SYSTEMATIC REVIEW: PROFESSIONAL DEVELOPMENT TRENDS FOR TEACHER TRAINING PROGRAMS TO USE EDUCATIONAL ROBOTICS FOR TEACHING STEM AT PRIMARY AND SECONDARY LEVELS

Saira Bano
Research Assistant at Center of Robotics (CoR),
Faculty of Information Technology and Computer Science, University of Central Punjab (UCP), Lahore
Punjab, Pakistan
Email: l1f24phdc0004@ucp.edu.pk

Syed Atif Mehdi
Director of Center of Robotics (CoR),
Faculty of Information Technology and Computer Science, University of Central Punjab (UCP), Lahore
Punjab, Pakistan
Email: syed.atif@ucp.edu.pk

ABSTRACT

STEM (Science, Technology, Engineering, and Mathematics) education has recently garnered academic interest focusing on educational robotics (ER). The success of this approach heavily relies on the role of teachers. This study aims to investigate the following: "What are the new trends of educational robotics (ER) for teacher training programs to enhance professional development (PD)?", "What are teachers' perceptions toward educational robotics (ER) after attending professional development (PD) training sessions?", and "Are professional development (PD) training programs beneficial for building positive attitudes in primary and secondary school teachers?" A systematic review was conducted to gather evidence from the latest empirical studies on educational robotics (ER) as a tool for teaching training. We searched online databases and found 12 relevant articles on this topic. The keywords are used to trace articles from 2018 to 2024 for analysis. The findings reveal that teacher training programs are important in implementing stem education through ER. It suggests that teachers' technical knowledge of ER and abilities to convey stem concepts in the classroom lead to effective learning, skill development, and motivation.

KEYWORDS
Educational Robotics, Learning, Professional Development, STEM, School Teachers, Teacher Training, Teacher Perception.

INTRODUCTION

Educational Robotics (ER) is the intersection of robotics and education, in which robots are used to teach and learn multiple concepts. This educational field has unique characteristics but still has no common definition (Schina et al., 2020). Using innovative technologies and strategies can help to create a modern learning environment. ER is a comprehensive tool that can aid in understanding the STEM (Science, Technology, Engineering, and Mathematics) disciplines (Hudson et al., 2020). Recently, scholars and educationists have shown interest in the benefits and effectiveness of robotics in educational trials.

It is a highly multidisciplinary field encompassing disciplines other than education and robotics. Students achieve multidisciplinary knowledge and skills by participating in such activities. ER is getting fame an excellent way to develop multiple skills. It engages students while keeping its distinctive impact on student's progress and understanding across many subjects. It also improves their ability to recognize their ideas and establish relationships between real-life situations and academic disciplines. The curriculum must implement this educational approach to achieve these goals (ÇALİK & ALTUN YALÇIN, 2022).

Robotics helps to enhance students', skills, and personalized learning. It also emphasizes the significance of resolving practical challenges and ethical concerns to take advantage of the positive aspects of technology (Konijn & Hoorn, 2020). Robotics instructions are the key to motivating and engaging students in the STEM area. The hands-on activities and real-world applications connectivity can help learners understand ER principles in a better way. Robotics participation in educational trials leads to building a stronger interest in STEM and future professional paths (Zhong & Xia, 2020). ER initiatives suffer from inadequate pedagogical frameworks and poorly trained teachers. It is essential to ensure that educators have the proper training to provide optimal learning experiences to students in this field (Castro et al., 2018). It requires a connection between immersive experiences proven strategies, and real-world applications successfully to teach STEM. There is a need to attend workshops and training sessions, learn from online available courses, and collaborate on lesson planning to gain expertise in teaching this trend (Huang et al., 2022).

LITERATURE REVIEW

According to constructivism theory, learning is an active process in which children are seen as active creators of knowledge. Each youngster forms their representation of the world through interaction with the environment, combining new information with previous knowledge. The theory of constructionism prioritizes utilizing tangible objective and practical situations to enrich the process of acquiring knowledge (Anwar et al., 2019). The ideas of transitioning from a learning-by-making approach, and manipulating material, forming an effective learning process. Particularly, when the learners are actively engaged in constructing an open-ended entity. ER serves as a crucial tool for spreading technology in education, often used to understand STEM concepts (Castro et al., 2018).

Ideas are generated when students participate in the construction of items and interact with their designs. Numerous studies have raised awareness of constructionism, which involves using technology to create an environment that accelerates Learning-by-Doing and Learning-by-Design. Constructionism is associated with constructivist concepts, including cognitive flexibility theory and conventional knowledge (Gorakhnath & Padmanabhan, 2020).

When learning in a vacuum, without real-world interactions, it is more challenging for teachers to connect with students and inspire them to be enthusiastic. Despite this, ER offers a simple method of transmitting educational content centered on games and joy, which children and adults enjoy while learning. STEM industries are thriving, therefore, there is a need to address negative perceptions of STEM disciplines and incorporate more real-world STEM examples that can help to highlight the issue, because experts believe that our current approaches are insufficient to prepare today's students for future needs (Plaza et al., 2019).

