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Original scientific paper
UDC: 37.013:004.8
http://doi.org/10.5937/IstrPed2502408M

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EFFECTIVENESS OF IN-SERVICE TEACHER TRAINING FOR DEVELOPING NECESSARY DIGITAL COMPETENCIES IN MODERN EDUCATION

Abstract: In-service teacher professional development in the area of fostering and empowering digital competencies should be systematically and institutionally organized, within a clearly defined legal and ethical framework. Program designers of professional development must be familiar with the theoretical foundations of digital competence, as well as with various models of training. The focus of this study was to examine the effects of a hybrid professional development workshop on teachers' digital competencies and pedagogical knowledge in the use of educational robots in teaching. The aim was to evaluate the effectiveness of the Bee-Bot robot workshop and determine the extent to which the training contributes to building teachers' theoretical and practical knowledge, as well as their readiness to achieve learning outcomes among students, particularly in the area of algorithmic thinking. The sample consisted of 150 primary school in-service teachers, including both classroom and subject teachers. Data were analyzed using descriptive statistics and one-way analysis of variance (One-Way ANOVA) with a post-hoc test (Tukey HSD). Although more than half of the participants had no prior knowledge of this technology, the results indicate that the training significantly contributed to the development of teachers' knowledge and digital competencies, with an average of 7.69 correct answers. Teachers' years of professional experience had no statistically significant effect on achievement, suggesting that the hybrid training model is equally effective for all teachers, regardless of the length of their professional experience. These findings confirm the effectiveness of hybrid training programs that combine different instructional modalities and highlight the need for broader inclusion of in-service teachers in future professional development initiatives.

Keywords: teacher professional development, in-service teachers, digital competencies, educational robots

Introduction

The teaching profession in contemporary education attracts significant attention due to the rapid development of artificial intelligence (AI) and modern technologies, raising debates about whether teaching is a profession that could be replaced. However, despite technological advancements, teachers remain a key factor in the educational process (Mandić, 2024). The role of teachers in future education is expected to transform, but the profession will not disappear, as technology in teaching should serve as a tool to support teachers' work rather than replace them. In this context, the development of teachers' digital competencies becomes crucial, enabling them to respond effectively to the challenges of digital transformation in education. A key question is how to adequately foster digital competencies among in-service teachers, considering that some may not have had courses related to educational technology or method for developing digital competence during their initial education. In-service teacher professional development and training programs aimed at digital competence development represent a critical mechanism for preparing educators to use modern technologies effectively in teaching (Babić et al., 2025). Such professional

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development programs should be designed to provide teachers with concrete, applicable technologies that can be integrated into classroom practice (Trujillo-Juárez et al., 2025). The primary aim is not only to familiarize teachers with new tools but also to support them in effectively integrating these tools into their teaching to achieve specific learning outcomes that contribute to student progress and well-being. Existing research indicates that high-quality professional development significantly enhances teachers' digital literacy and their capacity to apply technology innovatively in the classroom (Stavermann, 2025). The effectiveness of training has been recognized in both online and face-to-face (live) formats, each offering specific advantages and limitations Online models provide flexibility, accessibility, and self-paced learning, while face-to-face formats facilitate direct interaction, collaboration, and hands-on experience (Gu et al., 2025; Stavermann, 2025). The findings suggest that a hybrid professional development model, which combines the benefits of both approaches, can be effective and provides a foundation for designing programs to develop teachers' digital and pedagogical competencies. In this context, the design of the hybrid training program carefully considered the concept and strategic framework for developing teachers' digital competencies, as well as the role of in-service teacher professional development in supporting these processes. As a result, the program was structured appropriately and tailored to meet the specific needs of in-service teachers. This framework served as the foundation for the hybrid training model, one module of which forms the focus of this study, aiming to examine its effect on the development of digital competencies and pedagogical knowledge of in-service teachers in the use of educational robots in teaching.

