities. The introductory part of the planned learning situation allows for the combination of breathing exercises with syllable games, articulatory gymnastics, and oral-motor exercises.

The aforementioned fairy tale “The Three Little Pigs”, modified and supplemented with elements of language and musical play, provides children with numerous opportunities to encourage their verbal and musical expression and gives them the chance to recognise the sounds and rhythm that accompany the story. Through various activities, children develop their aural skills (sounds of instruments and animal noises), distinguish tempo (fast/slow – how the wolf blows and how the pigs run) and dynamics (the wolf's arrival, departure, and singing – quiet/loud), develop a sense of rhythm (rhythmic repetition, percussion), and expressive speech (language games). Furthermore, participating in group activities fosters team spirit and cooperation. We will present the main segments below.

After the musical dramatisation in which the three little pigs play different instruments (the youngest pig – the flute, the middle pig – the violin, the eldest pig – the shaker), the educator introduces the children to a language game.

Morphological games / Game: ‘Let's help the piglets remember their instruments.’

Aims:

– To develop the ability to form diminutives;

[26] The mentioned exercises have been carried out in the mother tongue of this paper' s authors – Serbian; the given word “palačinka” contains the letter ‘l’, which is not present in the English equivalent of that word - ’pancake’.

– To develop communication skills;

– To develop listening and comprehension skills;

– To stimulate the development of articulation by perceiving and imitating the sounds of musical instruments;

– Developing a sense of pitch, rhythm, and coordination through imitation and musical interaction;

– Encouraging creativity by linking the story with language and musical exercises.

Preparation: The children sit in a semicircle, and we begin a motivational conversation: 'Friends, our friends the piglets have forgotten what they called their instruments! Help me remind them!' The first piglet had a flute. If it called the flute 'flutie', what would it call the shaker? If it called the shaker 'shakery', what would it call the violin?

We tell the children that the piglets have forgotten how to play and that our task is to help them, to remind them what their instruments sound like and how they are played.

Imitating instruments:

The first pig plays the flute. How does a flute make its sound? Help them to remember! (The children blow through an imaginary flute and make the sound 'f-f-f', following the rhythm set by the educator.)

The second pig made a rattle. How do you use a rattle? (The children shake real or imaginary rattles and make the sound 'sh-sh-sh'.)

The third pig plays the violin. Show how we play the violin! (The children pretend to play the violin with their hands and make the sound 'v-v-v'.)

Musical Circle:

The teacher conducts and chooses a child to take over as conductor using a counting-out rhyme. The children are divided into three groups. The teacher points to one group who plays their instrument (e.g., points to the "flutes" and they make the sound "f-f-f"). Then they include the second group (e.g., 'maracas' – 'sh-sh-sh'), then the third ("violins", 'v-v-v'). In the end, they all play together, forming an improvised orchestra. The children come up with and suggest a name for the orchestra (e.g., 'The Singing Pigs').

Conclusion

The common features of speech and music, the primary and most obvious of which are rhythm and intonation, imply the need for integrated activities and content from these areas in the complex and continuous process of a child's speech and musical development at an early age. In addition to speech and music, other aspects of a child's development also occur simultaneously, which is why a holistic approach to learning dominates in educational practice. Movement is an indispensable part of a child's holistic and integrated development, and its importance is particularly emphasised in modern society, where there is less and less movement and where children's primary need for movement is neglected (Franolić, 2018:4).

The aforementioned premises have prompted the exploration of the possibility of language acquisition through movement-based musical activities, which are the focus of this paper. Based on the presented examples of integrated activities in individual segments of planned learning situations or in various forms of drama and creative play, several conclusions were drawn.

The integration of speech development and musical education involves the application of related content, as well as joint activities aimed at the simultaneous development and learning of children in both areas. The methodological aspects are based on movement, as the most natural and purposeful means of learning at the preschool age. From movements of the speech and singing apparatus, through the imitation of certain characters or actions, or as a form of expressing the experience of a particular musical characteristic, movement takes on the role of a cognitive tool that mediates between the two areas, enabling better memory, faster acquisition of knowledge, and positively influencing all aspects of a child's development.

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BRIDGING THE BODY AND MIND: A CONCEPTUAL FRAMEWORK FOR INTEGRATING PHYSICAL ACTIVITY AND STE(A)M EDUCATION IN K-12 SETTINGS

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Abstract: The global decline in childhood physical activity, coupled with increased curriculum pressures in STEM disciplines, demands innovative pedagogical approaches that resolve the tension between academic performance and student well-being. This conceptual paper addresses this challenge by establishing the PA-STE(A)M Framework, an actionable tool designed to map the integration of physical activity and STE(A)M education in K–12 settings. Grounded in embodied cognition theory, interdisciplinary learning theory, and neurobiological research, the framework organizes diverse pedagogical approaches along two key axes: the physical environment continuum (informal movement vs. structured physical education) and the subject integration continuum (activity assistance vs. core subject integration). Intersecting these dimensions reveals four operational pathways, each yielding distinct academic, physical, and cognitive outcome profiles. While movement-based instruction shows significant promise for enhancing student focus and transdisciplinary learning, practical implementation faces systemic barriers, including limited teacher readiness, rigid structural silos, and resource inequity across socioeconomic school districts. Ultimately, this framework underscores that the human body can serve as an active tool for deep learning, offering curriculum planners and educators a strategic blueprint to support both mind and body simultaneously.

Keywords: embodied learning; interdisciplinary curriculum; physical activity; STEAM education; curriculum framework.

Introduction

The global decline in physical activity (PA) among school-aged children represents a pressing public health challenge. The World Health Organization (2022) reports that over 80% of adolescents fail to meet recommended daily physical activity guidelines, a trend that accelerates rising rates of childhood obesity, metabolic disorders, and mental health concerns. Simultaneously, educational systems worldwide face structural pressures to optimize student performance in STEM (Science, Technology, Engineering, and Mathematics) disciplines. This systemic push frequently results in a zero-sum curriculum game where

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The paper is a result of the Erasmus+ Project: Teacher Training in Physical Activities and Embodied Learning through STEAM Education, Grant No. 2023-1-RS01-KA220-HED-000166894

instructional time allocated to physical education (PE) and active play is systematically stripped to make room for sedentary academic preparation (Centers for Disease Control and Prevention, 2019). The friction between critical public health mandates and rigorous academic accountability demands an innovative pedagogical compromise.

The integration of PA with STE(A)M (STEM and also Arts) education offers a compelling resolution to this dual problem. Rather than treating physical wellness and cognitive development as competing instructional targets, integrated models reconceptualize bodily movement as an active instrument for complex learning. This approach aligns with contemporary cognitive science models of embodied cognition and neurobiological frameworks showing a strong link between physical exercise and executive brain function (Diamond & Ling, 2016; Donnelly et al., 2016). Additionally, it supports transdisciplinary perspectives that treat science, arts, and bodily movement as integrated ways to express "multiple creativities" (Burnard et al., 2022). This integration is evident in the Nordic tradition of phenomenon-based learning, where students engage with authentic, real-world problems using exergames (Sinnemäki et al., 2025) and embodied exploration (Fenyvesi et al., 2021).

Despite strong theoretical justifications, the empirical literature exploring movement-integrated instruction remains highly fragmented. No unified framework has systematically categorized how PA combines with specific STE(A)M disciplines within K-12 settings, nor have the operational variations of these interventions been clearly synthesized. This conceptual paper addresses this gap by establishing the PA-STE(A)M Framework. The main aim of this study is to characterize the structural distribution, pedagogical strategies, and learning outcomes of movement-based STE(A)M programs while highlighting critical blind spots in the current literature.

Literature Review

Embodied Cognition Theory

The primary theoretical foundation for integrating movement with academic learning is embodied cognition theory. This perspective rejects traditional Cartesian dualism—which treats the mind as a centralized information processor distinct from the physical body—and argues that cognitive processes are grounded in sensorimotor interactions with the environment (Glenberg, 2010; Wilson, 2002). Abstract concepts, particularly those found in advanced mathematics and scientific reasoning, are understood through metaphorical mappings derived from baseline bodily experiences (Lakoff & Núñez, 2000). For example, a child's understanding of numerical scale, spatial orientation, or mathematical functions is deeply scaffolded by early sensorimotor interactions with volume, distance, and gravity. Physical manipulation of objects has been shown to build perceptual simulations that enhance conceptual reading comprehension

(Glenberg, 2010). When applied to STE(A)M education, this principle suggests that the physical enactment of scientific systems—such as acting out planetary orbits or using coordinated group movements to graph geometric equations—builds richer, more accessible mental schemas than purely symbolic worksheets (Goldin-Meadow & Beilock, 2010). Understanding emerges from physical engagement with content.

Interdisciplinary Learning Theory

Curriculum integration theory provides the organizational architecture needed to connect physical activity with academic inquiry. Fogarty's (1991) models of curriculum integration outline a spectrum ranging from simple "parallel" alignment—where separate subjects coordinate concurrent topics (such as evaluating heart rates in biology while running in PE)—to deeply "immersed" or "networked" configurations. In these higher-order configurations, traditional disciplinary boundaries dissolve, allowing students to explore authentic, complex problems. A clear example of this is phenomenon-based learning, which organizes inquiry around multifaceted, real-world questions. The STE(A)M movement expands this integration by intentionally weaving the "Arts" into STEM contexts to champion creative expression, aesthetic appreciation, and qualitative design thinking (Quigley & Herro, 2016). Physical movement fits naturally into this structure; it serves as a design space where students can physically test scientific hypotheses, generate kinesthetic data, and exercise creative agency. In a true transdisciplinary framework, physical activity is not a rest break between lessons, but an active way to co-create meaning (Burnard et al., 2022).

Neurobiological Mechanisms

Neuroscientific and educational research demonstrates clear mechanical connections between physical exercise and brain function. Acute, well-timed bouts of aerobic movement enhance short-term cognitive control, working memory, and attention management in children (Hillman et al., 2008). These cognitive boosts are driven by immediate physiological changes: increased cerebral blood flow, heightened neurotransmitter activity in the prefrontal cortex, and elevated expression of brain-derived neurotrophic factor, which supports neural flexibility and synaptic growth (Chaddock-Heyman et al., 2014). Longitudinal research reveals that routine physical activity throughout childhood correlates with greater hippocampal volume, improved long-term memory retrieval, and enhanced structural integrity in brain white matter, which accelerates processing speeds (Esteban-Cornejo et al., 2017). Crucially, these neurological benefits are significantly stronger when physical activity includes deliberate cognitive engagement and problem-solving, rather than just repetitive aerobic exercise (Best, 2010; Pesce et al., 2013). Combining cognitive challenge with coordinated movement optimizes neurological processes in ways that sedentary learning environments cannot reproduce.

Methodology and analysis

The PA-STE(A)M Framework operates as a multi-dimensional model designed to organize and map diverse pedagogical approaches. Instead of viewing integration as a singular method, the framework classifies interventions along two primary crosscutting continuums: the physical environment context and the depth of academic subject integration.

The Core Dimensions

- The Physical Environment Continuum: This dimension ranges from general physical activity (informal, non-sport, or classroom-bound movement) to structured physical education (formal PE classes, specialized sports environments, or gym-based curricula).
- The Subject Integration Continuum: This dimension separates technology and activity assistance (where movement or digital devices merely support, measure, or break up the school day without embedded subject instruction) from core subject integration where specific STE(A)M disciplines, concepts, and transdisciplinary academic curricula are taught directly through and within the physical movement.

When these two continuums intersect, they establish four distinct operational pathways, each yielding a specialized developmental and academic outcome profile:

Pathway 1: Physical Activity with Technology/Activity Assistance

This approach pairs general classroom settings or informal movement periods with supportive active breaks or basic tracking utilities, without embedding core academic lessons. A typical implementation involves short classroom movement intervals that utilize tools like wearable pedometers, step counters, or gamified active screens to prompt physical action.

Pathway 2: Physical Activity with Core Subject Integration

This approach embeds specific STE(A)M curricula directly into daily, general school movements outside of formal sports environments. Rather than using movement as a simple mental break, the physical action is intentionally designed to mirror or reinforce an academic concept. Examples include children physically pacing out geometric dimensions, jumping to count mathematical intervals, or using body geometry to represent algebraic functions within the standard classroom environment.

Pathway 3: Physical Education with Technology/Activity Assistance

This approach introduces digital devices, performance tracking tools, or gamified movement into formal physical education and sports environments, focusing on the activity itself rather than academic subject mastery. Common examples include utilizing wearable fitness trackers, heart rate monitors, and specialized sports telemetry tools during track, field, or team sports to monitor and optimize physical performance.

Pathway 4: Physical Education with Core Subject Integration

This approach converts formal physical education, sports, and athletic movement into an experiential laboratory for deep STE(A)M subject inquiry. It represents a transdisciplinary strategy where complex scientific, mathematical, or engineering concepts are explored through athletic performance. Examples include students using structured track-and-field activities to generate raw data for kinematic equations, analyzing body mechanics and leverage principles during gymnastics to study physics, or calculating kinetic energy expenditure during sports.

Conclusions

Summary of Gaps and Limitations

While combining physical activity with STE(A)M education shows clear promise, the field can be constrained in the implementation and environment. The first limitation could be related to teacher readiness. It could not be assumed that in regular classrooms, teachers possess the pedagogical content knowledge to integrate movement, or that PE teachers are equipped to teach advanced STEM concepts. The second obstacle is the structural silos, which is related to the organizational challenges of collaborative co-planning between PE specialists and classroom teachers within rigid, traditional school timetables. Lastly, the barriers is related to resource inequity. Depending on the schools and regions, there is variation in the access to space, wearable tracking devices, and integrated curriculum materials across different socioeconomic school districts.

Implications for Practice and Pedagogical Applications

The PA-STE(A)M Framework serves as an actionable design tool for educators, curriculum planners, and school administrators looking to move away from isolated active breaks toward structured, meaningful integrated learning. Teachers can use this framework to purposefully align their choice of movement with their main target outcomes. This model demonstrates that movement does not detract from academic achievement; rather, it makes learning more engaging. By using the human body as an active tool for learning, school systems can counter classroom fatigue, improve student focus, and deliver deep, transdisciplinary lessons that support both mind and body.

