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Dynamics of Changes in Teachers' Perceptions of STEM Coding Robotics: The Importance of a Teacher Professional Development Program

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Abstract. This study aimed to determine significant changes in teachers' perceptions of science, technology, engineering, and mathematics (STEM) activities (e.g., coding robotics). Although teachers' perceptions are important in integrating STEM in education, there is still limited understanding of teachers' perceptions regarding the integration of STEM education, particularly in teaching coding robotics. This study employed a pre-experimental design with a one-group pre-test and post-test. The research sample involved 41 teachers, ranging from elementary to high school level. Teachers' perception data were analyzed using non-parametric chi-square and the paired samples t-test to assess the impact before and after participating in the training program, while teachers' recommendations on implementing coding robotics were analyzed using descriptive thematic analysis. The results showed that the STEM coding robotics training program significantly changed teachers' perceptions of mastering coding robotics skills ($p < .001$; $t = -6.781$). The training also significantly changed teachers' perceptions of coding robotics implemented at elementary school level ($p = .001$; $t = -3.591$) and junior high school level ($p = .005$; $t = -2.987$), but no significant change in perception was found for senior high school teachers ($p = .103$; $t = -1.672$). Other detailed findings that were elaborated in this empirical paper include the association between teachers' perceptions of coding robotics and their recommendations for implementing coding robotics after attending the program. These findings underscore the value of targeted professional development in fostering teachers' readiness for 21st-century STEM instruction and advancing Sustainable Development Goals in education.

Keywords: coding robotics; STEM; teachers' perception; teachers' program

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1. Introduction

The rapid advancement of digital technologies in the 21st-century have significantly influence all fields – from social and political sectors to education (McCarthy et al., 2023). Because of these advancements, there is a need for supporting skills, recently referred to as 21st-century skills (Hursen et al., 2023). These 21st-century competencies promote learning and innovation skills, information technology and media skills, and life and career skills (Gunadi et al., 2022; Hursen et al., 2023). Many countries worldwide strive to achieve economic development by providing a skilled workforce to work in the fields of science, technology, engineering, and mathematics (STEM) (Alsalamat, 2024). As a result, STEM has gained significant attention globally, and this has led to the establishment of STEM schools (Jones et al., 2024).

According to Wahono et al. (2025b), STEM aims to develop students' capacities and career orientation by integrating knowledge from various disciplines. This emphasizes collaborative teaching and the development of professionally oriented competencies (Yildirim et al., 2022). In addition, STEM education provides teachers with opportunities to demonstrate to students how concepts, principles, and techniques from science, technology, engineering, and mathematics are used in an integrative manner in the development of products, processes, and systems that are used in their daily lives (Hursen et al., 2023). Moreover, STEM learning can develop 21st-century skills and students' higher-order thinking skills (Lavi et al., 2021; Wahono et al., 2025b). To achieve these parameters, teachers must be skilled in creating STEM instructional designs. Teachers' skills can be developed through training programs (Li et al., 2023) and, therefore, it is necessary to develop teachers' training programs that enhance STEM competencies, particularly in Indonesia.

One of the most suitable ways to empower 21st-century skills today is through coding skills (Mu et al., 2024; Silva et al., 2024). Coding activities involve skills that combine problem-solving, logical thinking, computational thinking, and design (Tuomi et al., 2018). Several countries, including the UK, Finland, Australia, Greece, and France, have made coding or developing programming skills mandatory, starting in elementary school (Mason & Rich, 2020). This is due to the 12% growth in technology-related jobs during this decade and the fact that 90% of jobs previously performed by humans are becoming automated. Furthermore, from a cognitive perspective, developing coding skills can enhance students' mathematical performance and problem-solving abilities (Miller, 2019; Scherer et al., 2021).

Additionally, research conducted by Miller (2019) indicates that learning through coding instruction can lead to higher levels of mathematical thinking in students, particularly in regard to identifying patterns and mathematical structures that can lead to generalizations. Tiryaki and Adıgüzel (2021) found that coding activities can enhance students' creativity and scientific attitudes. Moreover, various studies have shown that the benefits of computer science education can increase student engagement, motivation, confidence, problem-solving, decision-making, communication, and learning and performance in science, technology,

engineering, and mathematics (Anwar et al., 2019; Chai, 2019; Meral et al., 2024; Uslu et al., 2022). Given the technological advancements and the importance of coding skills today, it is essential to introduce STEM-based computer science (programming-coding) to teachers in Indonesia to help them catch up in the field of technology.

Teachers serve as the primary bridge in the teaching of coding, as school students are often too young to develop sophisticated self-learning and thus require guidance from teachers (Mu et al., 2024). Indeed teachers are expected to possess and be sufficiently competent in understanding coding skills so that they can teach students and equip them with programming and coding skills (Mury et al., 2022; Teidla-Kunitsõn et al., 2023). Hence, it can be concluded that future learning processes need to equip students with coding skills. However, training programs to develop coding skills in teachers are still quite rare, especially in Indonesia. Research by García-Carrillo et al. (2021) showed that teachers' understanding of the STEM approach involving coding robotics was greatly influenced by practical experience and training support.

This finding has not been widely studied in the Indonesian context, which has its own challenges relating to infrastructure readiness and teacher competence (Hasanah, 2024). In addition, there is still a lack of research in Indonesia exploring teachers' perceptions of teaching coding robotics in terms of knowledge, attitudes, and the obstacles they face (Budiyanto et al., 2022). Hence, it is necessary to conduct training programs that can develop teachers' coding skills to meet the skill needs of the 21st-century (Mury et al., 2022). This research fills this gap and is expected to make important contributions to the development of educational policies and teacher training programs, especially in the context of professional training.

Coding robotics activities in STEM learning are still limited in scope and are focused mainly on the technology that is used (Darmawansah et al., 2023; Meral et al., 2024). Therefore, understanding teachers' perceptions of coding robotics in STEM teaching and their knowledge of its application in classroom learning is crucial for the professional development of teachers in STEM education (Alsalamat, 2024). This empirical research explored changes in the perceptions of Indonesian teachers after participating in a coding robotics training program in STEM teaching through analyzing the answers to the following research questions:

- a) How do teachers' perceptions of mastering coding robotics skills change after participating in the teachers' professional development program?
- b) How do teachers' perceptions regarding coding robotics apply at each educational level change after participating in the teachers' professional development program?
- c) What are the recommendations of the participating teachers after attending the teacher professional development program regarding the implementation of coding robotics in classroom teaching?