Educators play a vital role in fostering an interactive and stimulating educational atmosphere that blends experimental learning with science, technology, engineering, and mathematics activities (Papadakis et al., 2021). Despite the increasing interest in educational robots, it requires pedagogical and technical expertise to utilize them effectively in schools. However, teachers have less training to introduce this new trend in school education. This lack of experience is a significant reason for the decreased efficiency in classrooms (Castro et al., 2018). To improve teachers' expertise, we need effective training programs, practical experiences, collaborative learning, continuous professional development (PD), a supportive community, an interdisciplinary approach, and strong problem-solving skills (Casey et al., 2021). The teachers must be able to establish the structure of the task or subject in technology classrooms. In this case, the teacher decides which task should be performed and how. The narrow focus

on knowledge of practice and technology causes students not to get a better understanding of technology (Boeve-de Pauw et al., 2022).
The training programs for teachers' PD and evaluation strategies should be efficient and capable of producing desired outcomes. STEM education holds great importance, and it is the responsibility of teachers to encourage students' competence and interest in this field. Teachers must receive adequate training and incorporate creative and practical STEM activities into their curriculum. It is crucial to implement rigorous assessment procedures to evaluate the effectiveness of these courses in improving proficiency and engagement of students for learning outcomes in STEM subjects (Scaradozzi et al., 2019).

In the study, by (Benitti, 2012), the use of ER is beneficial in advancing the understanding of science, technology, engineering, and mathematics. According to Hudson, ER is a comprehensive resource for comprehending STEM disciplines. Furthermore, the work of (Bano et al., 2023) highlights that robotics contributes to the developed skills required in the 21st century. Teachers play an important role in fostering student engagement and a positive attitude toward learning. They can engage students and build a positive attitude. According to the study, teachers can control how students receive and interact with educational material and tools (Hussain et al., 2006)Incorporating Educational Robotics into educational settings requires expertise and knowledge to integrate effectively into this new trend. Our study focuses on training programs incorporating educational robotics to enhance the Professional Development of primary and secondary school teachers. This paper consists of four sections. The second section elaborates on the methodology and data. The third section discusses the significance of PD and teachers' training and recommendations for future work. The fourth section concluded the study.

RESEARCH OBJECTIVES

1. The study aims to highlight the significance of Professional Development (PD) for teachers in primary and secondary education using Educational Robots. It also examines training programs that integrate ER to improve teachers' PD.

RESEARCH QUESTIONS

1. What are the new trends in Educational Robotics (ER) for teacher training programs to enhance Professional Development (PD)?
2. What are the teachers' perceptions toward Educational Robotics (ER) after attending training sessions?
3. Do ER training programs foster a positive attitude among primary and secondary school teachers?

RESEARCH METHODOLOGY

A systematic review identifies, evaluates, and interprets all available research on a specific area, and explores a particular topic in depth. This approach allows one to understand the topic and draw meaningful conclusions comprehensively. This review is carried out in four steps based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) methodology (Moher et al., 2009). It involves four steps: identification, screening, eligibility, and inclusion. These actions will be covered in this section. This study is structured based on the following three research questions:

Snowballing Approach

Initially, we apply the snowball approach to find a literature review of educational robotics teacher training. We used snowballing to include all papers cited from original work on the subjects (Benitti, 2012). In the first round, we identified 176 articles. In the second round, we discovered 69. After this, we selected the 3 most relevant articles. As a result, these three studies (Casey et al., 2021; Kılıç & Çakıroğlu, 2022; Scaradozzi et al., 2019), have been short-listed for this study.

Search Strategy

We searched articles using keywords, from these four online databases: IEEE (Institute of Electrical and Electronics Engineering) Xplore, ACM (Association for Computing Machinery) Digital Library, Google Scholar, and ScienceDirect. These databases include reports, peer-reviewed, journal articles, conference papers, and books on Educational Sciences. Since we focused on these online databases, studies that may have been published elsewhere may not have been included in our topic. The research was started by using these keywords, ("Teacher training OR Teacher perception") AND ("Teacher" OR "STEM" OR "Educational Robotics" OR "Robots") AND ("Professional Development" OR "Trends"), see Table 1. The search was restricted to the study title and abstract in this step.

This comprehensive study was conducted in March 2024. The research yielded a total of 802 resources, which included 186 publications that were discovered in ScienceDirect, 74 articles found in the ACM Digital Library, 293 publications in Google Scholar, and 249 from IEEE Xplore conference papers spanning the period of 2018 to 2024. We obtained a total of 802 articles. The 56 articles were repeated. 299 articles had no full-text availability. 345 articles were not related to our topic. 102 articles were related to our topics. After this, we analyzed and evaluated to collect relevant information and insights on the research subject, and 93 more articles with full-text availability were removed for many reasons, such as systematic reviews, and survey articles, observational studies were also eliminated. Our study primarily

concentrated on elementary and secondary school teacher training programs using ER. A total of 9 selected articles were thoroughly analyzed and evaluated in this review, shown in (Figure 1).

Table 1: ***Studies Obtained from Each Database by Using Keywords***

Source	Keywords for searching Article	Results
ScienceDirect	(“Teacher’s training “OR “Teachers Perception”) AND (“Teachers” OR “STEM” OR “Educational Robotics”) AND (“Teachers” OR “Robotics” OR “Robots”) AND (“Professional Development” OR “Strategies”).	186
ACM Digital Library	(“Teacher’s training “OR “Teachers Perception”) AND (“Teachers” OR “STEM” OR “Educational Robotics”) AND (“Teachers” OR “Robotics” OR “Robots”) AND (“Professional Development” OR “Strategies”).	74
Google Scholar	(“Teacher’s training “OR “Teachers Perception”) AND (“Teachers” OR “STEM” OR “Educational Robotics”) AND (“Teachers” OR “Robotics” OR “Robots”) AND (“Professional Development” OR “Strategies”).	293
IEEE Xplore	(“Teacher’s training “OR “Teachers Perception”) AND (“Teachers” OR “STEM” OR “Educational Robotics”) AND (“Teachers” OR “Robotics” OR “Robots”) AND (“Professional Development” OR “Strategies”).	249

Finally, we obtained 12 articles for this systematic review: 3 through a snowballing approach and 9 using keywords, see Table 2. Our research aimed to investigate the importance of PD by using ER and identify emerging trends for future needs. This study does not cover other disciplines of studies (e.g., Artificial intelligence (AI), Psychology). After analyzing the search results, articles have been selected based on the following criteria.