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https://doi.org/10.46793/STEPAM26.212V
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ENCOURAGING CHILDREN'S DEVELOPMENT THROUGH THE INTEGRATION OF STEM AND EARLY ENGLISH LANGUAGE LEARNING IN THE TRANSITION FROM KINDERGARTEN TO SCHOOL

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Abstract: The purpose of this paper is to present an example of good practice in fostering children's development through the integration of STEAM activities and early English language learning during the transition from kindergarten to primary school. The study explores how integrated project-based activities contribute to the development of inquiry skills, communication, collaboration, independence, and vocabulary enrichment in both the mother tongue and English. Transition is understood as a process that supports children's adaptation from preschool to primary education through continuity of learning experiences and the development of competencies essential for future learning. The STEAM approach provides opportunities for active, experiential, and inquiry-based learning while encouraging creativity, critical thinking, problem-solving, and communication. The research was conducted through the project 'Little Explorers', implemented collaboratively by a preschool teacher and an English language teacher. Children participated in investigations related to plants, nature, and simple scientific experiments, while simultaneously using English vocabulary in authentic learning situations. The findings indicate that integrating STEAM activities with early English language learning supports children's engagement, inquiry-based thinking, collaboration, and language development, while also strengthening competencies relevant to school readiness and successful transition to primary education.

Keywords: STEAM, early English language learning, preschool education, transition, project-based learning.

Introduction

Modern preschool upbringing and education is aimed at creating a stimulating environment in which the child actively participates in the learning process, explores, asks questions and comes to new knowledge through direct experience. In accordance with modern educational paradigms, emphasis is placed on the development of competences for lifelong learning, creativity, critical thinking, cooperation and communication (OECD, 2019).

One of the most important periods in a child's life is the transition from preschool to elementary school. This process implies adaptation to new rules, relationships and expectations, but also the development of skills that will enable the child to be successfully included in the school system. Transition is not a one-time event, but a continuous process involving the child, family, preschool and school teachers (Dockett & Perry, 2014).

Modern approaches emphasize the importance of integrated learning, which connects different areas

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of development and enables the child to acquire knowledge through experience and solving authentic problems. The STEM approach (Science, Technology, Engineering and Mathematics) represents one of the most significant innovative models of work in early education. STEM activities encourage children to explore, experiment, reason logically, and develop an investigative spirit (Tank et al., 2018).

Modern educational systems increasingly emphasize the development of competences for the 21st century, among which creativity, critical thinking, cooperation, communication and the ability to solve problems stand out (OECD, 2019; UNESCO, 2021).

At the same time, early learning of a foreign language offers the possibility of developing communication competences and broadening children's experiences through getting to know new concepts and cultures. Numerous studies show that children of preschool age acquire a foreign language most successfully through play, movement and everyday activities (Cameron, 2001).

Starting from these theoretical foundations, the paper discusses the possibility of connecting the STEM approach and early English language learning as support for the transition process from kindergarten to school. As an example of good practice, a project implemented in an older educational group before starting school was presented.

Transition from kindergarten to school

Transition represents one of the most important developmental transitions in early childhood. It implies the transition from one educational system to another and includes changes in the social, emotional, cognitive and organizational aspects of the child's life. Modern approaches to the transition emphasize the importance of continuity of experiences, active participation of the child and the development of socio-emotional competencies as a prerequisite for successful adaptation to the school environment (UNICEF, 2022).

According to Dockett and Perry (2014), a successful transition depends not only on the child's readiness for school, but also on the school's readiness to accept differences among children and provide support for their further development. Modern approaches emphasize the concept of continuity in learning, which implies connecting the experiences from kindergarten with the experiences that the child acquires in school.

The program basics of "Years of Uprise" especially emphasize the importance of respecting the individual potential of the child and building a positive self-image during the transition (MPNTR, 2018). In that process, the child should be an active participant, not a passive recipient of knowledge.

Numerous studies show that a well-organized transition contributes to a better adaptation to school, a higher level of self-confidence and greater motivation to learn (Pianta & Cox, 1999).

STEM approach in preschool education

STEM represents an interdisciplinary approach to learning that integrates natural sciences, technology, engineering and mathematics through problem solving and the investigation of phenomena from the immediate environment. Contemporary research indicates that STEM experiences can begin already in early childhood through everyday activities of research, experimentation and problem solving appropriate to the age of children (Fleer, 2019, 2022).

Unlike traditional work models, STEM does not start from the reproduction of knowledge, but from research and active engagement of children. Children ask questions, propose solutions, check assumptions, and draw conclusions based on their own experiences (Katz, 2015).

At preschool age, STEM activities can include:

- research of natural phenomena,
- experiments with water, air and light,
- construction and building,
- measurement and comparison,
- solving problem situations.

Such activities encourage the development of critical thinking, creativity, cooperation and communication, which is the basis for the development of 21st century competencies (National Research Council, 2012). The European Commission recognizes STEM education as one of the key factors in the development of competencies required for life and work in modern society (European Commission, 2020).

The special importance of the STEM approach is reflected in the fact that the child acquires knowledge through direct experience. Active participation in research activities develops independence, perseverance and the ability to solve problems, which is an important prerequisite for a successful transition into the school system.

Early English language learning in preschool age

Today, early learning of a foreign language is an integral part of many preschool education programs. Modern approaches are based on the view that a child acquires a foreign language in a similar way as his/her mother tongue - through communication, play and everyday situations (Cameron, 2001). Research shows that children acquire a foreign language more successfully when its use is connected to meaningful activities, play and exploration in authentic learning situations (Hadley et al., 2021).

According to Lev Vygotsky's theory of social constructivism (1978), learning takes place through social interactions and joint activities with adults and peers. In this sense, the acquisition of a foreign language should be integrated into everyday activities that make sense for the child.

Numerous studies indicate that early foreign language learning has multiple developmental benefits for preschool children. In addition to improving communication skills, it contributes to the development of

language sensitivity, that is, the ability to recognize and understand language structures, as well as enriching vocabulary. At the same time, the process of acquiring a foreign language encourages the development of attention, memory and flexibility of thinking, as children learn to connect different concepts, meanings and communication situations. Early familiarization with another language and culture also contributes to the formation of positive attitudes towards differences, the development of tolerance and openness towards other cultures and ways of life (Pinter, 2017).

When foreign language learning is integrated with research and STEM activities, children acquire language in authentic situations, through experience, play and problem solving, which contributes to the durability and functionality of acquired knowledge (Pinter, 2017; Hadley et al., 2021).

It is especially important when a foreign language is not learned in isolation, but through activities that have a practical purpose and are connected to the children's interests. In such situations, children spontaneously acquire new words and expressions without a sense of formal learning.

Integrating STEM and Early English Language Learning

The integration of the STEM approach and early English language learning represents an innovative work model that connects investigative learning with the development of communication competences. During STEM activities, children naturally come into contact with new terms and concepts. If part of those concepts are introduced in English, the child connects them with a concrete experience, which makes it easier to understand and acquire the meaning.

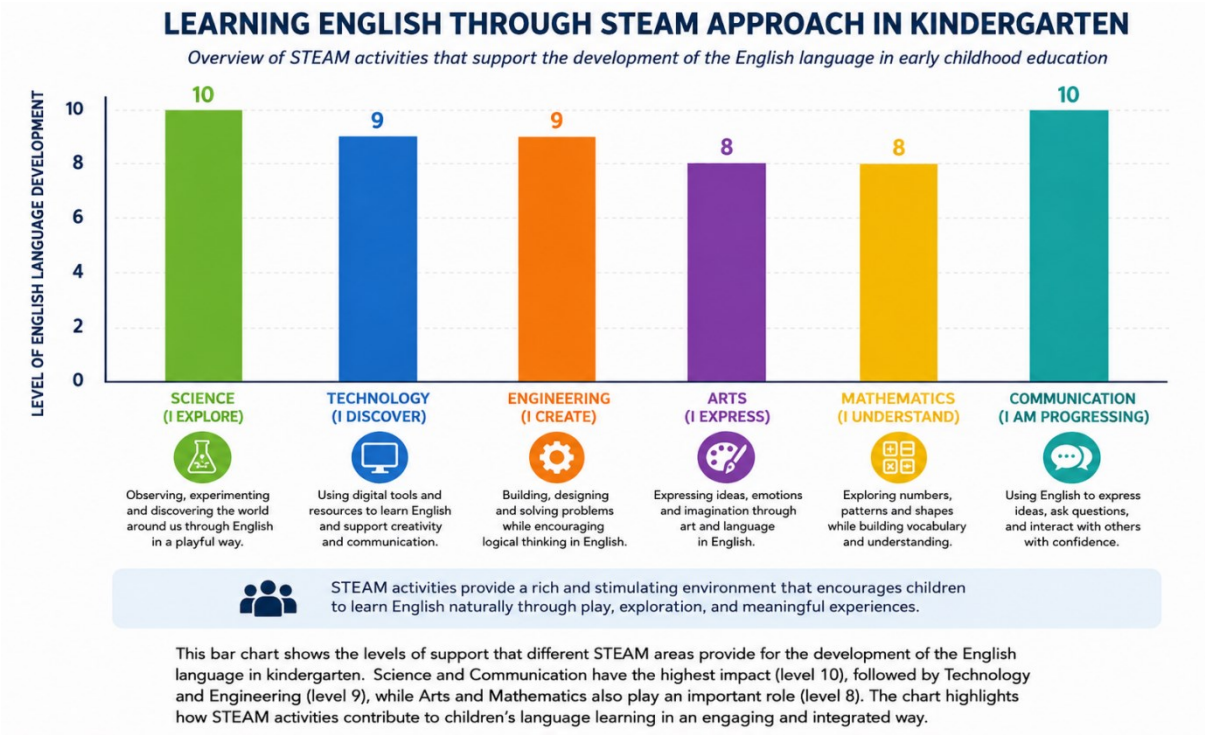

Figure 1. Learning English through the STEAM approach in kindergarten

For example, during the project about plants, children can learn the terms: *plant, seed, water, soil, flower, grow.* At the same time, through practical activities, they develop scientific literacy, the ability to perceive and reason. Such an integrated approach enables the development of several competencies at the same time: research, communication, social and linguistic. It also contributes to children's greater motivation to learn because activities arise from their interests and experiences (Edwards, 2017).

Research methodology

The research was carried out using a qualitative methodology with elements of action research and case studies. This approach was chosen with the aim to see in the natural context of preschool institutions the possibilities of encouraging children's development by integrating STEM activities and early English language learning during the transition process from kindergarten to school.

Action research enables the simultaneous monitoring and improvement of educational practice through the cycle of planning, realization, observation and reflection (Kemmis, McTaggart & Nixon, 2014). Given that the goal of the research was aimed at understanding the process of learning and development of children in an authentic environment, this approach proved to be the most appropriate.

Subject, aim and research questions

The subject of the research refers to the possibilities of encouraging children's development by applying an integrated STEM approach and early English language learning during the transition process from preschool to elementary school.

The goal of the research was to examine the contribution of the integration of STEM activities and early English language learning to the development of competencies important for successful school entry, as well as to present an example of good practice that can be applied in working with preschool children.

In accordance with the set goal, the following research questions were defined:

How do children participate in STEM activities during the implementation of the project?

How do children use concepts in English during research activities?

What changes can be observed in communication and cooperation among children?

How do integrated activities affect motivation for learning and research?

How does this approach contribute to the development of competencies important for the transition to school?

Research sample and context

The research was conducted in the Creative Workshop "Pinocchio" in Valjevo. The sample consisted of 25 children of the older educational group, aged 5.5 to 6.5 years, who were in the year before starting school and participated in English learning activities in the kindergarten as the part of educational program on regular basis. The sample was intentional, because all the children were involved in the "Little Explorers" project, which was the basis of the research. The preschool teacher in charge of the group and

the English language teacher jointly planned and implemented integrated learning project activities.

Description of the project

The research was carried out during eight weeks through the "Little Explorers" project. The project was created based on children's interest in plants, nature and experiments. The starting questions that the children asked were: "How does a plant grow?", "What does it need to live?" and "Why do some plants grow faster than others?". This approach is based on modern concepts of project-based learning that arise from children's interests and active construction of knowledge through experience (Fleer, 2022).

Activities included planting seeds, observing changes, experimenting with light and water, measuring plant growth, recording results, drawing and documenting the process. At the same time, concepts in English, such as plant, seed, flower, leaf, water and grow, which the children used in different situations during the project, were integrated into the activity.

Data collection

Multiple data sources were used to ensure methodological triangulation.

The main source of data was the systematic observation of children during the implementation of project activities. The observation was aimed at monitoring the frequency of asking questions, initiating activities, proposing solutions, cooperating with peers, using English language and the degree of independence in work.

An important source of data was the analysis of children's products, which included drawings, plant growth charts, photos of activities and notes created during the project. The analysis of these materials allowed a deeper insight into the process of learning, understanding and progress of children.

In addition, during the entire research, a reflective diary of the preschool teacher was kept, which contained a description of the activities carried out, observations on the children's engagement, observed changes and guidelines for further work planning.

Project documentation was used as an additional source of data, which included photos of activities, records of conversations with children and documented examples of their research.

Data processing and analysis

The collected data were processed using qualitative content analysis. The analysis process included identifying recurring patterns of behavior, comparing data obtained from different sources, grouping data into thematic categories and interpreting the results in relation to the research questions.

Based on the analysis, five analytical categories were distinguished:

1. investigative behavior and scientific thinking of children;
2. use of English language;
3. cooperation and communication;
4. independence and initiative;
5. competencies important for the transition from kindergarten to school.

The aforementioned categories enabled a systematic review of the effects of the integration of STEM activities and early English language learning on the development of preschool children.

Ethical aspects of research

The research was conducted in accordance with the ethical principles of working with preschool children. Children's participation in activities was part of regular educational work. When documenting the activities, the principles of confidentiality, privacy and anonymity of the participants were respected. All collected data was used exclusively for research purposes.

Research limitations

The research results refer to one educational group and cannot be generalized to the entire population of preschool children. Nevertheless, the presented example of good practice provides valuable insights into the possibilities of integrating STEM activities and early English language learning in the preschool context and can represent a starting point for future research and development of innovative educational programs.

Research results

The results of the research are presented through five thematic categories that emerge from the research tasks and the analysis of the collected documentation. Data were obtained by observing children during activities, analyzing children's products, teachers' reflective notes and project documentation.