Developing Teachers' Digital Competencies: Frameworks, Policy, and Professional Development

Digital competencies are recognized as essential skills necessary for lifelong learning and effective functioning in contemporary society. The need for their development has been recognized as a form of learning that should begin in early childhood, not as a separate subject, but integrated within a relevant context (Ala-Mutka et al., 2008). Digital competencies are expected to be incorporated across curricular subjects at all levels of education. However, this approach requires a systemic strategy that ensures the continuous development of digital competencies among educational staff (Mandić, 2024). The foundational framework for the development of teachers' digital competencies is provided by DigComp (Vuorikari et al., 2013), later refined through DigCompEdu (Redecker, 2017). Subsequently, assessment tools such as SELFIE for Teachers (2021) were developed, while more recent documents, including DigComp 2.2 (Vuorikari et al., 2022), point towards an expansion of the framework to integrate artificial intelligence with an emphasis on ethical considerations. These frameworks serve as a basis for designing professional development programs for teachers, aimed at building competencies necessary for the effective use of modern technologies in teaching. Developing the digital competencies of educational staff represents a cornerstone for fostering stuents' digital competencies, based on the premise that digitally literate teachers can effectively support the development of their students' digital skills (Matović et al., 2025). In this context, the Republic of Serbia has defined a national framework for teachers' digital competencies, first introduced in 2017 (Okvir digitalnih kompetencija – Nastavnik za digitalno doba, 2017), supplemented in 2019 (Okvir digitalnih kompetencija – Nastavnik za digitalno doba, 2019), with the current version updated in 2023 (Okvir digitalnih kompetencija – Nastavnik za digitalno doba 2023). These frameworks provide a reference point for the continuous development of teachers' digital competencies and offer systemic support in the process of digital transformation in education.

Given that the empowering of in-service teachers' digital competencies occurs primarily through continuous professional development, the following section presents an overview of relevant literature focusing on this process, which aims to support teachers in developing the skills necessary for the effective integration of modern technologies into teaching practice.

Development of In-Service Teachers' Digital Competencies through Professional Development: A Literature Review

Particular attention should be given to standardizing teachers' digital literacy through continuous professional development (Petrović et al., 2025). Even somewhat earlier studies indicate that the quality and effectiveness of professional development programs directly influence the extent to which digital technologies are integrated into teaching practice (Instefjord & Munthe, 2017; Tondeur et al., 2019). To create high-quality professional development materials for in-service teachers in the area of digital competencies, a systematic review of international practices and training models was conducted as a foundational step.

In identifying relevant empirical and theoretical studies, as well as strategic documents, clearly defined inclusion criteria were applied: the period from 2020 to 2025, publications in English and Serbian, with a focus on teacher professional development in the context of digital competencies and the use of modern technologies in education. The search of academic literature covered the Web of Science, Scopus, ERIC, Education Research Complete, and Google Scholar databases, using keywords such as "digital competence," "teacher professional development," "online teacher training," "ICT in education," and "digital skills for teachers." Additionally, strategic documents were identified through official institutional sources and policy documents to ensure a comprehensive overview of guidelines and priorities in the development of teachers' digital competencies. In addition to the clearly defined inclusive criteria, an exclusive criterion was applied: studies that met the search parameters but focused on the professional development of pre-service teachers were excluded from the review. The review of relevant studies and strategies conducted during this period indicates that online professional development programs for teachers generally have a positive impact on the development of digital competencies and the improvement of teaching practice (Angjeleska, 2022). A meta-analysis of 115 studies in the field of online teacher professional development highlights the importance of programs that integrate theoretical and practical components, include mentoring support from program designers, and facilitate collaborative learning (Stavermann, 2025). Research by Amemasor et al. (2025) confirms that training focused on developing digital competencies promotes the use of innovative teaching methods, while other studies (Blanc et al., 2025; Domínguez-González et al., 2025) emphasize the integration of critical, creative, and ethical use of technologies within long-term and institutionally supported programs. The example of Finland illustrates the implementation of systemic models of professional development that include mandatory teacher programs, the integration of AI, and a focus on pedagogical and ethical components, which contribute to a high level of digital competencies and teacher readiness to use modern technologies in the classroom (Ministry of Education and Culture, Finland, 2023). The OECD (2025) emphasizes the need for continuous technology integration in teaching and the development of teachers' pedagogical competencies, while El-Hamamsy et al. (2023) analyze an adapted cascade model that has proven effective for the systematic and sustainable enhancement of teachers' digital competencies. Research indicates that long-term professional development programs, whether delivered online or face-to-face, significantly improve teachers' digital competencies and their readiness to implement innovative teaching methods. Given that programs combining both formats have proven effective, it is justified to develop and implement a hybrid model of professional development that integrates the advantages of both online and live training (Munawar & Jannah, 2025).