Inclusive and Exclusive Criteria

The inclusion criteria for this investigation are the publication date of the article and relevance to the topic. The study excluded non-relevant articles that do not have practical value for teachers’ professional development, secondary studies such as surveys and reviews, and articles without outcomes. Additionally, articles without full-text availability are also eliminated.

A qualitative analysis of available data was conducted to provide comprehensive answers to the research questions. Another objective of the study is to determine the impact of teacher training programs on professional development and teachers’

perception toward educational robotics research after undergoing such training programs.

DATA ANALYSIS

The study only examines teachers' training programs for elementary and secondary pre-service and in-service educators, encompassing formal and informal instruction with outcomes. It aims to provide a comprehensive learning experience based on rigorous experimental research.

The training program has been observed to deliver significant benefits by enhancing STEM and ER skills among teachers. This presents an excellent opportunity for educators to acquire the knowledge and skills they need to prepare the next generation of students for the future.

Figure 1: ***The Article Selection Process***

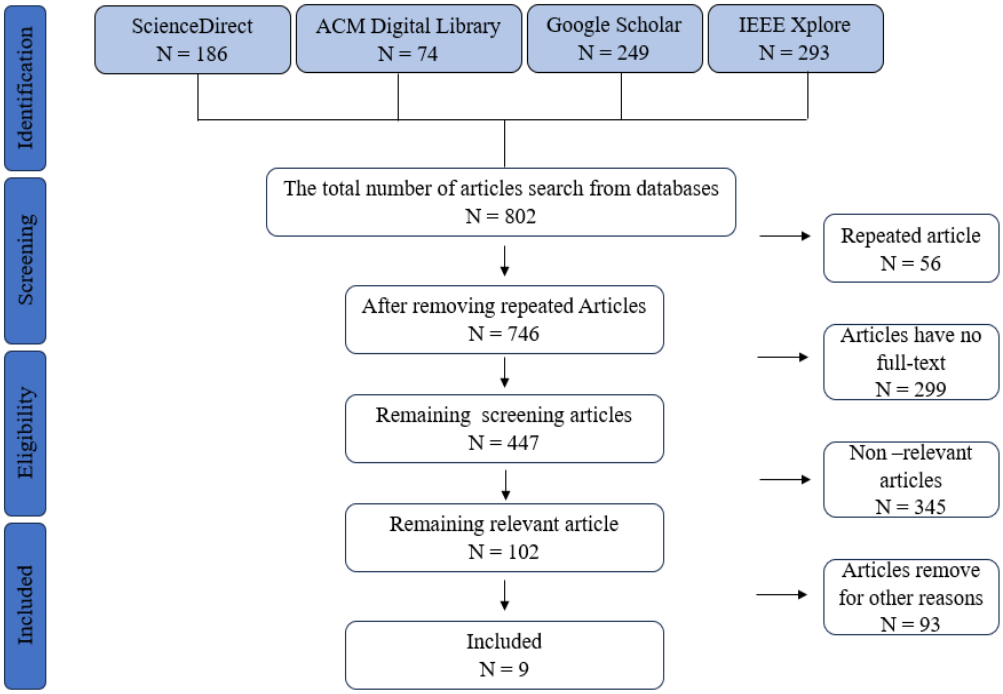


Table 2: *The Summary Representation of Findings*

The Main Findings	Source
The study aims to determine the impact of training programs on pre-service primary school teachers' perceptions toward ER.	(Silva, 2024)

The study aims to explore the impact of integrating unplugged Computational Thinking (CT) into STEM education on the CT skills of pre-service teachers.	(Çiftçi & Topçu, 2023)
This article demonstrates a professional development (PD) program for teachers' CT skills using virtual educational robotics.	(Kılıç & Çakıroğlu, 2022)
The study examines the effectiveness of STEM activities in mathematics for elementary pre-service teachers. The outcomes are positive and improved.	(Özçakır Sümen & Çalışıcı, 2022)
The article investigates teaching robotics fundamentals for human-robot collaborations.	(Selby et al., 2021)
The study focuses on the perspectives and attitudes of in-service and pre-service early childhood teachers on emergency resources in their daily teaching practice.	(Papadakis et al., 2021)
The study provides insight into the training process and its impact on teachers' attitudes toward the integrated STEM approach. The method blends educational coding with robots for primary schooling.	(García-Carrillo et al., 2021)
The study looks into pre-service preschool teachers' attitudes and self-efficacy about emergency response during a university course and their perceptions of the course.	(Schina, Valls-Bautista, et al., 2021)
The study discusses the acceptance of floor robots as a useful pedagogical tool among pre-service teachers.	(Casey et al., 2021)
The study presents an approach for introducing in-service teachers to ER, coding, Tinkering, and evaluating the outcomes.	(Scaradozzi et al., 2019)
The study aims to investigate the influence of teachers' attitudes and school context on reported instructional practice in integrated STEM using Structural Equation Modeling (SEM).	(Thibaut et al., 2018)
The study demonstrates the intervention in which a coach supported teachers in implementing STEM in school.	(Giamellaro & Siegel, 2018)