Development of investigative behavior and critical thinking

One of the most significant results of the research is related to the increased interest of children in researching natural phenomena. During the implementation of the "Little Explorers" project, children actively participated in research activities, spontaneously asked questions, made assumptions and suggested ways to test their ideas. The obtained findings confirm the views of the authors who point out that the early involvement of children in STEM activities contributes to the development of scientific literacy, research competences and problem-solving abilities (Bers, 2018; Fleer, 2022). At the beginning of the project, the questions that the children asked mainly related to the basic characteristics of plant growth, such as: "How does a plant grow?" and "Why does she need water?". However, as the activities progressed, the questions became more complex and indicated a more developed understanding of cause and effect relationships. For example, the children asked questions such as: "Will the plant grow if we put it in the dark?", "Why did one plant grow more than the other?" and "Does the plant need more water when it's warm?".

The above questions indicate the development of the ability to perceive, conclude and formulate assumptions, which is the basis of scientific thinking in early childhood (National Research Council, 2012). Through observation, it was found that during the project, children more and more often independently proposed ways to solve problems and check their assumptions. In the final stages of the project, most

children actively participated in planning simple experiments, monitoring changes and interpreting the obtained results.

The obtained findings confirm that integrated STEM activities encourage the development of investigative behavior and critical thinking in preschool children. Through direct experience, experimentation and joint reflection on the results, children developed curiosity, initiative and the ability to reason logically, which is an important prerequisite for a successful transition from kindergarten to school.

The obtained findings confirm the author's views that STEM activities encourage the development of research competencies and critical thinking through direct experience and active participation of the child (Tank et al., 2018).

Figure 1. Observed Indicators of Exploratory Behaviour

Indicator	*Observed change*
Asking questions	Marked increase
Formulation of assumptions	Moderate to high increase
Independent research	Independent research
Drawing conclusions	Drawing conclusions
Reasoning ideas	Reasoning ideas

Development of language competences and acquisition of English language

The analysis of the realized activities showed that the children spontaneously adopted and used English words during the STEM activities. English language activity was not organized as a separate area of work, but was integrated into everyday research situations and activities that arose from children's interests and project work.

During the implementation of the project, the children most often used terms such as *plant, water, seed, flower, leaf, sun* and *grow*. In addition to acquiring individual words, the children gradually began to use simple statements in English, such as: "This is a plant.", "It needs water.", "The flower is growing." and "The seed is small." The use of these expressions was most pronounced during the activities of observing, experimenting and talking about the changes they observed in plants. In the process of language acquisition, children rely on ready-made *lexical chunks* that they can use with less effort compared to inventing a new phrase or sentence. Within these fragments some parts can be changed and inserted: *It's a* ..... (Cameron, 2001: 50). These phrases are a source of grammar development as they can be shared and combined even though no formal grammar teaching is taking place.

Through observation, it was noted that in the initial phase of the project, children mostly repeated words and expressions after English language teacher or preschool teacher. However, as the activities progressed, they used the adopted terms more and more independently during the game, talking with their peers and presenting their observations. This progress indicates a gradual transition from reproductive to functional use of language in authentic learning situations.

The teachers' reflective notes indicate that the children showed a high level of motivation for using English language precisely because of its connection with concrete experience and activities that had meaning for them. Learning new words took place spontaneously, without insisting on the formal acquisition of language content, which contributed to a positive atmosphere and greater involvement of children in activities.

The obtained results confirm the findings of numerous authors who emphasize that children acquire a foreign language more successfully when it is integrated into everyday activities and connected to experiences arising from their interests and needs (Cameron, 2001; Pinter, 2017). The integration of STEM activities and early English language learning proved to be a stimulating framework for the development of language competences, communication skills and active participation of children in the learning process.

Only situational guidance can ensure language acquisition and its authentic use in real life contexts, as well as the stimulation of interest in children, and the achievement of a stable level of language acquisition and communicative ability.

Development of cooperation and communication

During the implementation of the project, significant progress was noted in the mutual cooperation of children. Most of the activities were organized in smaller groups, which encouraged joint problem solving, exchange of ideas and active involvement of each child in the learning process. Such organization of work enabled children to develop skills of communication, agreement and joint decision-making.

Such results can be related to the findings of the OECD (2021), which indicate that cooperation, communication and socioemotional skills are significant predictors of later school success.

Through observation, various forms of collaborative behavior were observed, among which joint planning of activities, distribution of tasks, mutual assistance during work, joint drawing of conclusions and presentation of group work results stand out. During the activities, the children showed their readiness to listen to the opinions of their peers, exchange ideas and jointly search for solutions to problem situations that arose during the research.

In the teacher's reflective notes, it was particularly emphasized that the more withdrawn children gradually became more active in communicating with their peers and increasingly confident in expressing their ideas. During the duration of the project, an increase in the frequency of mutual support was observed, as well as a greater willingness of children to assume different roles in the group work. Such changes indicate a positive impact of project-organized STEM activities on the development of social competences and a sense of belonging to a group.

The obtained results confirm the findings of the authors who point out that STEM activities create natural conditions for the development of collaborative learning and social competences, because they encourage children to explore together, share experiences and construct new knowledge through interaction

with peers (Katz, 2015). In this sense, cooperation proved to be not only a tool for the implementation of activities, but also an important development outcome that contributes to a more successful preparation of children for school.

Table 2. Changes in social interactions

Form of behavior	Beginning of the project	End of the project
Collaboration with peers	Moderate	High
Sharing materials	Moderate	High
Joint problem solving	Low	High
Independent presentation of ideas	Moderate	High

Development of independence and initiative

During the implementation of the project, a significant improvement in children's independence was observed. Through various research activities, the children gradually took responsibility for the tasks they performed, showing increasing initiative and confidence in their work. Compared to the initial stages of the project, when they more often sought the support of adults, in the final activities the children planned and carried out individual tasks more independently.

Forms of behavior that indicate the development of independence were especially singled out, such as watering plants independently, measuring their growth, recording changes, proposing new activities and making conclusions based on the collected data. The children showed responsibility for the tasks they undertook, as well as the willingness to independently solve minor problems that arose during the activity.

In the final stages of the project, it was observed that children initiate new experiments more often and ask additional research questions. Such behavior indicates the development of curiosity, self-confidence and internal motivation for learning, which is an important goal of modern preschool upbringing and education. In addition, children showed greater persistence in work and willingness to take responsibility for the results of their activities.

The obtained results confirm that STEM activities, based on research and experiential learning, create favorable conditions for the development of independence and initiative in preschool children. The development of these competencies is one of the important indicators of readiness for school and a successful transition to the next level of education, as it contributes to the training of the child for active and responsible participation in the learning process (Pianta & Cox, 1999).

STEM and English as support for the transition to school

The analysis of the research results shows that the integration of STEM activities and early learning of English can represent a significant form of support for the process of transition from preschool to elementary school. During the implementation of the project, changes were observed that indicate the development of competencies important for the successful inclusion of children in the school environment.

The results are in accordance with the recommendations of UNESCO (2021), according to which the education of the future should be based on cooperation, creativity, sustainable development and active involvement of children in learning processes.

In children, greater confidence in expressing their own ideas and opinions, more expressed curiosity and willingness to research, as well as greater perseverance in solving problems was observed. Also, better communication with peers, greater readiness for cooperation and a more developed ability to plan and organize activities were observed. During the project, the children showed initiative, took responsibility for the tasks they completed and actively participated in decision-making, which is an important indicator of their independence and readiness for new educational challenges.

The aforementioned competencies are recognized as significant indicators of school readiness, as they enable the child to adapt more successfully to the demands of the school environment and actively participate in the learning process. In addition to the development of cognitive and language skills, the integrated approach also contributed to the strengthening of socio-emotional competencies, which play an important role in the process of adaptation to school.

The obtained results are in accordance with the modern concept of transition, which emphasizes the continuity of experiences between kindergarten and school, as well as the active role of the child in the process of learning and development (Dockett & Perry, 2014). In this context, STEM activities and early English language learning can be seen as a significant resource for creating a stimulating environment in which a child develops the competencies necessary for a successful transition to the next level of education.

Based on the findings, it can be concluded that the integration of STEM and early English language learning contributes not only to the acquisition of new knowledge and skills, but also to the development of key competencies that support a successful transition, empower the child as an active participant in the learning process, and contribute to his/her long-term educational well-being.

Discussion

The results of the research indicate that the integration of STEM approaches and early English language learning is an effective model for encouraging the overall development of preschool children. The special importance of this approach is reflected in the fact that children acquired new knowledge and skills through active research, experimentation and direct experience, which is in line with modern understandings of the child as an active participant in the learning process. In such an environment, the child is not a passive recipient of information, but a researcher who asks questions, checks assumptions and constructs his own knowledge through interaction with peers, adults and the environment.

Analysis of the results showed that STEM activities encouraged the development of investigative behavior, critical thinking and problem-solving abilities. During the project, the children gradually moved

from simple observation of phenomena to asking more complex questions, formulating assumptions and drawing conclusions based on the collected data. Such findings confirm the results of previous research indicating that STEM activities represent a significant stimulus for the development of scientific literacy and research competencies in early childhood (Tank et al., 2018; Edwards, 2017).

A particularly significant finding relates to the integration of English language in STEM activities. The obtained results show that the children spontaneously acquired and used English words and simple statements in authentic situations, without formal teaching and insistence on the reproduction of language content. Language learning took place through research activities that had a clear meaning and practical purpose for the children. Such an approach confirms the views of authors who point out that early acquisition of a foreign language gives the best results when it is connected to the experiences, interests and daily activities of children (Cameron, 2001; Pinter, 2017).

In addition to cognitive and language development, the results indicate a significant contribution of the integrated approach to the development of social competences. Organizing activities in smaller groups enabled children to collaborate, exchange ideas, solve problems together and take on different roles during work. It is particularly significant that even the more withdrawn children gradually became more active in communicating with their peers, which confirms that project and research organized activities create a stimulating environment for the development of collaborative learning and a sense of belonging to a group.

The research results also indicate the development of independence and initiative in children. During the project, children increasingly independently planned activities, made decisions and took responsibility for the tasks they carried out. Such behavior is an important indicator of the development of competencies that are necessary for successful adaptation to the school environment.

Independence, responsibility, perseverance and willingness to solve problems are recognized as significant elements of school readiness and important prerequisites for successful further education.

A special contribution of this research is reflected in looking at the possibility of connecting the STEM approach, early English language learning and the process of transition from kindergarten to school. The obtained findings indicate that integrated activities contribute to the development of competencies that represent the basis for future school learning, whereby the transition is not viewed only as preparation for school, but as a process of continuous development of the child. In this sense, the research results support modern conceptions of transition that emphasize the continuity of experiences between kindergarten and school, as well as the active role of the child in the learning and development process (Dockett & Perry, 2014).

Although the results refer to a limited sample and cannot be generalized to the entire population of preschool children, they indicate the significant potential of an integrated approach for improving the quality of preschool education. At the same time, they open up space for future research that would include a larger number of institutions, different models of STEM activities and longer-term monitoring of the

effects of this approach on school adaptation and later educational achievements of children.

Conclusion

The results of the research showed that the integration of STEM activities and early English language learning represents a stimulating work model that contributes to the overall development of preschool children and provides significant support for the transition process from kindergarten to school. During the implementation of the "Little Explorers" project, positive developments were observed in the development of research behavior, communication skills, cooperation, independence and motivation for learning.

The obtained findings confirm that experiential learning, research and connecting different areas of development enable children to actively participate in the learning process and develop competencies important for future school education. The special value of the integrated approach is reflected in connecting STEM content with authentic English language learning situations, which encourages the development of cognitive, linguistic and socioemotional competencies.

Although the research results have limitations arising from the sample size, the presented example of good practice indicates the possibilities of successful implementation of integrated STEM programs in preschool institutions. Based on all of the above, it can be concluded that STEM activities and early English language learning represent a significant potential for improving the quality of preschool education and supporting children in the process of transitioning from kindergarten to school. The findings support contemporary international recommendations that emphasize the importance of integrated STEAM approaches, development of competencies for the 21st century and creation of a stimulating environment for the successful transition of children to formal education (OECD, 2019; UNESCO, 2021).

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https://doi.org/10.46793/STEPAM26.226ZC
Udk: 37.015.3-057.875]:004

IMPLEMENTING THE CREATIVE STEM APPROACH IN THE EDUCATION OF PRESCHOOL AND EARLY SCHOOL PEDAGOGY STUDENTS

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Abstract: This paper explores selected educational initiatives designed to incorporate the STEM approach into the preparation of future preschool and early childhood teachers at the University of Radom. Particular attention is devoted to the importance of cultivating creativity, innovation, and a sense of agency among both university students and young learners. The article discusses the application of active teaching strategies, including inquiry-based activities, experiments, and learning through research stations, as effective ways of implementing STEM principles. It also presents examples of collaboration with local educational institutions, outlines successive stages in introducing coding and educational robotics into teacher education, and highlights the importance of preparing future teachers to work with children representing diverse educational needs. Furthermore, the study emphasizes the necessity of strengthening students' digital competences as an essential component of contemporary teacher education. Although organizing such initiatives requires considerable institutional commitment, coordination, and logistical support, the experience demonstrates clear educational benefits, including enhanced self-efficacy, stronger motivation, and greater readiness among future teachers to integrate STEM practices into preschool and early primary education.

Keywords: STEM, student education, elementary education, creative activities, self-efficacy, 4Cs

Introduction – Promoting Creative Attitudes in Education

The revised national core curriculum for preschool and early primary education introduced by the Polish Ministry of Education (2026) in March 2026 and scheduled for implementation from September 2026, represents a significant shift in educational priorities. Rather than concentrating primarily on the transmission of extensive factual knowledge, the new curriculum places greater emphasis on developing key competences through active participation in learning. Among its central objectives is strengthening children's sense of agency, understood as their confidence in making decisions, planning activities independently, solving authentic problems, and accepting responsibility for the consequences of their actions.

In educational practice, these assumptions encourage wider implementation of project-based learning, inquiry-oriented activities, experimentation, and collaborative tasks in which learners actively construct knowledge instead of merely receiving information from the teacher. Equally important is the development of technical and digital competences. These competences are no longer interpreted solely as the ability to operate digital devices; instead, they encompass the responsible, creative, and critical use of technology for investigating real-world phenomena, solving problems, and supporting lifelong learning.