The need for developing such models has also been recognized in the national context, where institutional initiatives have been launched to provide systemic support to teachers in the area of digital transformation in education. Continuous support in this area is provided by the Center for Robotics and Artificial Intelligence in Education (CRAIE)[2], which functions as a national training

[2] More information is available on the official website of the Center for Robotics and Artificial Intelligence in Education (CRAIE): https://craie.edu.rs/

center and is recognized as a key institution for organizing in-service teacher professional development (Miščević et al., 2025; Marković, 2025).

The Concept of Training for the Use of Educational Robots

The training, whose workshop is the subject of this study, was implemented within the project "Building the Critical Computer Skills for the Future Ready Workforce" (Project No. 00136459), conducted by the United Nations Development Programme (UNDP) in partnership with the Ministry of Education and the Faculty of Education, University of Belgrade, and other project partners, with the support of the Government of the Republic of Serbia. The aim of the professional development program was to enhance and develop the competencies of primary and subject teachers for the effective integration of artificial intelligence into the educational process. The training concept is based on a hybrid model and comprises six modules covering topics such as understanding AI, VR, and 3D tools, the use of educational robots and chatbots for personalized learning and teaching, with a particular emphasis on ethical issues, data protection, and responsible AI use. This approach fosters the development of teachers' digital literacy and lays the foundation for a modern and stimulating educational environment. The online component of the training was designed according to the flipped classroom principle (Ristić, 2018), allowing participants to familiarize themselves with theoretical materials at home, which serve as a basis for practical application. The live component included scheduled lectures and workshops, providing participants with opportunities to develop digital competencies through practical examples of digital tools and resources applicable in teaching. The training was accredited under the hybrid model by the Institute for the Improvement of Education and Upbringing under catalog number 1366.

For the purposes of this study, the focus is on the training module related to the use of educational robots in the teaching process. The module was designed to provide teachers theoretical knowledge through online materials covering the characteristics and significance of educational robots, and practical skills through workshops involving the direct use of physical digital devices in specific teaching scenarios. Within the theoretical component, participants are introduced to the concept of educational robots, as well as the various types and functions they can have according to different classification criteria. The focus, however, is specifically on the Bee-Bot robot, as this model is age-appropriate for students and more accessible in the school context compared to other types of educational robots. The objective of the workshop is to develop teachers' digital competencies for the use of educational robots in teaching, where the robot is regarded as a tool to stimulate algorithmic thinking by creating problem-based situations in which students solve tasks by programming the robot's movements along a given path. This approach encourages the development of algorithmic thinking, creativity, and digital competencies in students. During the practical part of the workshop, participants apply educational robots in concrete teaching examples, integrating content from various subjects and educational areas.

As an example of an educational robot used as a tool rather than a learning goal (Matović, 2024), the Bee-Bot robot was selected, specifically designed for preschool and early primary school children. One of the key advantages of this robot is that it is designed without a screen and, due to its physical characteristics, resembles a toy, thereby fostering students' motivation and engagement in the learning process (Matović, 2024). This robot has proven to be an effective tool for achieving the learning outcomes, which include students' ability to explain the concept of an algorithm in their own words, analyze simple procedures involving repetitive actions and represent them algorithmically, identify and correct errors in algorithms, and determine the results of executing a given algorithm (Pravilnik o izmenama i dopuni Pravilnika o planu nastave i učenja za prvi ciklus osnovnog obrazovanja i vaspitanja i programu nastave i učenja za prvi razred osnovnog obrazovanja i vaspitanja, 2020).

Considering the importance of teachers' digital competencies for the effective use of modern technologies in teaching, which are developed through professional development, it is justified to examine the effectiveness of the training module focusing on the use of educational robots (Bee-Bot). The following section presents the methodological framework of this study, which investigates the workshop's effectiveness and the extent to which in-service teachers acquired knowledge and skills, with the aim of evaluating its impact on the development of teachers' digital competencies and pedagogical knowledge in the use of educational robots in teaching, using the Bee-Bot robot as a concrete example.