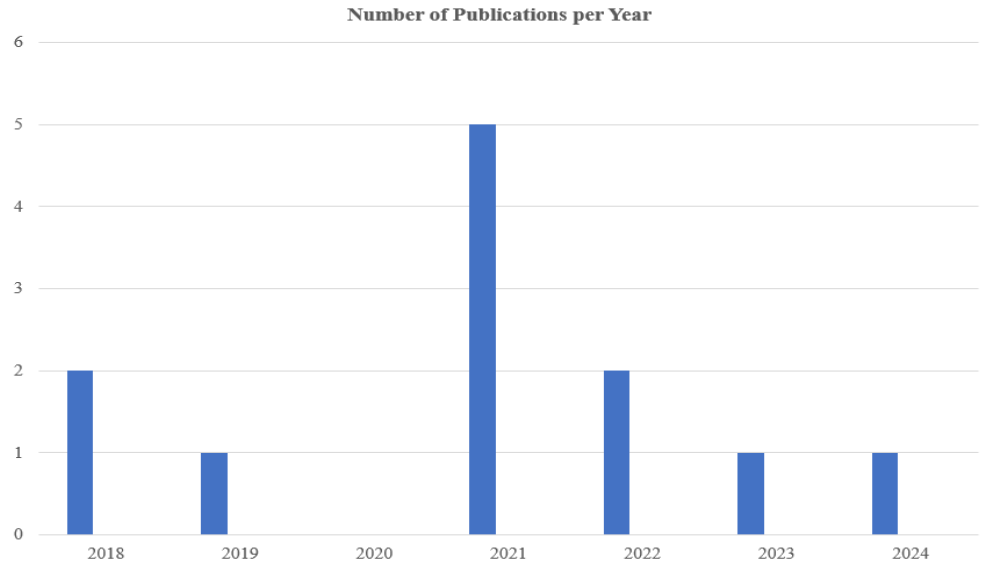
Article Selection Procedure

The process of selecting articles was conducted thoroughly and meticulously. The selection process involved four steps to ensure accuracy and relevance (see Figure 1). The first step involved searching online databases for studies. Articles deemed irrelevant or incomplete were excluded from consideration in the second step. The third step involved a more detailed examination of the remaining publications, focusing on their title, abstracts, and relevancy. Only articles that met the inclusion criteria were considered further. In the final step, full-length papers were selected based on inclusion criteria. To ensure that the study included only the most relevant

articles. This selection process ensured that only the most valuable and pertinent information was included in this analysis.

We may have reduced the number of studies by applying strict inclusion criteria during the review. The scope of this research is limited to a specific period (2018 to 2024). We chose this limited timeframe to highlight this field's most recent trends and current state.

Figure 2: ***The Articles Published per Year***



Our research uncovered the following: 2 articles were published in 2018, 1 in 2019, no publications in 2020, five papers in 2021, 2 publications in 2022, and one study each in 2023 and 2024. These findings provide valuable insight into the teachers' perceptions of ER, and PD program' trends, see Figure 2. However, this study has some limitations. We included all studies that met our inclusion criteria and were pertinent to our research questions. However, we did not conduct any further screening or shortlisting of papers based on the quality of their methodology or the reporting mechanism used to present their findings.

RESULTS AND DISCUSSION

We will analyze, summarize, and discuss the 12 papers from the perspective of recognizing the importance of in-service, pre-service, and school-based teacher training in ER and PD trends. These three research questions arise: what are the new

trends in Educational Robotics (ER) for teacher training programs to enhance Professional Development (PD), What are the teachers' perceptions toward Educational Robotics (ER) after attending training sessions? Do ER training programs foster a positive attitude among primary and secondary teachers? These concerns are addressed in this section. The field of ER is continuously evolving and offering an extensive integration of STEM that demands a range of multidisciplinary skills. Despite the growing interest, formal and informal educators often lack the necessary proficiency and self-assurance to teach STEM using robotics.

The strategy for integrating ER should replicate students' cognitive, and interpersonal skills while studying STEM disciplines. They participate in term-based activities that can entail designing, programming, constructing, and operating robot systems to develop abilities. PD opportunities for teachers can increase their confidence and enhance their ability to implement robotics and STEM programs (Choate et al., 2019). The utilization of robots in education, also known as ER. Robots are tools that show great potential and help learners understand STEM concepts and develop essential skills for the 21st century. Technology tools and resources can engage learners in interactive learning and experiment with real-world scenarios. It also makes it easier to comprehend complex concepts.

Technology integration in education helps to develop critical thinking, problem-solving, collaboration, social skills, and many other skills essential in the 21st century. It can effectively analyze, evaluate information, and collaborate in groups. As a result, students are better prepared for future job opportunities that require combining technical and soft skills (Bano et al., 2023).

There are no substantial pedagogical background studies on educational robots. Therefore, teacher training is equally challenging. The majority of the research centered on students' motivation for ER. Even though PD for teachers' STEM teaching training is deficient in topic understanding, particularly in preparing technical and pedagogical terms. Teacher training can improve the quality of ER use and provide an opportunity for adapting to these new trends (Castro et al., 2018). Teachers can continually interact with the latest trends in STEM education by implementing five key approaches: problem-centered learning, inquiry-based learning, cooperative learning, and collaborative learning. These approaches can significantly impact teaching; abilities and attitudes. Additionally, other factors in the school environment can also affect teaching methods, both directly and indirectly (Thibaut et al., 2018).