Introducing these curricular changes presents considerable challenges for teachers working in

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preschools and the early years of primary education. Successful implementation requires moving beyond traditional teacher-centered instruction towards learning environments that foster independence, cooperation, reflection, and active exploration. Consequently, teachers need to expand their expertise in learner-centered methodologies, project-based instruction, and the purposeful pedagogical integration of digital technologies into everyday classroom practice. This transformation also demands new approaches to lesson planning, assessment, and the creation of learning experiences that genuinely strengthen children's autonomy and decision-making. Therefore, the effectiveness of the reform will depend not only on teachers' professional commitment but equally on access to high-quality professional development, institutional support, and adequate educational resources.

Encouraging creativity and innovation also requires an educational environment in which participants are able to make independent decisions while accepting responsibility for their consequences and possible risks. Such conditions should be accompanied by relationships based on partnership and mutual respect, both between teachers and pupils and between university lecturers and teacher education students. This type of academic culture stimulates intellectual initiative, supports independent thinking, and motivates learners to undertake innovative actions (Karwowski & Pawłowska, 2009).

Żeber-Dzikowska (2017) emphasizes that teachers should inspire learners to explore, investigate, experiment, and continuously expand both their knowledge and imagination. Creative attitudes therefore become a fundamental element of effective education. Rather than relying on repetitive instructional routines, teachers should encourage divergent thinking by posing open-ended questions and designing learning situations that allow for multiple possible solutions, reflecting Guilford's concept of creativity (Nęcka, 2001). In this perspective, the educational value lies not only in achieving predefined learning outcomes but also in the process through which these outcomes are reached. Constructive feedback and thoughtful evaluation enable learners to analyze their own mistakes, improve their performance, and independently determine appropriate strategies for further learning.

Collaborative learning constitutes another important aspect of creative education. Working together enables students to distribute responsibilities, negotiate solutions, and develop both their sense of agency and interpersonal communication skills, competencies that have become increasingly valuable in contemporary professional environments.

According to Okraj (2013), teachers can actively encourage creativity through everyday educational practices. These include attentive listening instead of immediate evaluation, supporting learners' independence, demonstrating genuine interest in their ideas, providing assistance when necessary, and creating sufficient time and space for unrestricted thinking. Educational relationships founded on dialogue, openness, and partnership foster both intergenerational learning and peer tutoring. Furthermore, research conducted among school pupils indicates that the development of creative thinking can effectively accompany the process of socialization, allowing intellectual and social competences to develop

simultaneously (Łaszczyk, 2012).

From a broader perspective, the innovative capacity of societies constitutes one of the essential conditions for sustainable economic and social development. Contemporary labor markets require considerably more than technical expertise alone. Creativity, critical thinking, metacognitive awareness, communication, and collaborative problem-solving have become equally important for responding to rapidly changing technological and social realities (Kärkkäinen & Vincent-Lancrin, 2013). Collectively described as the 4Cs—Critical Thinking, Creativity, Communication, and Collaboration—these competences are increasingly recognized as indispensable for functioning successfully in technology-rich environments. As artificial intelligence continues to automate routine cognitive activities, occupations requiring originality, complex interpersonal interaction, and creative problem-solving are expected to become even more prominent (OECD, 2024).

Developing these competences requires more than simply incorporating them into curriculum documents. Their effective implementation depends on adopting innovative pedagogical models, including STEM and STEAM education, integrated learning, project-based approaches, and systematic collaboration among teachers. Evidence synthesized by Ammar et al. (2024), based on a review of forty-two studies concerning primary education, demonstrates that early exposure to integrated and inquiry-oriented STEM instruction contributes substantially to children's creativity, critical thinking, and problem-solving abilities.

These theoretical assumptions should also guide teacher education programmes at universities. Future teachers need opportunities to experience collaborative and inquiry-oriented learning themselves before implementing similar practices in schools. Nevertheless, simply identifying the 4Cs as educational priorities does not automatically translate into classroom practice (So et al., 2017). Teachers occupy a pivotal position in this process because the successful implementation of open-ended inquiry, collaborative dialogue, and design-oriented learning largely depends on their pedagogical competence and willingness to redesign traditional instructional practices (Patston et al., 2021).

Teacher self-efficacy, conceptualized within Bandura's (1977) social cognitive theory, represents one of the strongest predictors of successful educational innovation (Holzberger & Prestele, 2021). Research indicates that professional development programmes explicitly focused on twenty-first-century competences not only strengthen teachers' confidence in their own abilities but also promote collaboration among colleagues and improve the overall quality of school practice (Vincent-Lancrin et al., 2019). These positive effects become even more pronounced in schools characterized by collaborative professional cultures, where teachers jointly design STEM activities and participate in learning communities that reinforce both individual and collective efficacy (Wullschleger et al., 2025).

Preparing Preschool and Early School Teachers for STEM Education

Rapid technological advancement has substantially increased the importance of STEM education as a foundation for preparing future generations to function effectively in contemporary society. Consequently, both pre-service and in-service teacher education should extend beyond the acquisition of disciplinary knowledge and technical skills by fostering creativity, innovation, and the capacity to respond flexibly to educational change. Within this perspective, teacher preparation should be grounded in pedagogical models that encourage active participation in learning, independent inquiry, and authentic problem-solving. Educational approaches such as Problem-Based Learning (PBL), Inquiry-Based Learning (IBL), Design Thinking, Design-Based Research, and Project-Based Learning provide particularly suitable frameworks because they engage learners in constructing knowledge rather than passively receiving it. Current evidence further suggests that integrated STEAM education combined with project-based learning offers one of the most effective pathways for developing the competencies commonly referred to as the 4Cs (Tran et al., 2021).

The educational transformations observed over the past decade have also been accelerated by global crises, which have reshaped both teaching practices and perceptions of the teacher's professional role. Among these, the COVID-19 pandemic significantly strengthened the position of information and communication technologies within educational systems. As digital learning environments became an integral part of schooling, teachers increasingly assumed roles extending beyond knowledge transmission, functioning as facilitators of learning, mentors, coaches, and evaluators who guide students through complex learning processes rather than simply deliver instructional content (Janssen, 2020).

Because STEM education inherently combines scientific inquiry with technological applications, engineering design, and mathematical reasoning, its successful implementation requires educators who can confidently employ both digital tools and appropriate software in meaningful pedagogical contexts. Nevertheless, increased access to technological equipment does not automatically result in improvements in classroom practice. Lim and Chai (2008) observed that the mere presence of digital technologies in schools rarely produces educational innovation unless these tools are accompanied by pedagogically informed instructional strategies. Likewise, Surahman and Wang (2023) demonstrated that the effectiveness of ICT-supported education depends largely on teachers' own digital competences, as well as on their beliefs, attitudes, and willingness to integrate technology into everyday teaching.

These observations underline the necessity of preparing future teachers not only for present educational requirements but also for the continuous transformations that inevitably accompany technological and social development. Teacher education programmes should therefore cultivate adaptability and encourage future educators to seek creative solutions even in situations where schools experience limited access to technological resources. Whenever equipment is unavailable within the school

environment, alternative educational settings—including universities, science centers, research institutions, industrial laboratories, or educational innovation hubs—can provide valuable opportunities for students to experience contemporary STEM practices firsthand. Although organizing such activities often requires additional planning and logistical effort, they expose future teachers to authentic educational environments and reinforce the understanding that professional creativity involves searching for solutions rather than focusing on existing constraints. As Okraj (2013) argues, innovative educators perceive obstacles as challenges that stimulate professional growth rather than barriers preventing effective action.

Equally important is the broader educational environment in which creativity develops. Responsibility for nurturing innovative thinking should not rest exclusively with individual teachers but should also be supported by institutions capable of creating inspiring learning experiences. When such opportunities cannot be fully provided within the school itself, educational activities extending beyond the classroom become particularly valuable. Visits to science centers, technology laboratories, museums, industrial enterprises, or university facilities enable children to integrate knowledge from multiple subject areas while engaging in authentic problem-solving situations. Such interdisciplinary experiences naturally reflect the assumptions underlying STEM and STEAM education by combining scientific, technological, engineering, artistic, and mathematical perspectives within a single learning context.

Recommendations developed by the National Academies of Sciences, Engineering, and Medicine (2016) likewise emphasize the importance of strengthening collaboration between educational institutions and external partners. Professional workshops, mentoring initiatives, and partnerships connecting schools with industry or higher education institutions can significantly enhance teachers' ability to implement STEM approaches effectively. Similarly, educational camps, thematic projects, and visits to industrial or technological centers become particularly valuable when they incorporate inquiry-based tasks that actively engage participants in observation, experimentation, and scientific investigation rather than passive participation.

Educational robotics has emerged as another important component of contemporary STEM education. Research conducted by Çetin and Demircan (2020) indicates that introducing robotics during the first years of primary education contributes to the development of innovative attitudes from an early age. Activities involving programmable devices encourage children to think creatively, establish interdisciplinary connections, and solve problems collaboratively—competencies that are especially valuable in integrated early childhood education.

For this reason, teacher education programmes should place increasing emphasis on developing future educators' digital competences, particularly those related to coding and computational thinking. Preparing teachers to confidently use educational robotics, visual programming environments, and coding activities equips them to introduce STEM concepts effectively into preschool and early primary classrooms (Ziębakowska-Cecot, 2018; Ziębakowska-Cecot & Wieczorek, 2024).

Importantly, educational robotics and coding should not be viewed solely as methods of teaching technical skills. Their educational value extends considerably further by stimulating logical reasoning, supporting systematic problem-solving, promoting teamwork, and encouraging exploratory learning. While mastering these technologies, future teachers simultaneously develop pedagogical strategies that enable them to foster curiosity, experimentation, and independent discovery among young children.

Taken together, these considerations suggest that effective STEM preparation within teacher education programmes should rely on constructivist principles, experiential learning, and authentic project work. Future preschool and early primary teachers need opportunities not only to acquire theoretical knowledge but also to experience innovative educational practices directly. Workshops, interdisciplinary projects, thematic camps, laboratory activities, and collaborative learning experiences provide valuable contexts in which students can develop both professional confidence and practical teaching competence. As Ammar et al. (2024) emphasize, preparing educators capable of nurturing creativity and innovation in children requires combining technological literacy with openness to experimentation, reflective practice, and continuous professional development. Only by experiencing such approaches themselves can future teachers confidently implement STEM education in their own classrooms.

STEM in the Education of Future Preschool and Early School Teachers at the University of Radom

The introduction of programming into the preparation of future preschool and early primary teachers at the University of Radom was a gradual process that evolved alongside changes taking place within Polish education. Initial initiatives originated in the Technical and Information Education (TIE) programme, then offered by the former Faculty of Teacher Training, now the Faculty of Philology and Pedagogy. A major impulse for expanding these activities came in 2014, when the national Core Curriculum for Grades 1–3 formally introduced Computer Classes as a compulsory element of early primary education. This educational reform encouraged the university to incorporate programming content into courses attended not only by TIE students but also by those enrolled in the Preschool and Early School Education programme.

The first instructional activities concentrated on introducing visual programming environments that were considered accessible for future teachers without advanced technical backgrounds. Students became familiar with Lego Komeniusz, Baltie, and later Scratch, which enabled them to experience programming through intuitive and child-friendly environments. Although these tools proved relatively easy to master, many students initially approached the subject with limited enthusiasm. At that time, coding and educational robotics had not yet become common practice in educational institutions across the Radom region, making it difficult for many future teachers to appreciate the practical value of these competences for everyday classroom work.

To bridge the gap between university instruction and educational practice, opportunities were created for students to observe authentic robotics activities conducted with children. Beginning in 2014, groups of university students participated in afternoon visits to extracurricular Lego robotics classes organized by a private educational company in Radom. Similar study visits were arranged in subsequent years at a cooperating Special Educational Center. These experiences allowed students to move beyond theoretical discussions and observe how programming activities could engage children in authentic learning situations.

Students consistently evaluated these visits as one of the most inspiring components of their teacher education. Direct participation enabled them to recognize that educational robotics offers much more than opportunities to develop technical skills. They observed how programming activities naturally encourage creative thinking, strengthen mathematical reasoning, increase learners' sense of agency, and motivate children to cooperate while solving practical problems. Equally important, these experiences often inspired the university students themselves to improve their own digital competences and to perceive technology as an integral component of contemporary teaching rather than an additional educational burden.

Another important milestone resulted from the Comenius Regio project entitled "New Skills: Learning for Success," implemented between 2013 and 2015. Through this initiative, the university obtained its first educational robots – a BeeBot (Figure 1) and an Ozobot – which subsequently became regular teaching resources used with undergraduate, graduate, and postgraduate students of Pedagogy. Although the equipment available at that time remained relatively modest, it significantly expanded opportunities for introducing practical coding activities into university courses and marked the beginning of systematic work with educational robotics.



Figure 1. *Beebot used in a kindergarten in Radom during the implementation of the Comenius Regio project "New Skills: Learning for Success" (own sources)*

A further acceleration of these developments occurred in 2017, when programming and coding digital devices were officially incorporated into the Polish core curriculum for the first stage of education (Czerski, 2018). This reform substantially increased the educational importance of engineering and

technological competences within early childhood education. At the national level, one of the most influential initiatives supporting these curricular changes was Samsung's educational programme "Coding Masters" (Mistrzowie Kodowania). Between 2013 and 2018, approximately 4,000 teachers participated in professional development activities devoted to both unplugged and digital coding, educational robotics, and programming applications. The knowledge acquired through this programme subsequently reached more than 100,000 primary school pupils (Samsung).

An important continuation of these nationwide initiatives was Świć's "Coding on the Carpet" programme (2017), which substantially contributed to the dissemination of coding activities among preschool children. Rather than focusing exclusively on programming itself, these educational programmes promoted broader pedagogical goals, including creativity, imagination, independent reasoning, collaborative learning, and systematic problem-solving. Coding was therefore presented not as an isolated technical skill but as a means of supporting children's comprehensive cognitive development.

Despite the increasingly favorable educational climate at the national level, the implementation of similar ideas within university education progressed more gradually. Introducing innovative technological content into teacher preparation required changes not only in curricula but also in attitudes towards contemporary educational methods. Some academic staff and many students initially questioned whether programming should become an important element of early childhood education.