2. Literature Review

2.1 Teacher Professional Development in STEM Education

Teacher professional development refers to workshops or training programs that are designed to enhance teachers' abilities (Feldman-Maggor et al., 2022; Şahin et al., 2024; Yang et al., 2024). Professional development programs are the foundation for all types of educational change (Feri & Zulherman, 2021; Wahono et al., 2025a). These programs equip teachers with new skills and knowledge, qualifying them to become change agents in the education system (Yildirim et al., 2022). Professional development programs enable teachers to build the capacity to teach STEM confidently and competently in their future careers (Tuomi et al., 2018; Wahono et al., 2022). As technology rapidly advances, teachers' professionalism training improves their pedagogical and technological abilities (Hennessy et al., 2022). Teachers' abilities can be enhanced through participation in professional development training programs (Abakah, 2023; Bowman et al., 2020), and teachers who undergo training will increasingly develop knowledge in line with current needs.

In the context of STEM education, teachers' professional development programs are designed to help teachers advance in various fields and disciplines, particularly in content mastery and the design of integrated STEM learning approaches (Huang et al., 2022; Surahman & Wang, 2023). Empirical studies on teachers' professional development programs in STEM education reveal that the most common form of these programs is workshops (Chai, 2019). In addition to workshops, other professional development models include mentoring, which emphasizes content knowledge related to specific disciplines, pedagogical content knowledge, inquiry strategies, collaboration, and teachers' updates (Ufnar & Shepherd, 2019).

It is crucial to formulate professional development initiatives to enhance teachers' abilities to integrate disciplines, understand pedagogical approaches, and connect 21st-century competencies to real-world applications (e.g., creativity, collaboration, and digital technological literacy) (Kurup et al., 2019). Improving the quality and integration of STEM in the classroom depends on the teachers and making professional development programs essential for changing teachers' knowledge, beliefs, and attitudes (Mumcu et al., 2022; Ring et al., 2017). More research and discussion are needed relating to the knowledge and experience that teachers require to implement STEM education successfully and to achieve the desired impact on student learning in preparation for 21st-century challenges.

2.2 Coding Robotics and STEM Education

Coding robotics can be effective in teaching STEM education because it allows for the real-world application of engineering and technology concepts and helps demystify the abstractions of science and mathematics (Kim et al., 2015). Integrating coding robotics into education allows students to engage actively in STEM, thus encouraging constructive thinking (Gavrilas & Kotsis, 2024). Coding robotics education facilitates the development of technical and programming skills (Gavrilas & Kotsis, 2024; Hallström & De Vries, 2024).

Students can design and assemble various objects to gain a strong understanding of programming concepts (Ibrahim et al., 2020; Papadakis et al., 2022; Paucar-Curasma et al., 2023). The use of coding robotics in education not only enhances students' understanding of science and mathematics but also has a positive impact on academic performance (Ouyang & Xu, 2024; Wang et al., 2023). Coding robotics in education is an engaging activity that captures students' interest while enhancing their comprehension of STEM subjects. This approach uses practical exercises and problem-solving techniques, allowing students to integrate their prior knowledge with new concepts effectively (Darmawansah et al., 2023; Hughes et al., 2022).

The increasing significance of technology integration in education has led to the widespread adoption of coding robotics education (Meral et al., 2024). This indicates that STEM education has been increasingly integrated into coding robotics education in recent years. The technological advancements of the current era have made coding robotics popular at almost all educational levels (Glezou, 2021; Javaid et al., 2021; Seckin-Kapucu, 2023). Dissemination activities related to coding robotics are carried out through courses and training provided for teachers and students under the title of coding robotics (Filippov et al., 2017). In response to these developments, one of the essential skills that teachers need to possess in the 21st century is coding robotics.

Three dimensions are highlighted in programming: 1) from code to application, 2) from programming tools to community, and 3) from scratch to remix (Miller, 2019). Given the rapid advancements in technology and information, children must begin to learn programming or coding in elementary and secondary school (Ou et al., 2023). Even if they do not aspire to become programmers, coding skills will become a fundamental skill to meet future life needs (Tran, 2018). In conclusion, it is noted that teachers' perceptions in the context of the integration of STEM education and coding robotics are crucial for sustainable development and the effectiveness of current transformative educational approaches.

2.3 Teachers' Perceptions of STEM Coding Robotics

In the context of education, teachers' perceptions refer to the opinions, ideas, or mental structures that teachers hold about subjects, events, and procedures (Alsalamat, 2024). Teachers' perceptions play a significant role in shaping and guiding their behaviors, attitudes, and practices and their application of knowledge (Elmosaad, 2024). Understanding teachers' perceptions of a specific teaching content such as STEM coding robotics and their perceptions of skill mastery and its application serves as a fundamental and initial step in planning and developing instruction in this field (García-Carrillo et al., 2021; Margot & Kettler, 2019; Silva et al., 2024). Teachers' perceptions of STEM education greatly influence their willingness to adopt this approach and related teaching strategies (García-Carrillo et al., 2021). Understanding teachers' perceptions and beliefs provides insights into planners, designers, and curriculum developers on what should be emphasized in STEM teacher professional development programs and in the evaluation of existing STEM education programs.

Margot and Kettler (2019) stated that understanding teachers' perceptions is essential for developing teachers' STEM talents. Moreover, understanding teachers' perceptions of STEM education is crucial, as it can influence their decision-making. Teachers' age, gender, and teaching experience can affect their views on STEM education (Khwaengmek & Faikhamta, 2023). Exploring teachers' perceptions of integrated STEM education is one of the most important tasks for researchers and other educational decision-makers. This is because teachers' perceptions of STEM will directly affect their willingness and ability to implement it effectively in their classrooms (Margot & Kettler, 2019). In Indonesia, research on teachers' perceptions of STEM, particularly in coding robotics instruction, is still scarce. Despite the increasing interest in STEM learning in Indonesia, most existing research focuses more on the effectiveness of programs on student learning outcomes than on the perceptions of teachers as key actors in curriculum implementation (Hasanah, 2024).

Research that explicitly explores how teachers understand, respond to, and integrate coding robotics into learning is still very limited (Budiyanto et al., 2022). In fact, teachers' perceptions greatly influence the success of implementing technology-based learning innovations (e.g., coding robotics) (García-Carrillo et al., 2021; Silva et al., 2024). Additionally, according to Wahono and Chang (2019), knowledge and attitudes are fundamental domains for implementing appropriate and sustainable STEM education. Furthermore, the attitudes toward STEM education of teachers who participate in STEM teaching training programs can be positively influenced, improving their awareness and perspectives of STEM teaching.