Integrating ER in formal and informal learning environments for youngsters has numerous learning advantages that positively impact students' STEM skills (Bano et

al., 2023). Robotics improve K-12 education by encouraging hands-on learning and preparing children for a technologically advanced future. Resource restriction, teacher training, and curriculum alignment need attention. Although initial interaction with ER will be difficult, trainers should offer ongoing support while implementing ER activities in tertiary educational institutions. Training for professional development will help to enable the successful implementation of instructional robotics activities in schools. The acceptance of teachers for this new pedagogical approach, and self-efficacy toward ER, and DP require further investigation. The role of elementary and secondary school teachers is crucial to the most. Therefore, it is pivotal to incorporate fundamental programming and engineering skills into PD and teachers' training programs. Future teachers must be able to equip their students with 21st-century skills such as ER programming.

Competition activities also offer educational opportunities that boost motivation, engagement, and training in specific domains such as human-robot interaction. Their use has grown in popularity, as evidenced by the rise of national and international robotics competitions such as the World Robot Olympiad (WRO), First Robotic Competition (FRC), VEX Robotics, First LEGO League, and many others. There is also a need to expand ER competitions, which are particularly beneficial for low-income and underserved young learners (Theodoropoulos et al., 2017). Several platforms have been used in scientific research and STEM teaching due to the numerous benefits of educational robots in improving educational experience, and enthusiasm for learning. Additionally, young learners show a continual preference for humanoid robots (Kyprianou et al., 2023). Although educational robots are regarded as innovative instructional tools in and out of the classrooms, their efficiency is often assumed.

New Trends in ER Teacher Training Programs to Enhance PD

ER is a novel concept in K-12 school settings, but teachers lack the expertise to guide students through these courses. There are few studies on how to integrate CT into robotics courses. PD programs can support computer science teachers already working, helping them stay optimistic and motivated. These programs expand the possibility of implementing related robotics education. The five steps of analysis, design, development, implementation, assessment, and the virtual robot programming curriculum can help teachers improve their CT and teaching skills.

Most of the studies emphasized programs designed to enhance the skills of K-12 STEM education. There is also a need to highlight the training of teachers for ER in schools, particularly among elementary school teachers. Those have no technological

expertise and a limited scientific background. Our study emphasizes the importance of training teachers to enhance their PD of teachers through ER-based training programs that introduce new educational trends in school education.

In implementing STEM on a large scale, instructors need tools that can help them find and adopt successful practices and resources that are both specific and flexible. Since STEM is based on other progressive educational principles, these tools can also be applied in academic environments. However, there is currently no research on the concepts of STEM coach support. Providing teachers with directive coaching approaches that rely on the coach's expertise can create a hierarchy that restricts teachers' autonomy and prioritizes external concerns over internal ones. To effectively spread STEM education, teachers will require additional support. Furthermore, those implementing extensive school reform initiatives will need specialized and adaptable support that is appropriate for the educational environment (Giamellaro & Siegel, 2018).The coach can serve as an intermediary in the short term but it is not a sustainable strategy. It can be a temporary solution but not beneficial in the long term.

One of the most essential aspects of 21st-century is the continuous PD of in-service teachers' knowledge and self-confidence through training workshops. These workshops play a crucial role in promoting research on new approaches and innovative strategies that can be implemented in classrooms to enhance the quality of education. With the help of teachers' training, educators are equipped with the necessary skills and tools to prepare students for future challenges (Scaradozzi, 2019). There is also a need to highlight the added value of predatory workshops for teachers in terms of creating an educational impact on students' attitudes toward technology (Boeve-de Pauw et al., 2022).

To ensure that STEM education is integrated into 21st-century learning, educators must receive extensive training in ER. This includes developing a deep understanding of the various applications and technologies involved and the ability to design and implement constructive learning experiences. Additionally, ongoing PD is essential to keep pace with the rapid advances and challenges in the ER field. It enables teachers to stay with the latest tools and techniques. By investing in high-quality training and PD, teachers help students receive the skills and knowledge they need to thrive in the modern world.

ER Training Programs Foster a Positive Attitude Among Primary and Secondary Teachers

ER has a positive impact on preschool teacher training and boosts the quality of early childhood education, by integrating this technology into our pre-service education. It

can improve attitude and confidence levels in using it efficiently. Using robots in teacher training programs has the potential to have a positive impact on the overall quality of education. Better knowledge of STEM and ER can increase self-efficiency (Schina, Valls-Bautista, et al., 2021). Robotics is new to K-12 classrooms, and teachers are not prepared to guide students through courses (Kılıç & Çakıroğlu, 2022). There is a need for comprehensive teacher training that will enable teachers to adopt the most effective approach to technology. Teachers can help young students to learn coding with unplugged activities. coding exercises at an early age promote the development of students' competitive skills, related to problem-solving and social skills such as communication (Pollarolo et al., 2024).

ER provides multiple opportunities for learning at different educational levels. It is an aid to enhancing STEM teaching and learning. The role of STEM teachers in shaping students' education experiences and knowledge retention is crucial. Technology integration in education has expanded to encompass all levels of learning. It is noted that ER lacks a strong pedagogical framework, and unqualified teachers often oversee its implementation. Additionally, the potential of educational robots is restricted. Educational leaders within the school system are highly invested in STEM education advancement, recognizing its immense potential to foster the growth of STEM-focused schools. To this end, educators are actively exploring various aspects of science, technology, engineering, and mathematics education, including its perceived benefits, challenges associated with implementation, and the critical role that school leadership plays in promoting its widespread acceptance and adoption. Through rigorous research, analysis, and collaboration, these leaders ensure that students have access to the best possible education and are prepared to succeed in today's rapidly evolving technology.