Evidence of these reservations emerged from a survey conducted in 2017 among fifty-five students enrolled in the Preschool and Early School Education programme. The findings revealed that nearly half of the respondents (44%) still questioned the educational value of introducing programming in the earliest years of schooling (Kuźmińska-Sołśnia & Ziębakowska-Cecot, 2017). These results demonstrated that preparing future teachers for STEM education involves more than providing technological knowledge. Equally important is changing educational beliefs and increasing awareness of how programming, coding, and educational robotics can support children's holistic development, creativity, and independent thinking.

The gradual expansion of technological resources in Polish schools created favorable conditions for introducing more comprehensive STEM activities into teacher education programmes. Government initiatives supporting the development of school ICT infrastructure, including Active Board, enabled many educational institutions to acquire interactive equipment and digital teaching tools. An even more significant step was taken in 2021 with the launch of the Future Laboratories programme, implemented by the Ministry of Education and Science in cooperation with the GovTech Center. Through this initiative, primary schools obtained funding to purchase equipment designed to strengthen pupils' technological and engineering competences, including educational robots, 3D printers, and 3D pens.

These nationwide developments directly influenced the organization of teacher education at the University of Radom. As technological resources became increasingly available in schools, it became evident that university curricula also required revision in order to prepare future teachers for the realities of

contemporary classrooms. This process involved not only updating course content but also investing in new educational equipment and expanding opportunities for professional development. Additional workshops devoted to 3D printing and STEM education using Modi programmable building blocks were organised for students, eventually leading to the establishment of a dedicated STEM laboratory at the Faculty of Philology and Pedagogy in 2023.

Before the university created its own laboratory, practical STEM experiences were provided through cooperation with external educational partners. Study visits became an important component of teacher preparation, allowing students to observe technologies that were not yet available on campus. One of the most valuable destinations was the demonstration laboratory operated by the Future Industry Platform foundation, where participants explored educational applications of virtual reality, augmented reality, and additive manufacturing technologies. Students had the opportunity to test AR/VR headsets, observe various stages of 3D printing, and discuss how these technologies could enrich learning experiences in preschool and primary education.

Visits to Radom Public Primary School No. 17 complemented these activities by exposing students to authentic classroom environments in which equipment purchased through the Future Laboratories programme was already being incorporated into everyday educational practice. Observing teachers and children working with contemporary technological resources allowed university students to better understand both the possibilities and practical limitations associated with implementing STEM in real school settings.

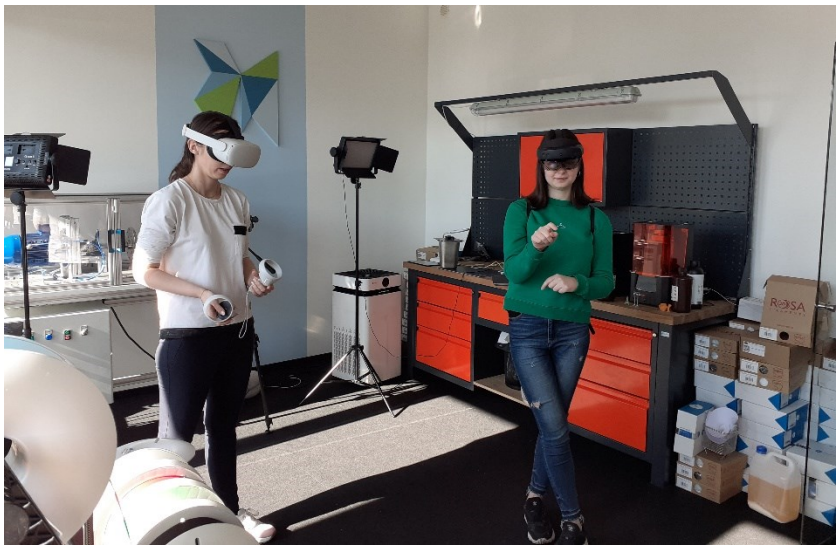

Figure 2. *Workshops AR/VR and 3D printing in the laboratory of the Future Industry Platform foundation (own sources)*

While the university was gradually expanding its STEM infrastructure, it also became important to evaluate whether these initiatives sufficiently prepared future teachers for professional practice. For this purpose, a diagnostic survey was conducted between May and June 2024 among 103 students enrolled in Preschool and Early School Education programmes, of whom approximately two-thirds were studying at the

University of Radom. The results demonstrated that although respondents acknowledged encountering STEM or STEAM-related content during compulsory courses and additional educational activities, many still considered the amount of instruction insufficient. More than half of the participants (52%) believed that STEM education should occupy a more prominent position within their university programme (Ziębakowska-Cecot & Wieczorek, 2024).

The survey also revealed another important challenge. Despite completing compulsory teaching placements in preschools and primary schools, slightly more than half of the respondents admitted that they had never independently designed or conducted a STEM or STEAM lesson. Consequently, many students did not yet feel adequately prepared to plan interdisciplinary activities integrating science, technology, engineering, and mathematics into early childhood education. These findings suggested that expanding theoretical instruction alone would not be sufficient. Future teachers needed opportunities to experience authentic STEM teaching situations in which they assumed responsibility for planning, organising, and conducting educational activities themselves.

These findings suggest that participation in school placements alone does not necessarily translate into readiness to implement interdisciplinary STEM education. Practical experience appears to require structured opportunities for designing, leading, and critically reflecting on authentic STEM activities during university studies.

Recognising these needs, the Faculty of Philology and Pedagogy decided that during the following academic year students would no longer remain passive observers of innovative educational practice. Instead, they would become designers and facilitators of STEM workshops prepared for groups of primary school children. This shift reflected the broader educational assumption that professional confidence develops most effectively through authentic teaching experience rather than through theoretical instruction alone.

Implementing this idea required overcoming a number of organizational and methodological challenges. One of the first issues concerned scheduling. Previous experience had shown that students rarely participated willingly in extracurricular activities organized outside their regular timetable. Consequently, the workshops had to be integrated into compulsory university classes. This practical limitation significantly influenced the selection of cooperating institutions. Because travel time needed to be minimized, only schools located within approximately fifteen minutes' walking distance from the university campus were considered. An alternative solution involved inviting groups of children directly to the university, allowing future teachers to conduct workshops within the facilities of the newly established STEM laboratory while avoiding lengthy travel during scheduled classes.

Collaboration with local primary schools proved particularly valuable in this respect. Teachers agreed to organise educational visits for classes of approximately twenty-five pupils, who travelled to the university using public transport. This arrangement created authentic learning conditions for both groups

of participants. Children were given an opportunity to experience university life and engage in activities unavailable in their schools, whereas teacher education students assumed responsibility for planning and implementing educational workshops in an unfamiliar yet professionally relevant environment.

Rather than treating these visits as isolated demonstrations of technology, the university adopted a broader educational objective. The workshops were designed to create learning situations in which university students could integrate methodological knowledge with organizational skills, teamwork, creativity, and reflective decision-making. In this way, STEM education became not only the subject of instruction but also the pedagogical framework through which future teachers developed their own professional competences. From the perspective of teacher education, this shift proved particularly significant. Instead of learning about STEM through observation alone, students became responsible for making pedagogical decisions in authentic teaching situations, thereby transforming theoretical knowledge into professional competence.

Designing and Implementing STEM Workshops for Primary School Children

Once the organizational framework had been established, attention shifted towards designing educational activities that would simultaneously support the professional development of university students and provide meaningful STEM experiences for visiting primary school pupils. The planning process extended far beyond selecting attractive technological tools. Equal emphasis was placed on identifying a thematic context capable of stimulating curiosity, encouraging interdisciplinary thinking, and naturally integrating scientific inquiry with engineering design and creative problem-solving.

The local educational environment offered an inspiring point of departure. The presence of both a civil and military airport in Radom, together with the city's aviation traditions and the opening of the FlyPort science centre at Warsaw-Radom Airport in autumn 2024, made aviation an appropriate and highly engaging theme for the project. Before preparing activities for children, university students participated in their own study visit to FlyPort, where they explored the interactive exhibition and analyzed how aviation-related topics could be transformed into learning experiences suitable for pupils in the first stage of primary education.

The visit served a broader pedagogical purpose than simply expanding subject knowledge. It was intended to encourage future teachers to experience inquiry-based learning from the learner's perspective before designing similar experiences for children. During subsequent university classes, students discussed methodological principles related to introducing young learners to technical devices, drawing particularly on the concepts proposed by Jelinek (2018). Rather than immediately preparing lesson plans, they first engaged in exploratory activities themselves, conducting simple experiments, analyzing technological phenomena associated with flight, and collectively constructing mind maps that organized the key concepts

of the planned educational project.

This preparatory stage encouraged students to connect scientific knowledge with methodological reflection. Crossword puzzles related to aviation terminology, designed by fellow students, were incorporated as introductory activities promoting collaborative learning. Participants also worked with Lego and Modi construction systems, building elements of airport infrastructure as well as aircraft models, some of which incorporated programmable features. These tasks required not only technical skills but also planning, communication, and creative experimentation.



Figure 3. *Aviation structures of PPIW students made of Lego and Modi bricks (own sources)*

The next stage involved transforming these experiences into educational workshops for children. Close cooperation with teachers from local primary schools played a crucial role throughout this process. Two classes, representing Grades 1 and 3, agreed to participate in the January STEM workshops organized at the University of Radom. Before the visits, consultations were held with classroom teachers to identify pupils' interests, previous educational experiences, and expectations regarding the workshops. Although both classes had already visited FlyPort several months earlier, they enthusiastically welcomed the opportunity to explore the topic from a different perspective while simultaneously experiencing university learning environments.

The workshops were designed not merely, as demonstrations prepared by university lecturers but as authentic teaching experiences led by future teachers themselves. To reinforce students' responsibility for the educational process, two group leaders were selected at random and entrusted with coordinating the preparation of the activities. Their role extended beyond organizational duties. They were expected to facilitate group discussions, distribute responsibilities among team members, make methodological decisions, and respond to emerging challenges during the planning phase.

Throughout this process, the university lecturer intentionally limited direct intervention. Rather than prescribing ready-made solutions, guidance was provided only at critical moments when methodological clarification or organizational support proved necessary. This approach reflected the constructivist assumptions underpinning STEM education by encouraging future teachers to develop autonomy, negotiate

ideas collectively, and assume responsibility for the quality of their instructional decisions.

Practical considerations also influenced the final design of the workshops. Taking into account the unfamiliar university environment, children's typical attention span, and available teaching time, each session was planned to last approximately sixty to eighty minutes. This timeframe created sufficient opportunities for hands-on exploration while reducing the risk of cognitive overload or declining engagement among younger participants.

Given that each visiting class consisted of approximately twenty-five pupils, a traditional whole-class lesson was considered unlikely to provide adequate opportunities for active participation. Instead, students proposed organizing the workshops according to the research station method, in which children worked in small groups and rotated between five thematic stations. This arrangement not only increased individual involvement but also reflected one of the central principles of STEM education—learning through direct experience, experimentation, and collaborative problem-solving.

For the Grade 3 pupils, every activity related directly to aviation. Individual stations combined technological, scientific, and engineering elements in different ways. One group used 3D pens to construct aircraft models based on prepared templates, while another designed memory games introducing the ICAO aviation alphabet. Additional stations focused on building aircraft from Lego and Modi bricks, completing coding challenges on a floor mat through graphic dictation, and conducting experiments illustrating the principles of flight using paper rotors and model rockets. Each activity required pupils to formulate predictions, test solutions, discuss observations with peers, and modify their ideas whenever necessary.

Rather than separating practical tasks from scientific explanation, students were encouraged to integrate both elements throughout the workshop. Consequently, introductory demonstrations—including simple experiments comparing the falling speed of different objects such as feathers and sheets of paper—served as starting points for discussion rather than ready-made explanations. Children were invited to formulate their own hypotheses before verifying them experimentally, thereby actively constructing scientific understanding instead of passively receiving information.

The workshops prepared for Grade 1 pupils followed the same methodological principles while adapting the level of complexity to younger learners' developmental needs. Although aviation remained an important component of the activities, the broader theme of transportation was introduced to provide opportunities for comparing aircraft with land and water vehicles. This wider thematic framework enabled children to investigate different engineering solutions while maintaining strong connections with everyday experiences familiar to them.



Figure 4. *Construction site – paper rotor (own sources)*

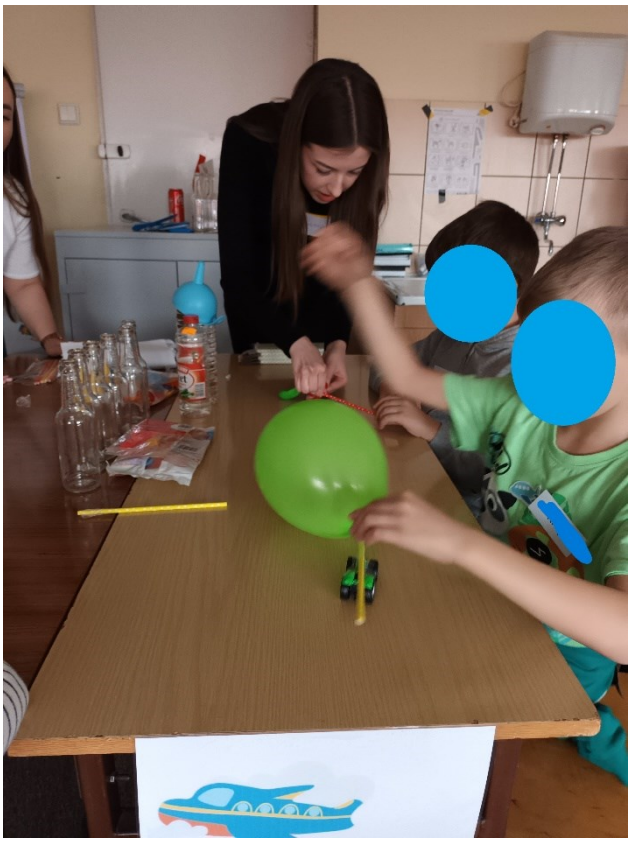

Figure 5. *Experimental station – a car propelled by the force of a balloon recoil (own sources)*

Responding to Diverse Educational Needs During STEM Workshops

An equally important stage of the project concerned adapting the workshops to the diverse educational needs of participating children. Since the objective extended beyond presenting attractive STEM activities, careful attention was devoted to ensuring that every pupil could engage meaningfully in

the learning process regardless of individual abilities or previous educational experiences.