Teachers need to be trained through professional development programs that focus on expertise in integrating STEM education and foster positive perceptions of STEM-based learning (Margot & Kettler, 2019; Şahin et al., 2024). Particularly in coding robotics instruction, to promote the integration of STEM education through teachers' professional development programs that are STEM-focused, it is necessary to investigate teachers' perceptions of STEM coding robotics instruction (Darmawansah et al., 2023; Drakatos & Christou, 2023). A study by Castro et al. (2018) reported a positive change in teachers' perceptions of educational robotics after participating in training and a more favorable change in their views on the potential of educational robotics being applied in their teaching practices.

A clear understanding of teachers' perceptions of STEM coding robotics can serve as a platform for supporting the continual improvement of higher and better quality STEM professional development (Wang et al., 2023). This empirical study analyzed the perceptions of teachers at schools ranging from elementary to high school regarding the integration of STEM education in coding robotics instruction. The analysis was viewed according to the various dimensions of gender, teaching experience, specialization, and educational levels of the participating teachers. By understanding their perceptions, challenges could be identified, and evidence-based recommendations could be proposed, showing that coding robotics

training through teacher professional development supports teachers in integrating STEM education into their classrooms.

3. Methodology

3.1 Research Design

This research employed a pre-experimental design: a one-group pre-test post-test approach, a type of quasi-experimental research that implemented STEM coding robotics activities for teachers at elementary, middle, and high school levels. This design is appropriate for the research purpose of measuring changes in teachers' perceptions of the intervention (STEM-based coding robotics training program). The primary focus was to understand the changes in teachers' perceptions after participating in STEM-based coding robotics training. Three research questions were posed to address the main research problem, and statistical and thematic descriptive analysis were used.

3.2 Participants

The subjects of this research were school teachers located in the region of East Java, Indonesia, specifically in Jember Regency and its vicinity. This study involved 41 teachers at elementary, middle, and high school levels (see Table 1). The demographic information of the participating teachers considered the criteria of gender, teaching experience, specialization or field of study, and educational level and is presented in Table 1. Furthermore, the researcher provided introductory information for the participants on the purpose of the study, the use of data, and the anonymity of the questionnaire in addition to instructions for filling out the Google Forms questionnaire. Each participant of the teacher professional development training program first granted informed consent through a letter of agreement to participate in a series of training program activities organized by the research team.

Table 1: Demographic information of the participants

Dimensions	Category	<i>n</i>	%
Gender	Male	15	36.58
	Female	26	63.42
Teaching Experience	<5 Years	12	29.27
	5–15 Years	15	36.58
	>15 Years	14	34.15
Specialization	Science	19	46.34
	ICT	6	14.63
	Mathematics	5	12.20
	Other	11	26.83
Educational Level	Elementary School	11	26.83
	Junior High School	17	41.46
	Senior High School	13	31.71

3.3 Instrument

In this study, data regarding teachers' perceptions of coding robotics were collected using a questionnaire developed by the research team. The instrument was thoroughly validated (both face and content validation) by experts through multiple iterations before being used to gather research data, ensuring its appropriateness and minimizing measurement errors. The questionnaire used in this study consisted of two main sections. The first section included questions related to the participants' demographics - gender, teaching experience, specialization, and educational level. The second section contained three specific questions designed to measure teachers' perceptions and ideas concerning coding robotics. The Pre-Intervention and Post-Intervention Question 1 was "Do you think the skill of coding robotics is difficult for teachers to master?"

The responses to this question were scored on a scale with the following options: Difficult = 0, Uncertain = 1, and Easy = 2. The Pre-Intervention and Post-Intervention Question 2 was "Do you think coding robotics can be taught or applied at all educational levels (elementary school, middle school, and high school)?" The responses to this question were scored on a scale with the following options: Cannot be applied = 1, Uncertain = 2, and can be applied = 3. Lastly, the Post-Intervention Open-Ended Question 3, "What ideas do you have for using coding robotics skills in classroom teaching?" was presented. This open-ended question allowed participants to provide essay-style responses, which were later analyzed using thematic descriptive analysis to interpret their recommendations on how coding robotics could be implemented in classroom teaching following the training program.

3.4 Procedure

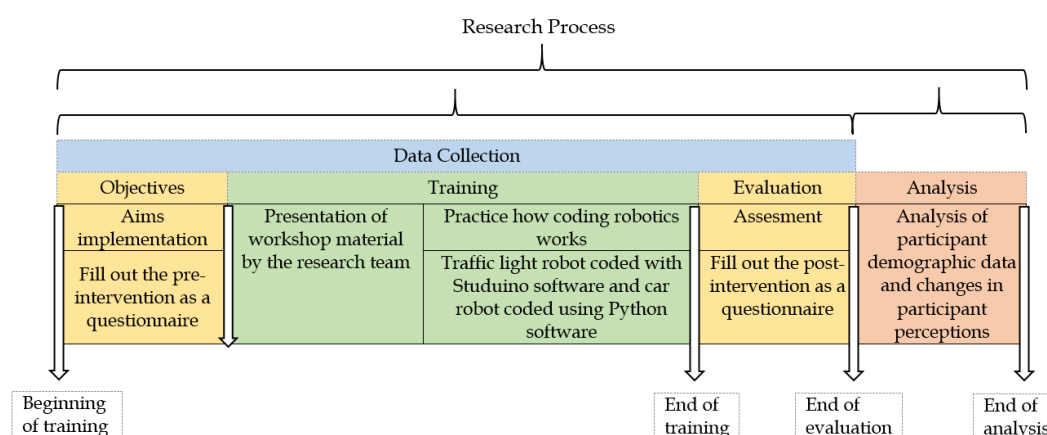


Figure 1: Research process

This study began with the planning stage, followed by the distribution of pamphlets or flyers to recruit participants for the teachers' professional development program on coding robotics in STEM education. The participants were teachers who had been teaching at elementary, middle, and high school levels in East Java, particularly in the Jember Regency and its surrounding areas. The participant registration phase was conducted until the quota was met of participants who fulfilled the mandatory requirements. The main requirements

for participants were that they were already teachers and were committed to attending the offline training program from start to finish. Once the participants were confirmed, the training program could start. The research process for this study is illustrated in Figure 1. The teacher professional development program started with participants completing a pre-intervention questionnaire, followed by a workshop presentation by the research team. Participants then directly practiced robotics coding, starting from the basics and working toward more complex aspects. Teachers used a STEM coding robotics kit with Studuino and Python software. After the training program was completed and the post-intervention data were collected, the research team analyzed the data to interpret the study's findings. Figure 2 shows the coding robotics process using Studuino and Python software on a laptop screen.