Floor robots are a simple yet effective educational tool that pre-service teachers can utilize to improve students' engagement and learning. These robots were created to enhance mathematics, STEM, and programming skills in K-12 education. Incorporating floor robots into the classroom can effectively boost the learning experience of students (Casey et al., 2021).

Teachers' Perceptions Toward ER After Attending Training Sessions

The training strategy in classroom practices has numerous advantages on science concepts to make them more problem-focused. Science is a tough and complex subject that is not enough to understand for students due to educators' lack of practice. There is significant initial indifference among educators about the particular concepts of STEM educational coding, and robotics. Training programs are intended to inspire teachers because they perceive the STEM approach as something new and able to bring

modifications to education, for expanding opportunities. There is a need to provide a new term in education. Additionally, the effectiveness of implementing this interdisciplinary approach in the early years of schooling has the potential for long-term benefits. On the other hand, the training of primary teachers has several challenges (García-Carrillo et al., 2021).

TeachBot course helps individuals understand essential robotics concepts and improve self-efficacy and confidence to use the technology, even without a four-year STEM background. The "Learning by Touching" approach simplifies technology usage while increasing comprehension (Selby et al., 2021). PD focuses on the activities of teachers' engagement to improve their practice, while learning refers to how a teacher's practice changes, sometimes as outcomes of training programs. This practice is essential for primary-level teachers (Goodwin et al., 2013).

Training programs for teachers to teach Computational Thinking (CT) through ER curriculum framework, learning objectives, and instructional practices to integrate CT techniques into educational robots. It improves competency in CT and robotics by encouraging a blended learning approach that combines academic knowledge with hands-on practice. By adding robotics activities into teaching practices, teachers can communicate more effectively the principles of CT such as problem-solving, algorithmic thinking, and logical reasoning. These activities provide PD opportunities for teachers to teach CT using robotics and encourage both educators and students to develop critical 21st-century abilities(Kılıç & Çakıroğlu, 2022).

Pre-service teachers benefit from STEM integration training, which includes problem-solving-based STEM activities such as engineering design projects in mathematics education. The practice enhances mathematical achievements, STEM awareness, and skills of pre-service elementary teachers (Özçakır Sümen & Çalışıcı, 2022). The unplugged CT integration STEM approach aims to improve the CT skills of pre-service teachers by focusing on hands-on activities that enhance problem-solving, algorithmic reasoning, and logical thinking. This novel approach is useful in contexts with limited digital resources (Çiftçi & Topçu, 2023).

In-service teacher education emphasizes the possibility of instructors combining ER training with ER implementation in their teaching practice as a key success factor. Technology introduction into the teaching and learning processes alters how and what can be taught. Teachers learn their curriculum subjects differently than students learn curriculum context through technological integration (Silva, 2024).

To address the increasingly complex challenges facing the world today, it is essential to focus on developing the skills of young individuals to become effective problem-solvers. This is crucial for meeting the demands of a rapidly changing global landscape. It is imperative to cultivate a diverse and innovative workforce that can adapt and thrive in the face of these challenges. The necessary can be met by incorporating an innovative mindset into K-12 STEM education through formal, informal, and other collaborative measures that encourage continuous creativity, critical thinking, logical thinking, and teamwork. To build and nurture a young population interested in innovation, early STEM education must tackle the issue of encouraging innovation skills and a discovery-oriented attitude toward monitoring the world in learners (Ammar et al., 2024). Educators have expressed their optimistic opinions regarding their pupils' learning as they acquire crucial 21st-century competencies like critical thinking, teamwork, innovative problem-solving, and oral presentation skills, according to most teachers, incorporating robotics and engineering-related activities into the curriculum yields positive outcomes, particularly in computer science proficiency.

The addition of educational robots in school curricula is highly desirable: however, it may pose certain challenges to the educational community. While the teachers' perception of robotics-based education remains favorable, governing bodies, academic researchers, and educational institutions must conduct further studies and investigations, to ensure a smooth and effective curriculum reform implementation.

The study's main objective is to highlight the importance of PD for primary and secondary school teachers using ER. Based on three research questions for this article, we concluded that PD programs are beneficial for both pre-service and in-service teachers. It also improves self-efficiency. Elementary teachers have limited scientific backgrounds, so training programs must be designed to enhance confidence and competence. If teachers gain confidence, they will feel more at ease teaching transdisciplinary subjects. Understanding how to build consistent and relevant PD opportunities is essential. These programs need to undergo several modifications.

This study provides a qualitative evaluation and analysis of multidisciplinary fields' potential for teacher training and PD success. Based on these findings (experimental studies), we provided recommendations for future ER teacher training programs. There is a need to highlight significant aspects of teacher training and the research required in teacher education and practice. Incorporating robotics technology education, or ER has been identified as an up-and-coming tool. With its ability to offer a wide range of educational benefits. This innovative approach can potentially revolutionize how we approach learning and teaching. Without the guidance and expertise of STEM teachers,

students would be at a significant disadvantage in their pursuit of academic success and personal growth.

Training sessions and classroom practice have advantageous effects on science concepts and make them more problem-focused. STEM is a multidisciplinary method of solving scientific challenges: for instance, educational coding and robotics provide instructions that a robot may execute specific tasks. Training sessions are intended to inspire teachers because they perceive the STEM approach as something new and can bring modification to education, expanding opportunities. Therefore, the contribution of these dedicated educators must be valued, they are essential to our society's progress and development.