Before the workshops took place, student coordinators consulted with the classroom teachers to obtain detailed information about the composition of each class. These conversations provided valuable insight into pupils' learning profiles, including the presence of children with diagnosed special educational needs, ADHD, lower cognitive functioning, or migration experience. Such information enabled future teachers to anticipate potential difficulties and to incorporate appropriate forms of educational support already during the planning stage rather than responding only after challenges had emerged.

The resulting modifications reflected the principles of inclusive education. Instead of relying on lengthy verbal explanations, presentations were redesigned to include concise written information supported by clear illustrations. Activities were organized into relatively short segments interspersed with brief transitions, allowing younger pupils to maintain concentration while reducing cognitive fatigue. At each research station, students prepared alternative versions of selected tasks so that children who completed activities more quickly—or, conversely, those requiring additional time or encouragement—could continue working at a pace suited to their individual needs.

Flexibility also proved essential in maintaining children's motivation. Recognising that not every participant would be equally interested in every activity, future teachers deliberately diversified the available tasks. Whenever signs of declining engagement appeared, children were encouraged to choose from additional challenges or explore different aspects of the topic. Consequently, differentiation was understood not as simplifying the curriculum but as providing multiple pathways through which pupils could participate successfully in the learning process.

From a pedagogical perspective, these experiences represented an important lesson for university students. Many had previously encountered inclusive education primarily through theoretical coursework. This experience highlights that inclusive STEM education depends less on sophisticated technologies than on teachers' pedagogical sensitivity and their ability to anticipate diverse learner needs during instructional planning.

Building Educational Relationships Through STEM Activities

Beyond the methodological aspects of the workshops, interpersonal relationships emerged as another significant factor influencing their success. From the very beginning, considerable emphasis was placed on creating a welcoming atmosphere that encouraged children to communicate openly with university students. Simple organizational solutions, including personalized name badges, helped establish direct contact and reduced the psychological distance often associated with unfamiliar university surroundings.

Throughout the workshops, future teachers consciously adopted a supportive rather than evaluative

approach. Instead of concentrating primarily on whether children completed tasks correctly, they acknowledged effort, persistence, and creative attempts to solve problems. Particular attention was given to situations in which pupils experienced difficulties, became discouraged, or expressed frustration. Rather than immediately providing ready-made answers, students sought to encourage reflection by asking guiding questions and offering emotional support appropriate to each child's needs.

This approach proved especially valuable when working with younger children, whose emotional responses were often immediate and highly visible. Novel tasks occasionally generated anxiety, impatience, or even tears, particularly among pupils who faced additional educational challenges, including children with migration experience. Such situations became authentic learning opportunities not only for the children but equally for the university students, who needed to respond quickly while maintaining a positive learning climate.

Working together, student teams attempted to identify early signs of emotional tension and intervene before frustration escalated into more disruptive behaviours. Redirecting children's attention, offering encouragement, or proposing an alternative strategy frequently proved sufficient to restore confidence and sustain engagement. These experiences highlighted that successful STEM education requires considerably more than well-designed technological activities. Emotional security, positive relationships, and responsive classroom management are equally important conditions for effective learning.

The workshops also revealed substantial variation in pupils' social and emotional competences. Whereas some children readily sought assistance, negotiated solutions with peers, and confidently approached unfamiliar challenges, others hesitated to ask for help even when they encountered obvious difficulties. Observing these differences encouraged university students to reflect more deeply on the importance of creating classroom environments in which every child feels comfortable expressing uncertainty, making mistakes, and learning collaboratively.

From the perspective of teacher education, these observations became one of the most valuable outcomes of the project. Students repeatedly emphasized during reflective discussions that managing interpersonal interactions, recognizing children's emotional needs, and adapting communication strategies proved just as demanding as organizing the STEM activities themselves. Consequently, they began to perceive effective STEM teaching not simply as the integration of science and technology but as an educational approach that combines subject knowledge with empathy, flexibility, and reflective pedagogical decision-making.

Viewed through the lens of teacher self-efficacy (Bandura, 1977), these experiences allowed pre-service teachers to move beyond observing innovative practice and to develop confidence through successful mastery experiences, collaborative problem-solving, and supported reflection.

Conclusion

The experiences gained through implementing STEM-oriented activities within the preparation of future preschool and early primary teachers demonstrate that this educational approach offers benefits extending well beyond the development of technological competences. For many university students, particularly those who had previously shown limited interest in engineering, coding, or robotics, participation in authentic project work became an opportunity to rediscover the value of experimentation, creativity, and collaborative problem-solving. Experiencing curiosity, enjoyment, and a genuine sense of agency during methodological workshops enabled them to better understand the learning processes they would later seek to promote among children.

Although many schools in the Radom region have benefited from national programmes supporting technological infrastructure, access to STEM activities remains uneven across different educational stages. Innovative equipment is still more frequently used with older pupils, while younger children often participate in more traditional forms of classroom activity. As a result, many university students complete teaching placements without observing or conducting interdisciplinary STEM lessons despite the growing importance of these approaches within educational policy.

The project described in this article sought to reduce this gap by creating opportunities for future teachers to design, implement, and evaluate STEM activities within an authentic educational setting. Working collaboratively with children, fellow students, and academic staff allowed participants to integrate theoretical knowledge with practical experience while simultaneously strengthening their professional confidence. These experiences suggest that authentic teaching situations may constitute one of the most effective ways of developing teacher self-efficacy in relation to STEM education.

Future initiatives should continue moving towards greater learner autonomy. Rather than encouraging children to reproduce predetermined models or follow detailed instructions, workshop activities ought to provide opportunities for generating original ideas, evaluating alternative solutions, and making independent decisions throughout the learning process. Such an approach is consistent with the broader educational objective of strengthening children's sense of agency while fostering responsibility for both the decisions they make and the consequences that follow.

Taken together, the experiences reported in this study indicate that STEM-oriented teacher education should be understood not primarily as technology training but as a process of developing pedagogical agency, professional judgement, and confidence in designing inquiry-based learning environments. These dimensions may prove equally important as digital competence in preparing future preschool and early primary teachers for educational practice.

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https://doi.org/10.46793/STEPAM26.245L
Udk: 37.091.4 MONTESORI
37.091.3:001.895

MULTISENSORY AND INTERDISCIPLINARY LEARNING AS A FOUNDATION FOR STEAM EDUCATION: A MONTESSORI PEDAGOGICAL PERSPECTIVE

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Abstract: Multisensory and interdisciplinary learning is increasingly recognised as a cornerstone of contemporary STEAM education; however, traditional instruction remains largely fragmented and insufficiently experiential. Montessori pedagogy provides a theoretically grounded and empirically validated framework that integrates multisensory stimulation, inquiry-based learning, and a holistic curriculum, yet its contribution to the development of STEAM education within traditional classroom instruction has not been sufficiently examined. This study aimed to investigate how elements of Montessori pedagogy can support multisensory and interdisciplinary learning and create conditions associated with STEAM competency development in a traditional classroom environment. The research was conducted using a qualitative action research approach and involved primary school classroom teachers (N = 22) participating in an online Montessori teachers' learning community. Data were collected through interviews, classroom observations, and reflective journals, and analysed using thematic analysis. The findings indicate that the application of specific Montessori didactic materials, the prepared environment, and the facilitating role of the teacher enable students to engage multiple senses simultaneously in the learning process. This approach enhances the understanding of abstract concepts through concrete experience, strengthens cross-curricular connections, and fosters the development of critical thinking, problem-solving, creativity, and learner autonomy.

Keywords: didactic materials, interdisciplinarity, Montessori pedagogy, multisensory learning, STEAM education

Introduction

Contemporary educational systems must redefine traditional approaches to meet 21st-century demands for creativity, critical thinking, and problem-solving — a challenge that has positioned STEAM education at the centre of modern pedagogical theory and practice (Gonzalez & Kuenzi, 2012). Many scholars have observed that interdisciplinarity in practice is often reduced to a fragmented connection of curricular content, lacking deeper integration of experiential and multisensory learning (Livstrom et al., 2019). Montessori pedagogy provides a significant framework for reconceptualising STEAM education, rooted in multisensory learning, experiential inquiry, the prepared environment, and an interdisciplinary approach to child development (Köchig et al., 2025; Lesandrić, 2024). Developed through scientific observation of the child, it is based on the premise that learning occurs through active engagement, sensory experience, and interaction with the environment, with particular emphasis on manipulating concrete materials and integrating diverse domains of knowledge into a meaningful whole (Lesandrić, 2024). A growing body of recent research recognises the convergence of Montessori pedagogy and STEAM education, especially in the areas of creativity development, executive functioning, and inquiry-based approaches (Randolph et al., 2023; Köchig et al., 2025), while the creation of conditions associated with

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STEAM competency development within traditional classroom instruction remains insufficiently explored.

Theoretical Framework

Constructivism as an Epistemological Foundation

This study adopts the constructivist paradigm, which views learning as an active, experiential, and constructive process. According to Piaget's theory of cognitive development, children build an internal conceptual world by manipulating objects in their environment, applying knowledge gained through real-world interactions as they move from concrete to abstract thinking. Constructivist theory highlights the learner's active role, inquiry, and collaboration, in contrast to the passive reception of pre-formed knowledge (Maras et al., 2018). Matijević (2001) identifies Maria Montessori as a pioneer of constructivism, while Saha and Adhikari (2023) note that both Montessori and Piaget believed knowledge acquisition is a spontaneous and natural process unfolding through logical structures. Piaget called these operations, while Montessori maintained they occur through object manipulation. At the neuroscientific level, Cardinali et al. (2021) describe how simultaneous activation of multiple sensory modalities promotes neural plasticity and deeper cognitive engagement, while Denervaud et al. (2020) report increased brain activity in regions associated with visual and mathematical processing, as well as greater acceptance of errors among students educated in Montessori schools.

Montessori Pedagogy: Principles and Elements

Montessori pedagogy is based on a holistic understanding of the child, in which academic, social, emotional, and physical development are considered inseparable (Dorer et al., 2018). According to L'Ecuyer et al. (2020), it is founded on four conceptual pillars: developmental stages, sensory education, the prepared environment, and spontaneous activities through repetition – all naturally aligned with the child's developmental needs and sensitive periods. The prepared environment, through the deliberate organisation of space and materials, guides the child from simpler to more complex tasks and from the concrete to the abstract (Philipps, 2003). However, research in state schools indicates that this element is the least represented in practice, due to spatial and material constraints (Lesandrić, 2024). The specific didactic materials, which Montessori termed "materialised abstraction," are self-correcting and cover five educational domains: practical life exercises, sensorial materials, mathematics materials, language materials, and cosmic education materials, thus fostering analytical thinking and cognitive control. The teacher's role is reduced to that of a facilitator – one who observes and supports rather than instructs (Montessori, 2023)—and Nash (2011) empirically confirms that students in such conditions achieve better outcomes and demonstrate higher levels of intrinsic motivation.

Multisensory Learning: Theoretical Foundations and Pedagogical Value

Multisensory learning involves the simultaneous engagement of visual, auditory, tactile, and kinaesthetic channels in the cognitive process. Ogbemudia et al. (2024) describe Montessori pedagogy as an inherently multisensory approach, while Shams and Seitz (2008) confirm that the synchronous stimulation of multiple modalities enhances information consolidation and facilitates the comprehension of abstract concepts. Within the Montessori framework, multisensoriality is implemented through concrete materials – the Mystery Bag develops stereognosis, sound cylinders promote auditory discrimination, and colour, smell, and fabric tablets engage multiple senses simultaneously (Lesandrić, 2024; Köchig et al., 2025). This aspect is particularly evident in mathematics, where manipulating concrete materials enables children to understand and apply content that, if presented abstractly, would remain disconnected from real life – a finding also supported by Nisa et al. (2019).

STEAM Education: Definition, Evolution, and Pedagogical Principles

STEAM education arose from the expansion of the STEM concept to include the arts, recognising the importance of creativity in holistic education (Gonzalez & Kuenzi, 2012). Yakman (2008) formally proposed this paradigm, and the shift was driven by a growing demand in the labour market for innovative and interdisciplinarily competent individuals (Marmon, 2019). The STEAM approach requires integrated learning situated in authentic contexts (Kelley & Knowles, 2016). Livstrom et al. (2019) caution that the subject-based structure of traditional schools presents a fundamental obstacle to the implementation of such initiatives. In STEAM instruction, the teacher acts as a facilitator, guiding inquiry-based experiences and developing not only content mastery but also critical thinking and problem-solving skills.

The Convergence of the Montessori Approach and STEAM

The connections between Montessori pedagogy and STEAM education are multiple and systemic. Livstrom et al. (2019), in a study of 96 American Montessori schools, demonstrate that integrated STEAM emerges organically in Montessori environments through authentic engagement within communities of practice, without the artificial imposition of interdisciplinary connections. Both paradigms share key pedagogical characteristics: a learner-centred orientation, project-based and inquiry-driven approaches, intrinsic motivation, and holistic development (Köchig et al., 2025). Montessori education meaningfully situates academic disciplines in relation to local and global challenges. For example, engineering can be integrated within the context of the "Great Lessons" – five narratively grounded lessons on the history of the universe, the Earth, life, humanity, and the development of mathematics and language (Lesandrić, 2024).

Methodology

This study is based on a qualitative action research design conducted within an online Montessori teachers' learning community in the Republic of Croatia. Action research was chosen as the methodological framework because, as Ferrance (2000) states, it is not concerned with theoretical problems but enables teachers to address issues directly relevant to them, over which they can exercise influence and effect change.

The aim of this study was to examine how elements of Montessori pedagogy can support multisensory and interdisciplinary learning and create conditions associated with STEAM competency development in a traditional classroom environment. In line with this aim, three research questions were formulated:

RQ1: In what ways does the application of elements of Montessori pedagogy – specifically didactic materials, the prepared environment, and the facilitating role of the teacher – support multisensory and interdisciplinary learning and contribute to the development of students' STEAM competencies in traditional classroom instruction?

RQ2: Which elements of Montessori pedagogy do primary school classroom teachers apply to achieve educational outcomes in mathematics, nature and society, language, and arts subjects, and to what extent do these elements strengthen the cross-curricular connections characteristic of the STEAM approach?