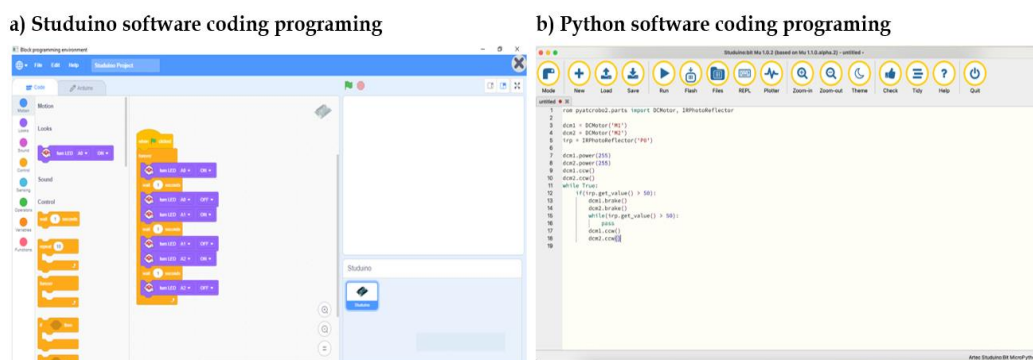


Figure 2: Coding using Studuino and Python software

The training and mentoring activities were conducted offline (in-person). The training for teachers in STEM coding robotics was provided by the research team who were also the main presenters. They covered both the theory of STEM-based coding robotics and its practical implementation, which included designing a traffic light robot and a robot car with coding using Studuino and Python software. This training program activity was carried out over two days, and each session lasted for eight hours. Participants in the training program designed robots and performed simple coding in groups using Studuino and Python software integrated with robotics. This was followed by direct testing.

In this training activity, the coding robotics module prepared by the research team served as the primary guide for the participants during the coding process. Participants were introduced to two types of coding robotics: the creation of a traffic light robot and the creation of a robot car, with the coding process practiced directly on each participant's laptop. The traffic light robot was coded using the Studuino software, while the robot car was coded using the Python software. At the end of the training program, the participating teachers were asked to complete a post-intervention questionnaire.

3.5 Data Collection

Data collection for this study was facilitated through Google Forms. The data were derived from the pre-intervention and post-intervention questionnaires that were completed by the participants of the teacher professional development program. The researchers provided introductory information for the participants about the

research objectives, data usage, questionnaire anonymity, and instructions for completing the questionnaire. Before collecting the research data, participants were informed that the data collected during the STEM coding robotics training would be published, and their consent was sought. The research data that were collected comprised participant demographics and changes in their perceptions after participating in the coding robotics training program in STEM education. After the training program was completed and the research data had been collected, the research team conducted data analysis to interpret the findings.

3.6 Data Analysis

Data analysis was performed using the statistical software Statistical Package for Social Sciences (SPSS). A non-parametric chi-square statistical test was used to examine the relationship between participants' responses and their gender, teaching experience, specialization, and educational level, with a significance level of $\alpha = 0.05$. Additionally, a paired samples t-test was conducted to analyze the significant differences between pre-intervention and post-intervention results regarding perceptions of coding robotics skill mastery and the applicability of coding robotics at different educational levels. Before conducting a paired samples t-test, a normality assumption test was conducted with the test results showing that the data were normally distributed ($p > .05$). Descriptive data analysis was also used to assess participant demographics, including gender distribution, teaching experience, specialization, and educational level. A qualitative thematic descriptive analysis was employed to interpret participants' recommendations for implementing coding robotics in classroom teaching after completing the training program.

4. Results

This study aimed to explore teachers' perceptions of implementing STEM coding robotics at elementary, middle, and high school level. Teachers' perceptions of STEM coding robotics serve as a source of information for developing future teacher professional development programs for STEM and coding robotics education. As this field continues to grow, teachers require ongoing support to keep pace with advancements, pedagogical techniques, and the integration of evolving technologies in education. Based on this, it was crucial to involve teachers in coding robotics training (Figure 3) and to understand their changed perceptions after participating in the program. This provided valuable insights into STEM-based computer science (coding robotics) education, addressing technological gaps and enhancing their teachers' knowledge of STEM education.



Figure 3: The coding and assembly process of the traffic light robot and the robot car conducted by the participants (plural)

The professional development of teachers and training in coding robotics within STEM education are crucial driving forces in today's education, particularly in understanding teachers' perceptions of the implementation of coding robotics in STEM teaching. In encouraging teachers' innovation in computer science-based learning (coding robotics), it is essential to explore changes in their perceptions after undergoing coding robotics training through STEM teaching. A strong perception of STEM is a good starting point for learning and implementing STEM teaching. The way that teachers view STEM education can be influenced by various factors such as gender, experience, specialization, education, and training. Recognizing the importance of STEM education and the critical role that teachers play in the successful implementation of the rapidly evolving coding-robotics-based learning, the researchers analyzed the responses to the research questions posed in this study as indicated in the following subsections.

4.1 Teachers' Perceptions of Mastering Coding Robotics Skills

The first research question of this study was, "How do teachers' perceptions of mastering coding robotics skills change after participating in the teacher professional development program?" To answer this question, a quantitative analysis was conducted to interpret the results obtained through the questionnaires. The findings are presented in Table 2.

Table 2: Changes in teachers' perceptions of mastering coding robotics skills

Dimensions	Item	Perceptions	Total <i>n</i> (%)	χ^2	<i>p</i> -value	<i>V</i>
Gender	Pre-intervention	Difficult	34 (82.9)	2.271	.321	.235
		Moderate	3 (7.3)			
		Easy	4 (9.8)			
	Post-intervention	Difficult	8 (21.6)	2.724	.256	.271
		Moderate	8 (21.6)			
		Easy	21 (56.8)			
Teaching Experience	Pre-intervention	Difficult	34 (82.9)	9.320	.054	.477
		Moderate	3 (7.3)			
		Easy	4 (9.8)			
	Post-intervention	Difficult	8 (21.6)	7.444	.114	.449
		Moderate	8 (21.6)			
		Easy	21 (58.8)			
Specialization	Pre-intervention	Difficult	34 (82.9)	5.846	.441	.378
		Moderate	3 (7.3)			
		Easy	4 (9.8)			
	Post-intervention	Difficult	8 (21.6)	4.361	.628	.343
		Moderate	8 (21.6)			
		Easy	21 (56.8)			

Table 2 provides the results of the chi-square test of independence, indicating that there was no significant association between gender, teaching experience, and specialization and teachers' perceptions of mastering coding robotics skills ($p > 0.05$). Participants' data before and after the training program are as follows: gender dimension ($\chi^2 = 2.271$, $p = .321$; $\chi^2 = 2.724$, $p = .256$), teaching experience dimension ($\chi^2 = 9.320$, $p = .054$; $\chi^2 = 7.444$, $p = .114$), and specialization dimension ($\chi^2 = 5.846$, $p = .441$; $\chi^2 = 4.361$, $p = .628$).