Teaching training improves teachers' attitudes toward ER and fosters positive perceptions of an integral STEM approach to educational coding and robotics activities practice in the classroom. The existing literature on the importance of teacher training programs and new trends for elementary and secondary school teachers for in-service and pre-service teachers. In this context, we analyzed 12 studies on the significant role of instructors in emerging educational approaches such as ER.

RECOMMENDATIONS

Teachers' PD in ER is essential for equipping teachers with the skills and confidence needed to integrate robotics into the curriculum effectively. Future training programs for educators should focus on hands-on workshops that provide technical training on robotics platforms (e.g., LEGO Education, Arduino, or VEX) and pedagogical strategies for fostering computational thinking, problem-solving, and collaboration. Emphasizing interdisciplinary applications, such as connecting robotics to STEM, ensures broader educational benefits while supporting innovative teaching methodologies. Active learning methods like project-based learning are especially effective in PD settings. Collaborating frameworks, such as professional learning communities (PLCs) and mentorship with robotics experts, enhance knowledge transfer into classroom practice. Sustained PD, incorporating coaching, and reflective practices, empowers educators to adapt robotics activities to diverse students' needs. This approach promotes innovation and engagement in the classroom and fosters students' academic success and personal growth through the involvement of STEM educators.

REFERENCES

Ammar, M., Al-thani, N. J., & Ahmad, Z. (2024). Social Sciences & Humanities Open Role

of pedagogical approaches in fostering innovation among K-12 students in STEM education. Social Sciences & Humanities Open, 9(August 2023), 100839. https://doi.org/10.1016/j.ssaho.2024.100839

Anwar, S., Bascou, N. A., Menekse, M., & Kardgar, A. (2019). A systematic review of studies on educational robotics. Journal of Pre-College Engineering Education Research, 9(2), 19–42. https://doi.org/10.7771/2157-9288.1223

Bano, S., Atif, K., & Mehdi, S. A. (2023). Systematic review: Potential effectiveness of educational robotics for 21st century skills development in young learners. Education and Information Technologies, 1–19. https://doi.org/10.1007/S10639-023-12233-2/TABLES/2

Benitti, F. B. V. (2012). Exploring the educational potential of robotics in schools: A systematic review. Computers and Education, 58(3), 978–988. https://doi.org/10.1016/j.compedu.2011.10.006

Boeve-de Pauw, J., Ardies, J., Hens, K., Wullemen, A., Van de Vyver, Y., Rydant, T., De Spiegeleer, L., & Verbraeken, H. (2022). Short and long-term impact of a high-tech STEM intervention on pupils' attitudes towards technology. International Journal of Technology and Design Education, 32(2), 825–843. https://doi.org/10.1007/s10798-020-09627-5

ÇALİK, H., & ALTUN YALÇIN, S. (2022). The Effect of STEM and STEM-Based Robotics Activities on Constructive Learning Environments Opinions of Teacher Candidates. IBAD Sosyal Bilimler Dergisi, 12, 137–163. https://doi.org/10.21733/ibad.948455

Casey, J. E., Pennington, L. K., & Mireles, S. V. (2021). Technology Acceptance Model: Assessing Preservice Teachers' Acceptance of Floor-Robots as a Useful Pedagogical Tool. Technology, Knowledge and Learning, 26(3), 499–514. https://doi.org/10.1007/s10758-020-09452-8

Castro, E., Cecchi, F., Salvini, P., Valente, M., Buselli, E., Menichetti, L., Calvani, A., & Dario, P. (2018). Design and Impact of a Teacher Training Course, and Attitude Change Concerning Educational Robotics. International Journal of Social Robotics, 10(5), 669–685. https://doi.org/10.1007/s12369-018-0475-6

Choate, B., Dubosarsky, M., & Chen, K. (2019). An innovative professional development model for teaching robotics to novice educators. Proceedings - Frontiers in Education Conference, FIE, 2018-Octob, 1–5. https://doi.org/10.1109/FIE.2018.8658771

Çiftçi, A., & Topçu, M. S. (2023). Improving early childhood pre-service teachers' computational thinking skills through the unplugged computational thinking integrated STEM approach. Thinking Skills and Creativity, 49(May). https://doi.org/10.1016/j.tsc.2023.101337

García-Carrillo, C., Greca, I. M., & Fernández-Hawrylak, M. (2021). Teacher perspectives on teaching the stem approach to educational coding and robotics in primary education. Education Sciences, 11(2), 1–16. https://doi.org/10.3390/educsci11020064

Giamellaro, M., & Siegel, D. R. (2018). Coaching teachers to implement innovations in STEM. Teaching and Teacher Education, 76, 25–38. https://doi.org/10.1016/j.tate.2018.08.002

Goodwin, M., Brawley, M., Ferguson, P., Price, D., & Whitehair, J. (2013). A Whole-School

approach to STEM education: Every child, every class, every day. ISEC 2013 - 3rd IEEE Integrated STEM Education Conference, 1–4. https://doi.org/10.1109/ISECon.2013.6525203

Gorakhnath, I., & Padmanabhan, J. (2020). Educational robotics through LEGO for enhancing critical thinking skill in science. Journal of Critical Reviews, 7(19), 1303 –1312. https://doi.org/10.31838/jcr.07.19.159

Huang, B., Siu-Yung Jong, M., Tu, Y. F., Hwang, G. J., Chai, C. S., & Yi-Chao Jiang, M. (2022). Trends and exemplary practices of STEM teacher professional development programs in K-12 contexts: A systematic review of empirical studies. Computers and Education, 189(July), 104577. https://doi.org/10.1016/j.compedu.2022.104577