RQ3: What factors facilitate or hinder the implementation of Montessori pedagogy within the traditional educational system, and how does participation in an online learning community contribute to the development of the teacher competencies required for STEAM-oriented instruction?

The research sample consisted of 22 female primary school classroom teachers (N=22) from the Republic of Croatia who voluntarily participated in the online Montessori teachers' learning community - a professional development space for sharing practice, collaborative planning, and reflective evaluation of Montessori implementation. The study also included critical friends (N=11) — primary school teachers, school counsellors (a pedagogue, a psychologist, and an educational rehabilitator), and one university professor of pedagogy, five of whom held Montessori teacher certification. Their role was to systematically observe classroom activities using structured observation protocols, provide critical peer feedback within the online learning community, and participate in two structured individual interviews. Their observations and interview responses constituted an independent data source within the triangulation framework. The research was conducted during the 2021/2022 academic year and received ethical approval from the Ethics Committee of the Faculty of Humanities and Social Sciences at Josip Juraj Strossmayer University of Osijek.

Data were collected through triangulation of multiple sources: structured individual interviews with the teachers (conducted at the beginning and end of the study), classroom observation protocols, a research

journal, and reflective records. Data analysis was conducted using thematic analysis. Interview transcripts, classroom observation protocols, and research journal entries were read multiple times to ensure transcription accuracy and then coded manually — sentence by sentence and paragraph by paragraph — without qualitative data analysis software. The coding process yielded situational, activity, event, strategy, and relational codes, which were subsequently organised into 15 categories and condensed into four overarching themes: Achievement of Educational Outcomes, The Role of Specific Didactic Materials, Classroom Atmosphere, and the Online Montessori Teachers' Learning Community. The present paper draws selectively on findings relevant to multisensory and interdisciplinary learning and STEAM competency development; a comprehensive presentation of all four themes exceeds the scope of this article. Credibility was further strengthened through data-source triangulation, comparing findings across all three data sources.

Results and Discussion

Multisensory and Interdisciplinary Learning and the Development of STEAM Competencies through Elements of Montessori Pedagogy

The findings of this study clearly confirm that the use of specific Montessori didactic materials, the prepared environment, and the teacher's facilitating role create conditions for the simultaneous engagement of multiple sensory channels in the learning process – the fundamental mechanism by which Montessori pedagogy supports the development of STEAM competencies. The participating teachers, across all observed subjects (mathematics, nature and society, Croatian language, visual arts, and music), demonstrated that the use of Montessori didactic materials encourages students to engage in simultaneous visual, tactile, and kinaesthetic activity, rather than the passive reception of information typical of frontal instruction. As Ogbemudia et al. (2024) and Shams and Seitz (2008) confirm, synchronous multisensory stimulation deepens cognitive engagement and facilitates comprehension of abstract concepts. Teachers in this study experienced this directly: "Using Montessori materials, we somehow connect life with learning and learning with life - and I see that as the greatest and immeasurable value" (Teacher 8, personal communication, April 2021).

A particularly illustrative example is the use of the Mystery (stereognostic) Bag in geometry instruction: students identify three-dimensional shapes solely through touch, developing stereognosis as a complex cognitive skill that integrates the perception of surface texture, temperature, and size. This example demonstrates how Montessori didactic materials do not activate a single sense in isolation, but stimulate integrative cognitive processes. As one peer observer noted in the classroom observation protocol: "I cannot help but notice that, alongside the mathematics outcomes, the senses are being intensively developed - particularly the sense of touch" (Peer observer 1, personal communication, November 2021). This multisensory integration is directly correlated with the scientific and mathematical thinking required by

STEAM education. Regarding the interdisciplinary dimension, a consistent finding across the observed activities is that the use of Montessori didactic materials makes it virtually impossible to isolate the achievement of a single educational outcome. Their application necessarily activates outcomes and expectations from multiple subject areas and cross-curricular themes simultaneously. This realises what Kelley and Knowles (2016) describe as the essence of the integrated STEAM approach: identifying connections between disciplines and providing relevant context for learning content, rather than teaching isolated skills. This was evident across subjects: one teacher noted that a single activity simultaneously achieved outcomes in Croatian language, visual arts, and cross-curricular themes - "The purpose of this material is clearly visible in achieving several outcomes at once: phonological awareness, reading, and making connections" (Teacher 3, personal communication, April 2022). This confirms that Montessori materials do not serve a single curricular purpose, but function as integrative tools that generate interdisciplinary learning organically. Taken together, these findings support Randolph et al.'s (2023) meta-analytic conclusion that Montessori pedagogy positively influences executive functions, creativity, and problem-solving - the core competency profile of STEAM education.

Specific Montessori Elements in Teaching Practice and the Strengthening of Cross-Curricular Connections

The analysis indicates that participating teachers most consistently applied specific didactic materials, somewhat less frequently adopted the facilitating role, and least often implemented the prepared environment - a distribution reflecting not pedagogical shortcomings, but material, spatial, and institutional constraints.

In mathematics, materials ranging from the Mystery Bag to concrete numerical manipulatives enabled students to grasp content through hands-on engagement rather than abstract rules - what Sablić et al. (2022) describe as a cognitive link between abstract concepts and real-life application. This was confirmed in practice: "Through manipulation of these concrete materials, students much more easily achieve outcomes and recognise the purpose of mathematical content" (Peer observer 4, personal communication, October 2021). This direct connection between manipulation and meaning-making is the mechanism through which Montessori mathematics materials support STEAM competency development. In Nature and Society - inherently interdisciplinary in its integration of natural, social, and technical content - Montessori activities supported an inquiry-based approach consistent with reform-based science education (Livstrom et al., 2019). In Croatian Language, materials fostered phonological awareness and literacy, while Visual Arts and Music activities activated the aesthetic dimension that extends STEM into STEAM - one that Montessori pedagogy organically encompasses through its emphasis on creativity and sensory experience.

A recurring challenge confirmed by the study is that the subject-centred structure of traditional schools presents a fundamental obstacle to multidisciplinary initiatives (Livstrom et al., 2019). Notably,

teachers frequently found it difficult to classify activities within a single subject, as the same activities simultaneously achieved outcomes across multiple curricular areas. This indivisibility is interpreted not as a methodological shortcoming, but as evidence that Montessori materials function as natural generators of interdisciplinarity. One peer observer captured this dynamic precisely: "It seems as though the cross-curricular expectations are hidden messages you receive simply by handling the material" (Peer observer 7, personal communication, June 2022). This finding is consistent with the European Reference Framework's foundations for 21st-century competencies (Škola za život[31], 2019).

STEAM Competencies as an Outcome Framework: Convergence with Montessori Pedagogical Goals

The findings document a complex interplay of factors shaping the scope and quality of Montessori implementation in traditional classrooms. Facilitating factors include teachers' pedagogical competence and enthusiasm, peer support through the online learning community, positive student responses, and improved educational outcomes. Hindering factors encompass spatial limitations (shared classrooms, unsuitable furniture), the high cost and limited availability of original Montessori materials, the considerable time demands of activity preparation, and institutional constraints stemming from limited familiarity with Montessori pedagogy among school leadership and colleagues.

The online learning community proved to be the central mechanism through which participating teachers overcame professional isolation and built practice confidence. Participants consistently highlighted peer feedback - previously inaccessible to them -as the decisive factor in sustaining their implementation efforts. One teacher described this directly: "This was the first time I had anyone give me feedback on whether what I am doing is right. That confirmation was my motivation to keep going" (Teacher 3, personal communication, June 2022). This finding aligns with the professional learning community characteristics identified by Thoma et al. (2017): shared values, reflective practice, and a focus on student learning, as well as with Mirosavljević (2021).

As Köchig et al. (2025) emphasise, effective integration of STEAM content within the Montessori framework requires not merely material familiarity, but theoretical understanding of the developmental principles underlying each material's use. This was clearly reflected in the data: teachers with deeper pedagogical understanding applied materials more creatively, while those with surface-level knowledge remained at instrumental application. Future professional development programmes must therefore address both dimensions.

Finally, the material and financial burden of implementation falls entirely on individual teachers. As one peer observer noted: "I think teachers invest too much of their own money into their work, because unfortunately schools do not have sufficient funds - and often, even when they do, they are not receptive to

[31] Croatian curriculum reform

our needs" (Peer observer 4, personal communication, May 2022). This testimony illustrates that the implementation gap is not a question of teacher competence or motivation, but of structural and financial conditions. This structural deficit requires a response at the level of educational policy, not individual effort.

Conclusion

In response to the first research question, it can be concluded that elements of Montessori pedagogy organically support multisensory and interdisciplinary learning, contributing to the development of the very competencies that STEAM education identifies as its primary educational goals: critical thinking, problem-solving, creativity, and learner autonomy. This convergence is not coincidental: both traditions are grounded in constructivist epistemology and share the ideal of an independent inquirer supported by a teacher-facilitator (Randolph et al., 2023; Köchig et al., 2025).

In response to the second research question, clear evidence was found that the participating teachers applied Montessori elements across primary school subjects, simultaneously achieving outcomes from multiple curricular areas and thereby strengthening cross-curricular connections aligned with the European Reference Framework and the demands of curricular reform. This finding is particularly significant for pedagogical theory, as it empirically demonstrates that authentic interdisciplinarity - of the kind that STEAM requires - results from a pedagogical philosophy, rather than a methodological adjustment within an unchanged subject-based timetable structure (Livstrom et al., 2019).

In response to the third research question, the online Montessori teachers' learning community proved to be an effective professional development model, while spatial, material, and institutional constraints represent systemic barriers requiring a policy-level response.

On the basis of the findings discussed, the following recommendations are offered. For teaching practice, the gradual integration of Montessori elements is recommended, beginning with the most accessible – namely, didactic materials and the facilitating stance of the teacher. For educational policy, it is essential to institutionally recognise the value of Montessori elements in the development of STEAM competencies and to ensure systemic conditions for their implementation. Several limitations should be acknowledged: the sample consisted of 22 voluntarily participating female teachers from a single national context, studied over one academic year, which limits transferability. Researcher reflexivity was maintained throughout through the use of a research journal, peer debriefing within the online learning community, and member checking with participating teachers. These constraints point to the need for longitudinal, mixed-methods, and comparative studies across diverse educational contexts. In conclusion, Montessori pedagogy does not offer a ready-made blueprint for STEAM education – it offers a coherent pedagogical philosophy that makes STEAM possible from within, from the very logic of child development.

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MUSIC AS THE "ARTS" COMPONENT IN THE STEAM MODEL: AN ANALYSIS OF SCIENCE FESTIVAL ACTIVITIES IN CROATIA (2017–2025)

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Abstract: Science festivals are key venues for non-formal education and the STEAM approach. Since 2003, the Science Festival in Croatia, under the patronage of the Ministry of Science and Education and with co-financing from other public institutions and societies, has actively promoted these goals. This paper explores the role of music within festival programmes from 2017 to 2025, viewing it as a vital "Arts" component of the STEAM model. The objective is to identify and analyse activities involving active child participation—such as workshops and performances—focusing on their pedagogical potential. The research is descriptive-analytical, employing qualitative content analysis of a sample comprising all available festival programmes from the specified period. Data collection involved archival analysis of official websites and multimedia materials. The results systematise frequency trends and a typology of music activities through a thematic matrix, while synthesising pedagogical patterns. The implications suggest that integrating interactive musical elements into science popularisation is essential for developing interdisciplinary STEAM strategies.

Keywords: *Science Festival, STEAM approach, music pedagogy, interactive learning, non-formal education*

Introduction

The STEAM (Science, Technology, Engineering, Arts and Mathematics) model emerged as an expansion of the STEM (Science, Technology, Engineering and Mathematics) approach, inserting the arts ("A") into the connection between the natural sciences, technology, engineering and mathematics. Yakman (2008) was the first to describe STEAM as an integrative and holistic approach to lifelong learning, in which the arts are interdisciplinarily linked with the STEM disciplines rather than understood merely as an aesthetic addition. The introduction of the arts has been presented as a way of re-visioning education, although the notion of the arts within STEAM remains contested and diversely interpreted (Colucci-Gray et al., 2019). Although STEAM is often equated with arts integration, these are distinct approaches: arts integration typically links the arts with one further subject, whereas STEAM rests on a broader, holistic blending of multiple subjects and introduces new competencies such as divergent thinking and cultural competency (Huser et al., 2020). Within this integrative perspective, the arts are also linked to the development of students' creativity, for instance when musical and physical phenomena are combined to produce a soundtrack (Filipe et al., 2024).

Beyond a wider range of subjects and disciplines, integration within STEAM also occurs at different levels of connection. Ng et al. (2022) distinguish disciplinary, multidisciplinary, interdisciplinary and transdisciplinary approaches to STEAM integration — from teaching individual content, through a shared

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theme, to the close linking of two or more disciplines for knowledge construction and, finally, connection oriented toward real-world problems. Analyses of how disciplines relate within STEAM likewise stress that there is no single approach to STEAM but rather a range of disciplinary interrelationships (Williamson & Panigabutra-Roberts, 2021).

Science festivals are public events that celebrate science, technology, engineering and mathematics in a festive and accessible atmosphere, with the aims of sparking curiosity, promoting scientific literacy and enabling the public to meet scientists (Canovan, 2026). At the same time, the term "science festival" covers a wide variety of formats, and research often fails to describe the festivals it studies (Ramsey & Boyette, 2021). The role of science festivals in non-formal learning can also be viewed through the concept of science capital. Gathings and Peterman (2021) report that festivals can contribute to the development of science capital, with greater shifts recorded among participants who interacted with scientists and among members of groups underrepresented in STEM. Public science events are thereby confirmed as an important part of the local science learning ecosystem. The arts at science festivals can further contribute to an interdisciplinary approach to science and broaden participation to populations that would not otherwise engage in exclusively STEM activities (Rosin et al., 2023).