Methods

The study employed a **one-group posttest-only quantitative design** (McNeil, 1990) aimed at examining the effects of the Bee-Bot training program on teachers' knowledge improvement. The **aim** of the research is to evaluate the effectiveness of the workshop[3] on the use of Bee-Bot robots for the purposeful integration of this technology into teaching practice. The study sought to determine the extent to which the training contributed to the development of theoretical and practical knowledge among in-service teachers and their readiness to achieve corresponding educational outcomes in students through the use of educational robots, particularly in the areas of algorithmic thinking, creativity, and digital competencies. In line with this objective, the **research tasks** were defined as follows: 1) To assess participants' performance on a knowledge test following the training (focused on the use of Bee-Bot robots); 2) To examine whether teachers' years of professional experience influence the degree of mastery of the new theoretical and practical knowledge acquired through the training; and 3) To analyze individual knowledge test items in order to identify areas in which participants demonstrated the highest and lowest levels of knowledge and competencies related to the features and use of Bee-Bot robots.

The study was conducted as a **single-group quantitative investigation** (post-test design), in which the outcomes of participants in the Bee-Bot robot training were analyzed following the completion of the full program, comprising both theoretical and practical components. For the purposes of the study, a knowledge test consisting of 10 questions was used as the **research instrument**, with binary coding: 0 = incorrect, 1 = correct response. The test covered general knowledge about Bee-Bot robots, their technical characteristics and functioning, as well as potential applications in the educational process, particularly in integrative lessons aimed at developing algorithmic thinking. The **sample** consisted of 150 training participants, including 75 in-service subject teachers and 75 in-service class teachers from primary schools. The **dependent variable** was the total number of correct answers on the test, while the **independent variable** was the years of professional experience of the in-service teachers. For the **statistical analysis** of the collected data, descriptive statistics were applied (mean number of correct answers, standard deviation, minimum, and maximum), as well as a one-way analysis of variance (One-Way ANOVA) with a post-hoc test (Tukey HSD) to examine whether there were significant differences in training participants' performance depending on their length of teaching experience.

Results

Research tasks 1: The first research task aimed to determine the participants' performance on the knowledge test following the training on the use of Bee-Bot educational robots. The test was conducted after participants had completed both the online and live components of the training. Specifically, the aim was to assess the contribution of the training on educational robots to the development of teachers' knowledge and competencies in the application of Bee-Bot robots in teaching practice.

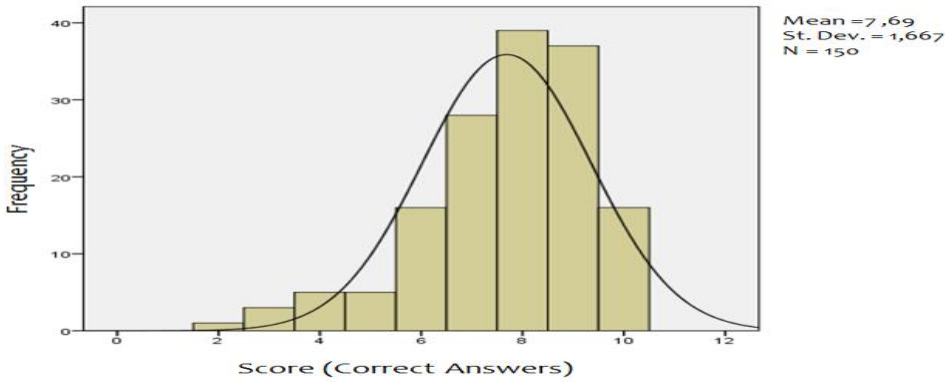
[3] In the following text, we will use the term "training," although it refers exclusively to this module, which covers content related to educational robots, and not to all six modules of the program.

Table 1. *Descriptive Indicators of Participants' Performance on the Knowledge Test After Completing the Training*

Indicator	Number of Participants (N)	Minimum Number of Correct Answers	Maximum Number of Correct Answers	Mean Number of Correct Answers	Standard Deviation
Knowledge Test Score	**150**	**2**	**10**	**7,69**	**1,667**

Based on the descriptive indicators presented in Table 1, participants scored between 2 and 10 correct answers, with a mean of 7.69 and a standard deviation of 1.667. The minimum (2) and maximum (10) values indicate a wide range of responses, and the distribution of the total number of correct answers on the test (Chart 1) shows a slight negative skew.

Chart 1. *Distribution of total correct answers*



Research Task 2: The second research task aimed to examine whether teachers' years of professional experience affects the level of development of new theoretical and practical knowledge gained through the training. For the purposes of analysis, length of service was categorized into three groups: 1) up to 5 years; 2) 5 to 10 years; and 3) more than 10 years of professional experience. The results of the descriptive statistics by group are presented in Table 2.