Hudson, M.-A., Baek, Y., Ching, Y., & Rice, K. (2020). Using a Multifaceted Robotics Based Intervention to Increase Student Interest in STEM Subjects and Careers. Journal for STEM Education Research, 3(3), 295–316. https://doi.org/10.1007/s41979-020-00032-0

Kılıç, S., & Çakıroğlu, Ü. (2022). Design, Implementation, and Evaluation of a Professional Development Program for Teachers to Teach Computational Thinking via Robotics. In Technology, Knowledge and Learning (Issue 0123456789). Springer Netherlands. https://doi.org/10.1007/s10758-022-09629-3

Konijn, E. A., & Hoorn, J. F. (2020). Robot tutor and pupils' educational ability: Teaching the times tables. Computers and Education, 157(December 2019), 103970. https://doi.org/10.1016/j.compedu.2020.103970

Kyprianou, G., Karousou, A., Makris, N., Sarafis, I., Amanatiadis, A., & Chatzichristofis, S. A. (2023). Engaging Learners in Educational Robotics: Uncovering Students' Expectations for an Ideal Robotic Platform. Electronics, 12(13), 2865. https://doi.org/10.3390/electronics12132865

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Journal of Clinical Epidemiology, 62(10), 1006–1012. https://doi.org/10.1016/j.jclinepi.2009.06.005

Özçakır Sümen, Ö., & Çalışıcı, H. (2022). The effects of STEM activities applied in mathematics courses for elementary pre-service teachers in Turkey. International Journal of Mathematical Education in Science and Technology, 53(12), 3352–3376. https://doi.org/10.1080/0020739X.2021.1944679

Papadakis, S., Vaiopoulou, J., Sifaki, E., Stamovlasis, D., & Kalogiannakis, M. (2021). Attitudes towards the use of educational robotics: Exploring pre-service and in-service early childhood teacher profiles. Education Sciences, 11(5). https://doi.org/10.3390/educsci11050204

Plaza, P., Sancristobal, E., Carro, G., Blazquez-Merino, M., Garcia-Loro, F., Munoz, M., Albert, M. J., Morinigo, B., & Castro, M. (2019). Scratch as Driver to Foster Interests for STEM and Educational Robotics. Revista Iberoamericana de Tecnologias Del Aprendizaje, 14(4), 117–126. https://doi.org/10.1109/RITA.2019.2950130

Pollarolo, E., Papavlasopoulou, S., Granone, F., & Reikerås, E. (2024). Play with coding toys in early childhood education and Care Teachers ' pedagogical Strategies , views and

impact on children ' s development . A systematic literature review. Entertainment Computing, 50(December 2023), 100637. https://doi.org/10.1016/j.entcom.2024.100637

Scaradozzi, D., Screpanti, L., Cesaretti, L., Storti, M., & Mazzieri, E. (2019). Implementation and Assessment Methodologies of Teachers' Training Courses for STEM Activities. Technology, Knowledge and Learning, 24(2), 247–268. https://doi.org/10.1007/s10758-018-9356-1

Schina, D., Esteve-González, V., & Usart, M. (2021). An overview of teacher training programs in educational robotics: characteristics, best practices and recommendations. Education and Information Technologies, 26(3), 2831–2852. https://doi.org/10.1007/s10639-020-10377-z

Schina, D., Usart, M., Esteve-Gonzalez, V., & Gisbert, M. (2020). Teacher views on educational robotics and its introduction to the compulsory curricula. CSEDU 2020 - Proceedings of the 12th International Conference on Computer Supported Education, 1(Csedu), 147–154. https://doi.org/10.5220/0009316301470154

Schina, D., Valls-Bautista, C., Borrull-Riera, A., Usart, M., & Esteve-González, V. (2021). An associational study: preschool teachers' acceptance and self-efficacy towards Educational Robotics in a pre-service teacher training program. International Journal of Educational Technology in Higher Education, 18(1). https://doi.org/10.1186/s41239-021-00264-z

Selby, N. S., Ng, J., Stump, G. S., Westerman, G., Traweek, C., & Asada, H. H. (2021). TeachBot: Towards teaching robotics fundamentals for human-robot collaboration at work. Heliyon, 7(7), e07583. https://doi.org/10.1016/j.heliyon.2021.e07583

Silva, R. (2024). Pre-service teachers ' perceptions towards integrating educational robotics in the primary school. 20(4).

Theodoropoulos, A., Antoniou, A., & Lepouras, G. (2017). Teacher and student views on educational robotics: The Pan-Hellenic competition case. Application and Theory of Computer Technology, 2(4), 1. https://doi.org/10.22496/atct.v2i4.94

Thibaut, L., Knipprath, H., Dehaene, W., & Depaepe, F. (2018). The influence of teachers' attitudes and school context on instructional practices in integrated STEM education. Teaching and Teacher Education, 71, 190–205. https://doi.org/10.1016/j.tate.2017.12.014

Zhong, B., & Xia, L. (2020). A Systematic Review on Exploring the Potential of Educational Robotics in Mathematics Education. International Journal of Science and Mathematics Education, 18(1), 79–101. https://doi.org/10.1007/s10763-018-09939-y

Hussain, Shakir & Lindh, Jörgen & Shukur, Ghazi. (2006). The Effect of LEGO Training on Pupils' School Performance in Mathematics, Problem Solving Ability and Attitude: Swedish Data.. Educational Technology & Society. 9. 182-194.