Based on the data in Figure 4, the gender differences did not show a significant difference in the perception that coding robotics skills could be easily mastered by teachers after participating in the training program. The perception that coding robotics skills could be easily mastered by teachers increased significantly by 47.8% (from 6.7% to 54.5%) among the male participants and by 46.2% (from 11.5% to 57.7%) among the female participants. In addition, teachers with less than five years of teaching experience agreed that coding robotics skills could be easily mastered by teachers and showed the highest increase after participating in the training program with a rise of 60% (from 6.7% to 66.7%). Regarding the specialization dimension, changes in perceptions for participants with mathematics specialization ranked first in the level of agreement that coding robotics skills could easily be mastered by teachers after completing the training program, with an increase of 100%. This was followed by participants specializing in Information and Communication Technology (ICT) with a 50% increase. Overall, the results highlight a substantial improvement in teachers' confidence

in mastering coding robotics skills after the training program, with notable variations across experience levels and specializations.

Figure 4: Changes in teachers' perceptions of mastering coding robotics skills

Table 3: Differences in teachers' perceptions of mastering coding robotics skills

Item	Mean	Std. Deviation	<i>t</i>	<i>df</i>	<i>p</i> -value
Differences in perceptions of mastering coding robotics skills	1.2432	0.59654	-6.781	36	.000
Pre-intervention	1.2432	0.59654			
Post-intervention	2.3514	0.82382			

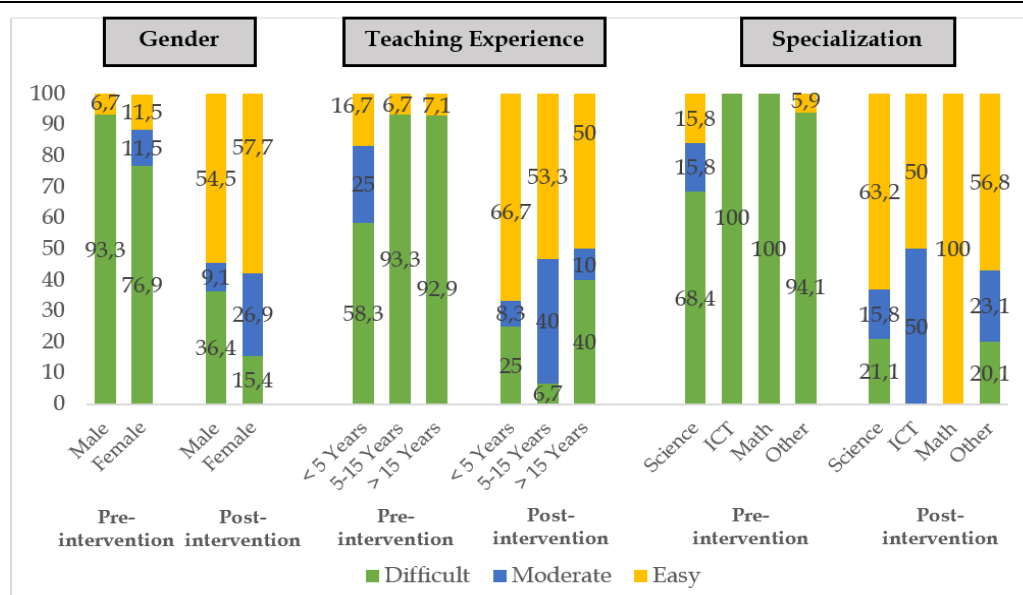


Table 3 presents the results of the paired samples *t*-test that was used to analyze the significance of the differences in the participants' mean perceptions of mastery of coding robotics skills through the teacher professional development program. To determine the significance of these perception differences, data collected before and after the training program from participants' pre-intervention and post-intervention questionnaires were used. The table shows that there was a statistically significant difference between the mean scores of the participants' responses regarding their perception of mastering coding robotics skills through the teacher professional development program ($p < .05$). The difference lies in the change in participants' perceptions, with a significant increase in those who agreed that coding robotics skills could be easily mastered by teachers after participating in the training program for two days and with each session lasting eight hours.

4.2 Teachers' Perceptions of the Application of Coding Robotics

The second research question of this study was, "How do teachers' perceptions of coding robotics change when applied at each educational level after participating in the teacher professional development program?" To answer this question, a quantitative analysis was conducted to interpret the results obtained through the questionnaires. The findings are presented in Table 4.

Table 4: Changes in teachers' perceptions of the application of coding robotics across all educational levels

Dimensions	Item	Perceptions	Total <i>n</i> (%)	χ^2	<i>p</i> -value	<i>V</i>
Elementary School	Pre-intervention	No	8 (19.5)	2.114	.715	.227
		Unsure	9 (22.0)			
		Yes	24 (58.5)			
	Post-intervention	No	0 (0.0)	1.417	.492	.196
		Unsure	2 (5.4)			
		Yes	35 (94.6)			
Junior High School	Pre-intervention	No	5 (12.2)	10.965	.027	.517
		Unsure	5 (12.2)			
		Yes	31 (75.6)			
	Post-intervention	No	0 (0.0)	37	37	37
		Unsure	0 (0.0)			
		Yes	37 (100.0)			
Senior High School	Pre-intervention	No	0 (0.0)	2.634	.268	.253
		Unsure	6 (14.6)			
		Yes	35 (85.4)			
	Post-intervention	No	0 (0.0)	1.085	.581	.171
		Unsure	36 (97.3)			
		Yes	37 (100.0)			

Table 4 presents the results of the chi-square independence test, indicating that there was only one instance of a significant association with teachers' perceptions of implementing coding robotics at different educational levels. This significant association was found in the pre-intervention perceptions of teachers regarding coding robotics implementation at the junior high school level ($p < .05$). Additionally, no significant associations were found at the elementary school and senior high school levels regarding teachers' perceptions of implementing coding robotics at these levels ($p > .05$). Participants' data before and after the training program are as follows: at the elementary school level ($\chi^2 = 2.114, p = .715; \chi^2 = 1.417, p = .492$), at the junior high school level ($\chi^2 = 10.965, p = .027; \chi^2 = 37, p = 37$), and at the senior high school level ($\chi^2 = 2.634, p = .268; \chi^2 = 1.085, p = .581$).