As a modern concept, the science festival was first introduced in 1989 in Edinburgh, Scotland[33]. Since then, the concept of opening science to a wider audience has spread across the world. One of the more notable examples is the Science Days festival, held annually at Europa-Park in the German town of Rust. In the Republic of Croatia, the first such festival, under the name Festival of Science (Festival znanosti), was organised in 2003 (Index.hr, 2003). Its founding institutions were the Universities of Zagreb, Split, Rijeka, Zadar and Osijek, in cooperation with the Nikola Tesla Technical Museum and the British Council, and under the patronage of the Ministry of Science and Education of the Republic of Croatia. Over more than two decades, the festival has established itself as a key site of non-formal education and grown into a platform connecting the scientific community with the wider public, with particular emphasis on children and young people (Zrna, 2016). According to its official website[34], the aims of the festival are: to bring science closer to the public by presenting scientific activities and results; to improve public perception of scientists; and to motivate young people to engage in research and knowledge acquisition. In the past decade, a marked popularisation of the festival has been observed within educational institutions, which are also the most frequent organisers of activities (Prgomet & Zrna, 2021). In contrast to its modest beginnings, festival activities today involve stakeholders across the entire educational vertical, from kindergartens to higher-education institutions, while the themes span a broad, interdisciplinary range across all branches of science. The activities promoting the popularisation of science are diverse and accessible to all: from classic lectures, workshops, exhibitions, experiments and demonstrations to panel discussions and debates,

[33] https://oisf.org/info/about-oisf/background/
[34] https://festivalznanosti.hr/

dramatic performances and concerts. The growth in themes and the rise in the number of participants has contributed to an increasing inclusion of the arts in the festival, which can also be linked to the emergence of the STEAM model of connecting the sciences. A particularly notable rise can be traced in musical activities within the festival, along with the diversity of audiences to which these activities are addressed.

Methodology

Research design

The study employs a descriptive-analytical research design grounded in qualitative content analysis. This approach was selected because the aim is not to measure a predefined variable but to identify, classify, and interpret the presence and forms of musical content within a large and heterogeneous body of programme documentation. Qualitative content analysis allows both the systematic categorisation of recurring features—frequency, activity type, scientific field, and target audience—and the interpretive reconstruction of the pedagogical patterns these features reveal.

Aims and research questions

The objective of the study is to identify and analyse activities within the Croatian Science Festival in which music functions as the "Arts" component of the STEAM model, with particular attention to activities involving active child participation. The analysis is guided by three research questions: (1) How frequent are music-related activities in the Science Festival programmes between 2017 and 2025, and how are they distributed across activity types? (2) With which scientific fields is music most often integrated, and what does this reveal about its interdisciplinary role? (3) Which pedagogical patterns—including creativity, inclusion, and cultural identity—emerge from these activities?

Sample

The sample comprises the official programmes of the Croatian Science Festival for the period 2017–2025. It includes all available printed programme booklets and digital materials published for each annual edition. The period was chosen to capture recent festival practice across changing annual themes: Time (2017), Discoveries (2018), Colours (2019), Culture of Science (2020/2021), Life (2022), Nature and Society (2023), Intelligence (2024), and Networks (2025)[35]. Because the festival is decentralised across more than forty host cities and a wide range of institutions—universities, polytechnics, institutes, schools, kindergartens, museums, and libraries—the sample reflects programming produced by diverse organisers rather than a single curatorial body.

[35] The 2020 edition is not presented separately in the analysis due to disruptions caused by the COVID-19 pandemic

Data collection procedure

Data were collected through archival analysis of publicly available sources: the official festival websites, programme booklets, and accompanying multimedia materials such as photographs, recordings, and activity descriptions. Each annual programme was reviewed in full, and every entry was screened for musical content. Relevant activities were extracted together with their descriptive metadata: title, brief description, activity type, host institution, associated scientific field, and target audience.

Analysis criteria and coding

An activity was included if its title or description indicated a connection with music, identified through a set of keywords: music, rhythm, dance, concert, sound, song, playing instruments, singing, composing, and creativity. Each included activity was coded along three dimensions: activity type (e.g. workshop, lecture, poster, presentation, concert or performance, exhibition, quiz, puppet play); scientific field (the primary disciplinary domain with which music was integrated); and target audience, coded using the festival's own categories of S0 (preschool), S1–S3 (primary and secondary levels), children with special needs (PP), and the general public. To ensure consistency, each activity was treated as a single unit of analysis and counted once, regardless of how many audience groups it addressed. The coded entries were organised into a thematic matrix cross-tabulating year, activity type, scientific field, and audience; this matrix served both as the basis for the frequency analysis and as the framework for synthesising the pedagogical patterns reported in the Discussion. To reduce the dispersion of individual formats, the activity types were further grouped into three macro-categories: interactive workshops; educational lectures and posters; and performances and concerts.

Methodological limitations

Two limitations follow from the design. First, the analysis relies on the documentation that organisers chose to publish; activities described too briefly to reveal a musical dimension may have been under-counted, and the completeness of digital archives varies across years. Second, no separate programme is analysed for 2020, when that edition was merged with 2021 under the shared theme "Culture of Science"; these data are therefore reported as a single point. These constraints affect coverage rather than the validity of the categories identified, but they should be kept in view when interpreting year-on-year change.

Results

Temporal distribution and activity types

Across the analysed period, music-related activities show a clear upward trajectory, from a marginal presence at the start to a substantial and diversified offering in the most recent editions. The annual distribution by activity type and target audience is presented in Table 1. Three phases are discernible: an

initial period of sporadic, single activities; an expansion that begins after the first editions and accelerates following the 2020/2021 hiatus; and a peak in 2024, followed by a contraction in 2025. Two features recur across the stronger years. The interactive workshop is consistently the dominant format, and the range of formats widens over time, with lectures, posters, presentations, performances, and even a quiz and a puppet play appearing in the later editions—an indication of a maturing and increasingly varied use of music within the programme.

Table 1 Music-related activities by year, type, and target audience (2017–2025)

Year	Quantity and type of activities	Target audience
2017	1 protocol (performance), 1 workshop	S1, S2, general public
2018	1 lecture	General public
2019	6 workshops	S0, S2, S3
2021	7 workshops, 3 lectures, 1 poster, 1 concert	S0, S1, S2, S3, general public
2022	9 workshops, 3 lectures, 1 play, 1 presentation, 1 exhibition	S0, S1, S2, S3, general public
2023	9 workshops, 2 lectures, 2 presentations, 2 performances/concerts	S0, S1, S2, S3, general public
2024	12 workshops, 3 lectures, 2 posters, 3 presentations, 1 performance, 1 quiz	S0, S1, S2, S3, special needs (PP), general public
2025	4 workshops, 3 lectures, 1 performance, 1 show, 1 poster, 1 puppet play	S0, S1, S2, S3, general public

Note. S0 = preschool; S1–S3 = primary and secondary education levels; PP = children with special needs.

Distribution across scientific fields

The integration of music with scientific content was analysed across seven fields, as shown in Table 2. As expected, Arts and Musicology accounts for the largest share, since music itself is the object of study. The more telling finding is the breadth of the remaining activities: music is integrated with psychology and the cognitive sciences, physics and technology, pedagogy, the natural sciences, mathematics, and the social sciences. This spread across the natural, technical, social, and humanistic domains indicates that, within the festival, music does not function as an isolated artistic addition but as a connective thread running through the full breadth of the STEAM spectrum.

Table 2 Distribution of identified music activities by scientific field (2017–2025)

Scientific field	Activities	Share
Arts and Musicology	37	44.0%
Psychology and Cognitive Sciences	13	15.5%
Physics and Technology	11	13.1%
Pedagogy and Education	9	10.7%
Natural Sciences	9	10.7%
Mathematics	3	3.6%
Social Sciences	2	2.4%
Total	84	100%

Target audiences and reach

The activities address the full range of festival audiences, from preschool children (S0) through all levels of primary and secondary education (S1–S3) to the general public, as recorded in Table 1. Coverage of younger age groups broadens over time: preschool audiences, absent from the earliest editions, become a standard target from 2019 onward, and the later programmes consistently span all educational levels. The 2024 edition is notable for explicitly including children with special needs, signalling an intentional move toward inclusive programming.

Representative examples of activities

To illustrate the patterns identified above, several representative activities are described below.

A first group links music with the natural and technical sciences through experiential, often interdisciplinary formats. In "Even Trees Sing"[36] ("I drveće pjeva"), a lecture on communication between plants and the effect of sound on plants, animals, and humans was followed by a sound walk through an arboretum, using a device that converts variations in electrical conductivity into sound. In "Music from the Chemical Formula of Proteins"[37] ("Glazba iz kemijske formule proteina"), amino acids were encoded across three octaves (55 tones, including semitones), exploring how listening to molecular "music" can reveal molecular properties more intuitively than reading chemical formulas, including ways to sonify chemical reactions. "Let's Make the Brain Dance" ("Plešimo mozgom") demonstrated the positive effects of dance on brain development through creative movement, while "Physics Lives in Music"[38] ("Fizika živi u glazbi"), aimed at younger primary-school pupils, showed how sound is created, transmitted, and visualised through experiments with sound waves. The interactive puppetry and drama performance "Traveller Soundy"[39] ("Putnik Zvuković") presented the history of sound-reproduction technologies—from the phonograph to the smartphone—in a child-friendly way.

A second group reflects an inclusive orientation, addressing the use of music therapy in developing musical intelligence in children with autism spectrum disorders, and music education drawing on music-therapy elements and assistive technology. A third group connects music with cultural identity, integrating traditional music into a STEAM context so that children can recognise the value of their cultural heritage through the lens of contemporary science and technology.

[36] https://www.festivalznanosti.hr/2025/karlovac/
[37] https://www.festivalznanosti.hr/2021/osijek/?eventId=1899
[38] https://www.festivalznanosti.hr/2022/osijek/?eventId=2261
[39] https://www.facebook.com/ZnanstveniPiknik/posts/tjedan-dana-smo-do-11-tog-znanstvenog-piknika-od-danas-kre%C4%87emo-s-odabranim-objav/5418635361584205/

Discussion

The results of the study show that music-related activities at the Science Festival follow an upward trajectory from year to year. Besides the increase in the overall number of musical activities, a progressively wider range of activities that are fundamentally built on themes from the field of music can be observed. These activities are broadly interdisciplinary and connect different fields of science, which contributes to viewing science in the form in which it actually appears in the real world. This may be one of the key factors attracting a diverse audience to the Science Festival, and the results show that the festival's musical activities engage audiences of all ages and varied interests. The activities encompass different forms and methods of teaching and presentation, from classic lectures, workshops, experimental exercises, discussions, and exhibitions to dramatic performances, concerts, and the like. In these forms, music is presented and treated as a core scientific element rather than, as is often the case, an accompanying or background one. Introducing musical activities into the festival broadens the scope of the scientific field (Huser et al., 2020), while a wider mode of engaging with a scientific field—encompassing multidisciplinarity, interdisciplinarity, and transdisciplinarity—makes it possible to connect several scientific disciplines and forms of knowledge oriented toward real-world problems and challenges (Ng et al., 2022). Introducing the arts and cultural practices into education not only strengthens cognitive development and skills such as innovative and critical thinking, communication, and collaboration, but also fosters social adaptability and cultural awareness, contributing to the building of personal and collective identities and to the appreciation of others (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2006). In this sense, recognising music as an equal "A" component of the STEAM model can be understood as part of a broader pedagogical shift toward a more balanced, humanising, and sustainable education—one that nurtures the linking of seemingly distant disciplines and new forms of literacy and creativity (Canovan, 2026).

The pedagogical concept of musical activities at festival events is diverse and inclusive. Particularly prominent is the fostering of creativity, inclusion, and cultural identity, which enables science to contribute to broader social development. Activities connected with music and musical content at the Science Festival can contribute to science learning in a non-formal environment (Gathings & Peterman, 2021), while reaching a broad and varied audience (Rosin et al., 2023), which ultimately softens the hard boundaries of so-called "serious" science and brings it closer to those whom science otherwise reaches less easily.

This study has shown that, in line with the growth and development of the festival, music and musical activities appear increasingly often in the programme of the Science Festival in the Republic of Croatia, and that their forms and content broaden and integrate other fields of science. The limitations of this study are evident in the incomplete documentation of the festival, most often found on the websites of the festival itself, the universities, and other event organisers. Activities are usually listed by title only,

while the actual content of the activities was harder to find, and at times impossible. This content analysis does not measure outcomes and achievements, which would be significant to investigate in order to see the effect. For future research, it would be significant to conduct an evaluation of these activities.

Conclusion

This analysis confirms a growing role for music as the "Arts" component of the STEAM model within the activities of the Science Festival in Croatia between 2017 and 2025. Over this period, musical activities not only became more frequent but also more varied in form, ranging from interactive workshops and lectures to performances, concerts, and dramatic productions. The examined activities display strong interdisciplinarity, linking music with the natural and technical sciences as well as with the social sciences and humanities, which suggests that music functions less as a decorative addition and more as a connective thread across the STEAM spectrum. Designed for audiences across the entire educational vertical, from preschool children to the general public, and encompassing children with special needs, these activities reveal a holistic and inclusive potential. Taken together, the findings position music as a key pedagogical tool that fosters creativity, critical thinking, and emotional engagement with scientific content. Given the observed trends, music can be expected to take on an increasingly prominent and systematically integrated role in future editions of the festival, opening space for further research that would evaluate the actual educational outcomes of such activities.

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CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

37.091.39(082)(0.034.2)
37.091.4(082)(0.034.2)
37.014.5(082)(0.034.2)

INTERNATIONAL Conference STEPAM approach in contemporary education - challenges and perspectives (2026 ; Jagodina)
Conference proceedings [Elektronski izvor] / International Conference STEPAM approach in contemporary education – challenges and perspectives, Jagodina, 11-12. 05. 2026. = editors Aleksandar Ignjatović ,Olivera Cekić-Jovanović, Ivana Ćirković-Miladinović ; organized by the Faculty of Education, University of Kragujevac, Jagodina, Serbia. - Jagodina : University of Kragujevac, Faculty of Education, 2026 (Jagodina : Faculty of Education). - 1 elektronski optički disk (CD-ROM) : tekst ; 12 cm

Sistemski zahtevi: nisu navedeni. - Nasl. sa naslovne strane dokumenta. - Tiraž 50. - Napomene i bibliogrfske reference uz tekst. - Bibliografija uz svaki rad.

ISBN 978-86-7604-260-9

a) Настава - Методика - Иновације - Зборници b) CTEM образовање - Зборници

COBISS.SR-ID 200134409



ISBN 978-86-7604-260-9