Table 2. *Descriptive statistics of knowledge test scores by years of professional experience*

Years of professional experience	N	M (Mean)	SD (Standard deviation)	Minimum number of correct answers	Maximum number of correct answers
Up to 5 years	**26**	**7.35**	**2.04**	**2**	**10**
5 to 10 years	**25**	**7.52**	**1.83**	**3**	**10**
More than 10 years	**99**	**7.82**	**1.51**	**4**	**10**

To determine whether teachers' years of professional experience had an impact on the level of theoretical and practical knowledge developed through the training, a one-way analysis of variance (One-Way ANOVA) was conducted. Prior to the analysis, the assumption of homogeneity of variances was tested using Levene's test, which indicated that the assumption was met ($F(2,147) = 1.167$, $p = .314$). The results of the ANOVA showed that there was no statistically significant difference in teachers' test scores based on years of professional experience ($F(2,147) = 0.975$, $p = .380$).

Research Task 3: An item-level analysis of the knowledge test was conducted to identify which questions participants answered most successfully and which presented the greatest challenge.

Each question had four answer options, with only one correct. The results, presented through the number of correct and incorrect responses and the percentage of correct answers per question, are shown in Table 3. Percentages of correct answers ranged from 54.7% to 98.7%. The highest success rate was observed for the question *The use of educational robots (Bee-Bots) in integrative teaching can contribute to…* (98.7%), while the lowest percentage of correct answers was obtained for the question *What can in-service teachers use as an alternative to physical educational robots (Bee-Bots) when the device is not available?* (54.7%). The questions in Table 3 are presented in descending order of participant success; they were not arranged in this order on the actual knowledge test.

Table 3. *Success on the Knowledge Test: Number of Correct and Incorrect Answers*

Question	Total Participants (N)	Correct Answers	Incorrect Answers	Percentage of Correct Answers (%)
The use of educational robots (Bee-Bots) in integrative teaching can contribute to…	150	148	2	**98,7%**
Educational robots (Bee-Bots) specialized for younger school-age children contribute most to the development of…	150	143	7	**95,3%**
Bee-Bot is designed to move along…	150	133	17	**88,7%**
The distance Bee-Bot travels when moved one step forward/backward is…	150	127	23	**84,7%**
At what angle can Bee-Bot rotate to the left or right?	150	114	36	**76,0%**
Bee-Bot is specifically designed for…	150	111	39	**74,0%**
What is Bee-Bot?	150	110	40	**73,3%**
The main purpose of educational robots (Bee-Bots) in teaching is…	150	95	55	**63,3%**
One of the key features of Bee-Bot is…	150	89	61	**59,3%**
What can in-service teachers use as an alternative to physical educational robots (Bee-Bots) when the device is not available?	150	82	68	**54,7%**

Discussion

Research Task 1: The results indicate that participants achieved an average score of 7.69 correct answers out of a possible 10 on the knowledge test following the training. This finding points to a significant level of mastery of the theoretical and practical content covered by the training program. However, the wide range of scores (from 2 to 10 correct answers) indicate individual differences in achievement levels, which may be related to varying lengths of professional experience – a factor further examined in the next research task.

A slight negative skew in the distribution of results (Chart 1) indicates that a larger number of participants achieved above-average scores, which can be interpreted as one of the indicators confirming the effectiveness of the training. The combination of online and face-to-face (live) segments contributed to knowledge construction, given that 87% of participants had no prior knowledge of the functions and possible applications of Bee-Bot robots (verified during training registration). The success on the knowledge test suggests that the hybrid professional development model supported the understanding of both theoretical foundations and practical skills. This finding confirms that different forms of learning, implemented both online and live, contributed to a better understanding of how to use Bee-Bot robots and their potential application in the educational context. It can be assumed that the interactive nature of the training, which included didactic-methodical instructions, demonstrations, and practical tasks, played a decisive role in the achieved level of mastery. The results may indicate the need to maintain a hybrid model in future professional development programs, as the online segment provided a clear theoretical foundation in line with

the flipped classroom concept, while the live segment enabled direct and practical application of theoretical knowledge.