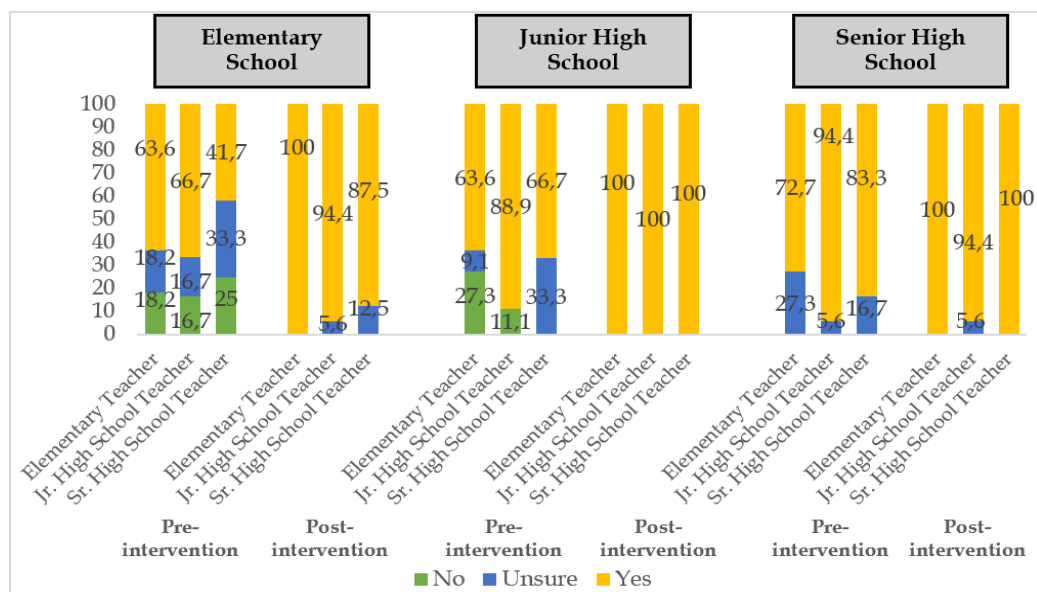


Figure 5: Changes in teachers' perceptions of coding robotics if implemented at different educational levels

Based on the data in Figure 5, teachers from across all educational levels experienced an increase in positive perceptions towards the implementation of coding robotics at each level of education after participating in the training program. Elementary school teachers experienced the largest positive increase in their perception of implementing robotics coding after participating in the training program at 81.8% (100%-18.2%). Overall, the perceptions of teachers from across all educational levels demonstrated the highest confidence that robotics coding could be implemented at the junior high school level after participating in the training program, with a percentage of 100%.

Table 5: Differences in teachers' perceptions of implementing coding robotics

Item		Mean	Std. Deviation	<i>t</i>	<i>df</i>	<i>p</i> -value
Elementary School	Pre-intervention	1.4324	0.80071	-3.591	36	.001
	Post-intervention	1.9459	0.22924			
Junior High School	Pre-intervention	1.6486	0.71555	-2.987	36	.005
	Post-intervention	2.0000	0.00000			
Senior High School	Pre-intervention	1.8649	0.34658	-1.672	36	.103
	Post-intervention	1.9730	0.16440			

Table 5 presents the results of the paired samples *t*-test that was used to analyze the significance of the differences in teachers' average perceptions of implementing coding robotics at each educational level. To determine the significance of these differences, pre-intervention and post-intervention data were collected through questionnaires that were administered before and after the training program. The results of this study indicate that training in implementing coding robotics has a significant impact on teachers' perceptions at the elementary and junior high school levels ($p < .05$) but does not show significant changes at the

senior high school level ($p > .05$). The implications of these findings suggest that training is more effective for teachers at lower levels of education, possibly because they have less experience with technologies such as coding robotics and because there is curriculum flexibility that allows for easier integration of innovative learning methods. In contrast, at the high school level, teachers' perceptions tended to change less, possibly due to their already high baseline perceptions.

4.3 Participants' Recommendations on Idea for Implementing Coding Robotics

The third research question of this study was, "What are the recommendations of the participating teachers after attending the teacher professional development program regarding the implementation of coding robotics in classroom teaching?" To address this question, a qualitative thematic descriptive analysis was conducted to interpret the research data that were obtained through the questionnaires. The results are presented in Figure 6.

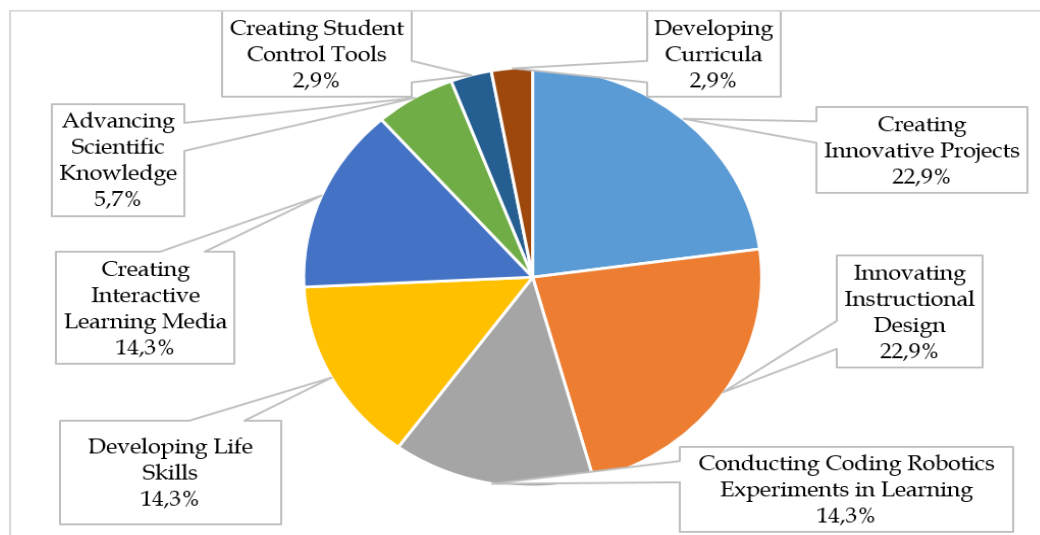


Figure 6: Idea themes for using coding robotics in education

Figure 6 shows eight themes relating to the ideas that teachers conceived after participating in the training program. These eight themes were based on the various responses provided by the participating teachers and identified through thematic analysis conducted by the researchers. The eight thematic ideas for integrating coding robotics into classroom teaching were creating innovative projects, innovating instructional design, conducting coding robotics experiments in learning, developing life skills, creating interactive learning media, advancing scientific knowledge, developing curricula, and creating student control tools.

Projects focused on innovation and instructional design demonstrated the highest percentage at 22.9%. For example, the idea under the theme of 'creating innovative projects' expressed by teachers included, "I will equip students with coding skills to create new, innovative products that can be applied in daily life such as developing robotics-based agricultural technology products, creating automatic trash bins, automatic lights, grass-cutting robots, floor

cleaners, classroom cleaning robots that can detect obstacles, collision sensors, and more”.

Moreover, a teacher's idea with the theme of ‘innovating instructional design’ might include, *“I want to make learning more engaging and enjoyable by introducing coding robotics to students from an early age, as it is highly relevant to contemporary needs”.*

Regarding the findings in Figure 6, teachers who attended the training realized the importance of coding robotics in the world of education. They proposed various ways of implementing coding robotics in the classroom, with the focus on learning innovation, creative projects, and developing students’ skills to be better prepared to face challenges in the digital era.

5. Discussions

Recently, developing countries, including Indonesia, have concentrated on improving and developing human resource capacities, especially in the field of STEM, coding, and robotics. This effort aims to achieve higher economic goals in line with the national vision for Indonesia’s Golden Era by 2045. However, Indonesia still lags developed countries in terms of the quality of STEM coding robotics education. This research is considered important as it adds to our understanding of how teachers in Indonesia at elementary, middle, and high school perceive coding robotics in STEM teaching before and after participating in a teacher professional development program. It highlighted the significance of understanding teachers’ perceptions across all educational levels of STEM coding robotics as a key element in the implementation. When teachers’ perceptions of coding robotics in STEM teaching are understood, effective programs can be created to help teachers in developing these teaching practices. The successful implementation of STEM coding robotics teaching is crucial for students to benefit from the capabilities offered by modern education (Mwangi et al., 2022; Negrini et al., 2023; Wang et al., 2023).

Following participation in the coding robotics training program, teachers’ perceptions of their ability to master and teach coding robotics significantly improved. This positive shift was most evident among elementary and junior high school teachers, which aligns with prior research emphasizing the benefits of early integration of robotics in education (Gavrilas & Kotsis, 2024). These findings are consistent with the literature (Alsalamat, 2024; Samara & Kotsis, 2023; Yildirim et al., 2022; Zhang et al., 2023). For Example, Gavrilas and Kotsis (2024) state that STEM training fosters a strong positive perception of integrating coding robotics into STEM education. Overall, the quantitative results of the current study suggest that the coding robotics training program in STEM teaching had a positive impact on teachers’ perceptions across all educational levels. It is important to note that teachers’ perceptions of the importance of STEM education affect their capacity to learn and develop as STEM educators (Bell, 2016). Furthermore, teachers with positive perceptions of STEM are a crucial factor in the successful implementation of STEM coding robotics programs (Alsalamat, 2024; Gavrilas & Kotsis, 2024).

Some studies reflect the extent to which teachers can understand coding robotics in STEM teaching (Darmawansah et al., 2023; Drakatos & Christou, 2023; Kaygısız et al., 2020; Ortega-Ruipérez & Alcalde, 2023). However, teachers can face challenges when teaching coding robotics due to a lack of training on how to implement it (Castro et al., 2023; Khanlari, 2016; Ouyang & Xu, 2024). Additionally, research has indicated that teachers can encounter difficulties in implementing STEM coding robotics because of time constraints and a lack of resources (Ali et al., 2023; Yuldashevna & Khurana, 2024). Moreover, several studies provide strong evidence that training programs offered to teachers are beneficial for building their knowledge about modern trends in STEM education practices, particularly in programming and coding robotics (Anwar et al., 2019).

This study investigated the relationship between teachers' gender, teaching experience, specialization, and educational level and their perceptions of mastering coding robotics skills in STEM teaching and its application at each educational level. The results showed that no significant associations were found between teachers' perceptions of mastering coding robotics and its application. These findings align with previous research that indicates no observed correlation between teachers' perceptions and STEM coding robotics education (Alsalamat, 2024; Gavrilas & Kotsis, 2024). For instance, Alsalamat (2024) found no significant relationship between teachers' gender, teaching experience, and specialization and their perceptions of coding robotics in STEM teaching. This was possibly due to differing teaching goals among individual teachers.

The dynamics of teachers' perceptions when viewed through the gender dimension showed no significant differences after participating in the training program. This is consistent with literature stating that gender differences do not significantly affect teachers' perceptions of teaching STEM coding robotics (Gavrilas & Kotsis, 2024). Additionally, the study observed that teachers with less than five years of teaching experience had better perceptions of mastering coding robotics skills. This might be because teachers with less experience are generally younger than those with more than five years of teaching experience. Therefore, the researchers conclude that age might influence teachers' perceptions of mastering coding robotics. This is supported by literature suggesting that coding robotics training is more suitable for younger participants (Anwar et al., 2019; Gonzales et al., 2021; Jung & Won, 2018).

Changes in the perceptions of teachers with mathematics and ICT specializations showed more favorable perceptions after participating in the coding robotics training than teachers with other specializations. This may be due to their greater knowledge of disciplines related to coding robotics (mathematics, technology), which may have provided them with more resources and resulted in better perceptions of teaching STEM coding robotics. This aligns with literature indicating that teachers in mathematics and ICT have better perceptions of coding robotics teaching than other teachers (Aksu & Durak, 2019; Mallik et al., 2023). However, the overall results showed that the coding robotics training program in STEM teaching enhanced positive perceptions among teachers in other specializations as well. Therefore, it can be concluded that teachers in other

specializations have the opportunity to learn more about coding robotics, which could further improve their perceptions of coding robotics.

Teachers at each educational level had better perceptions after participating in the coding robotics training, although they believed they could implement it better with guidelines than without. This finding is consistent with the literature that teachers at all educational stages can introduce programming and robotics, even if implemented with guidelines (Chevalier et al., 2016; Uğur-Erdoğan, 2021). A deeper analysis revealed that as the educational level increased, teachers had more positive perceptions of implementing coding robotics in STEM teaching. This research reflected that if teachers at each educational level attend coding robotics training programs, their perceptions of applying STEM coding robotics teaching could be enhanced. According to Ortega-Ruipérez and Alcalde (2023), teachers' perceptions of learning ability are similar across educational levels.

The findings of this study imply that practice-based training programs such as STEM coding robotics can strengthen teachers' readiness to face the challenges of 21st-century learning, especially in the context of transformative education in Indonesia. The increasingly positive perceptions of teachers from various backgrounds show the significant potential for integrated coding robotics across disciplines in primary and secondary education curricula. In the future, research could be directed toward longitudinal studies to evaluate the sustainability of the impact of training and to observe the changes in teachers' teaching practices and student learning outcomes (Alsalamat, 2024; Anwar et al., 2019; De Jager, 2023). In addition, it is necessary to explore more adaptive training models that address the needs of teachers from different educational levels (Ortega-Ruipérez & Alcalde, 2023).