Research Task 2: In-service teachers' professional experience did not have a statistically significant effect on the level of development of new theoretical and practical knowledge gained through training on the use of educational robots, as shown by the analysis of variance. Although a slight increase in average performance is observed with more years of professional experience, the differences between groups are not statistically significant. This can be interpreted as an indication that the effects of the training are not conditioned by years of professional experience, and that all participants, regardless of their work in practice, have equal opportunities to successfully acquire new knowledge and skills. Additionally, the training content was tailored to participants regardless of their prior level of digital competencies. Despite the misconception in the literature that teachers with more professional experience do not have the ability to develop digital competencies (Negrín-Medina et al., 2022), regional studies suggest that years of professional experience are not necessarily associated with teachers' level of digital competencies (Dautović, 2024), and this finding aligns with the results of our study.

Research Task 3: Within the third research task, an item-level analysis of the knowledge test was conducted to identify which content areas participants mastered most successfully and where the greatest difficulties occurred. The analysis shows that the level of success varied between 54.7% and 98.7%, indicating a relatively high overall acquisition of content, but also the presence of certain conceptual uncertainties in some questions. The highest percentage of correct answers was recorded for the question concerning the pedagogical potential of using educational robots in integrative teaching, suggesting that participants largely understood the role of the robot as a tool to support the development of students' algorithmic thinking. High performance on this question may also indicate that teachers more effectively learned and integrated concepts closely related to practical classroom application. This result is likely due to the fact that during the training, participants independently solved tasks using Bee-Bot robots, thereby simulating students' work and enabling experiential understanding of the pedagogical potential of this technology. On the other hand, the lowest level of success was achieved on the question related to alternatives to physical robots in teaching, which points to a potential lack of familiarity with digital simulations and virtual tools that can replace the use of physical devices.

Considering overall performance on the test, in-service teachers achieved the highest number of correct answers on questions related to specific ways and possibilities of using educational robots. Questions requiring knowledge of a broader range of technological solutions or conceptual understanding of robotics proved more challenging; however, this did not indicate complete lack of knowledge, as over 50% of participants answered correctly. Nevertheless, this finding may serve as an indicator of the need for additional training in this area, with greater focus on alternative digital software that can facilitate the development of students' algorithmic thinking, such as Bee-Bot robot emulators. Similar findings have been reported in other domestic studies, indicating that effective integration of technology in teaching, particularly technologies based on AI software, requires in-service teacher training to support the digital transformation of education (Mandić et al., 2025; Matovic et al., 2025).

Conclusion

The results of the conducted study confirmed that the hybrid model of professional development can represent an effective approach for developing the digital competencies and pedagogical knowledge of in-service teachers within the context of contemporary teaching practice, which is consistent with the findings of similar research (Munawar & Jannah, 2025). The training contributed to the development of in-service teachers' digital competencies regarding the purposeful use of educational robots (Bee-Bot) in teaching, as well as to understanding how this technology can serve

as a tool to foster students' algorithmic thinking. Simulations of teaching situations during the training enabled participants to recognize how educational robots can be employed to support algorithmic thinking and problem-solving in integrative teaching, confirming the applicability of the *five-step model* as an effective methodological approach for the adequate use of this technology (Matović & Ristić, 2024). It was observed that the length of professional experience did not have a significant impact on participants' achievements, confirming that pedagogically well-designed and structured training can be equally successful for all in-service teachers, regardless of differences in work experience (Dautović, 2024).

The findings further emphasize the need for a systematic approach to professional development, combining theoretical and practical concepts with the possibility of flexible implementation across different modalities. A particular contribution of this study lies in highlighting the importance of using educational robots as a tool, rather than an end, for developing algorithmic thinking and a range of other competencies necessary for students' lifelong learning.

Implications

Future training programs should include a greater focus on alternative solutions, in the form of digital tools that can be applied when physical devices (Bee-Bot robots) are unavailable. In addition, conducting longitudinal studies would be valuable for monitoring how participants who have completed the training implement the acquired knowledge in practice. In this context, it is also necessary to develop an instrument for assessing students' progress when using educational robots in the teaching process.

Limitations

Although the training focused on a single type of educational robot (Bee-Bot), this choice was deliberate, based on its pedagogical suitability for younger school-age children and its potential to support the development of algorithmic thinking skills (Matović, 2024). Additionally, Bee-Bot is more readily available in school contexts compared to more complex robots. However, this focus may limit the generalizability of the results to other types of educational robots and different application contexts. A second limitation concerns the methodological approach, which relied primarily on quantitative indicators. Including qualitative data in future research could provide a more detailed understanding of participants' experiences and how the acquired knowledge can be applied in real classroom settings.

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