6. Limitations

The study was limited to exploring changes in the perceptions of teachers at schools ranging from elementary to high school regarding coding robotics in STEM teaching using questionnaires as research instruments. A major limitation of this study was the unequal number of participants across the variables of gender, teaching experience, specialization, and educational level. However, this limitation was mitigated by the fact that the number of participants in each research variable was adequately represented.

Additionally, the study was confined to 41 teachers from Jember and the surrounding areas. Although the study was limited by the number of participants and its focus on Jember, Indonesia, the findings may be generalized to other regions or districts and even other countries with similar educational contexts. The participants from Jember and its surroundings already reflect a diverse mix of ethnicities, religions, cultures, and languages, thus making the findings broadly representative of Indonesia.

7. Conclusion and Implications

The study revealed that teachers' perceptions of mastering coding robotics skills and their application in STEM teaching significantly improved after participating in the teacher professional development program. No significant associations

were found between gender, years of teaching experience, specialization, and educational level of teachers and their perceptions of coding robotics in STEM teaching. Additionally, when differentiated by dimension, gender differences did not show significant effects on coding robotics training. The dynamics of perception changes showed that teachers with less than five years of teaching experience and those from mathematics and ICT specializations had the most favorable perceptions of mastering coding robotics skills. Furthermore, the most positive changes in teachers' perceptions were observed when coding robotics was applied at the junior high school level. The study also uncovered eight recommendations from teachers regarding ideas for implementing coding robotics after the training. The teachers' idea with the theme of creating innovative projects and innovating instructional design demonstrated the highest percentage.

This research article provides important insights into the changes in the perceptions of teachers at schools ranging from elementary to high school regarding the mastery and application of coding robotics in STEM teaching after participating in the teacher professional development program in Indonesia. These findings can be valuable for educational developers and others involved in teacher professional development and be used as a starting point for designing and developing professional programs for each educational level related to STEM education, particularly in coding robotics.

One of the main innovations of this research was the integration of coding robotics skills into teacher professional development programs based on gender, years of teaching experience, specialization, and educational level. This research also enriched the international literature on teacher training in the field of new technologies, especially in the context of developing countries such as Indonesia. By adopting a perception-based approach and emphasizing the importance of teacher training, this research is expected to be a reference for the development of educational policies and the design of technology-based teacher training in the digital era. Therefore, although these findings are local, they are globally relevant and can be adapted to other regions or countries with similar educational conditions.

8. Recommendations

It is recommended that future research on teachers' perceptions use a larger sample size, provide more resources or tools to support the training program, and consider additional variables that may influence teachers' perceptions of STEM education. Additionally, future training programs should be designed to prepare teachers better for STEM coding robotics instruction and to support them in implementing STEM coding robotics teaching according to their specialization and educational level.

9. References

- Abakah, E. (2023). Teacher learning from continuing professional development (CPD) participation: A sociocultural perspective. *International Journal of Educational Research Open*, 4, 100242. <https://doi.org/10.1016/j.ijedro.2023.100242>
- Aksu, F. N., & Durak, G. (2019). Robotics in education: Examining information technology

- teachers' views. *Journal of Education and E-Learning Research*, 6(4), 162–168. <https://doi.org/10.20448/journal.509.2019.64.162.168>
- Ali, N., Santos, I. M., Alhakmani, R., Khurma, O. A., Khine, M. S., & Kassem, U. (2023). Exploring technology acceptance: Teachers' perspectives on robotics in teaching and learning in the UAE. *Contemporary Educational Technology*, 15(4), 469. <https://doi.org/10.30935/cedtech/13646>
- Alsalamat, M. K. M. (2024). Secondary stage science teachers' perceptions toward STEM education in Saudi Arabia. *Sustainability*, 16(9), 3634. <https://doi.org/10.3390/su16093634>
- 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), Article 2. <https://doi.org/10.7771/2157-9288.1223>
- Bell, D. (2016). The reality of STEM education, design and technology teachers' perceptions: A phenomenographic study. *International Journal of Technology and Design Education*, 26(1), 61–79. <https://doi.org/10.1007/s10798-015-9300-9>
- Bowman, M. A., Vongkulluksn, V. W., Jiang, Z., & Xie, K. (2020). Teachers' exposure to professional development and the quality of their instructional technology use: The mediating role of teachers' value and ability beliefs. *Journal of Research on Technology in Education*, 54(2), 188–204. <https://doi.org/10.1080/15391523.2020.1830895>
- Budiyanto, C. W., Fenyvesi, K., Lathifah, A., & Yuana, R. A. (2022). Computational thinking development: Benefiting from educational robotics in STEM teaching. *European Journal of Educational Research*, 11(4), 1997–2012. <https://doi.org/10.12973/eu-jer.11.4.1997>
- Castro, A., Medina, J., Aguilera, C. A., Ramirez, M., & Aguilera, C. (2023). Robotics education in STEM units: Breaking down barriers in rural multigrade schools. *Sensors*, 23(1), 387. <https://doi.org/10.3390/s23010387>
- 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>
- Chai, C. S. (2019). Teacher professional development for science, technology, engineering and mathematics (STEM) education: A review from the perspectives of technological pedagogical content (TPACK). *The Asia-Pacific Education Researcher*, 28(1), 5–13. <https://doi.org/10.1007/s40299-018-0400-7>
- Chevalier, M., Riedo, F., & Mondada, F. (2016). How do teachers perceive educational robots in formal education? A study based on the Thymio robot*. *IEEE Robotics and Automation Magazine*, 23(2), 16–23. <https://doi.org/10.1109/MRA.2016.2535080>
- Darmawansah, D., Hwang, G. J., Rong, M., Chen, A., & Liang, J. C. (2023). Trends and research foci of robotics-based STEM education: A systematic review from diverse angles based on the technology-based learning model. *International Journal of STEM Education*, 10, Article 12. <https://doi.org/10.1186/s40594-023-00400-3>
- De Jager, T. (2023). How can educators effectively be trained to teach coding and robotics in STEAM field programs? *Jurnal VARIDIKA*, 35(1), 1–12. <https://doi.org/10.23917/varidika.v1i1.20840>
- Drakatos, N., & Christou, A. (2023). The teaching of robotics to prospective teachers and its application in the classroom. *World Journal of Advanced Research and Reviews*, 19(1), 482–495. <https://doi.org/10.30574/wjarr.2023.19.1.1332>
- Elmosaad, Y. (2024). Teachers' perceptions of their influence on student practices to enhance the school environment: A cross-sectional study in governmental general education schools in Al-Ahsa Province, Kingdom of Saudi Arabia. *Cureus*, 16(1), 1–12. <https://doi.org/10.7759/cureus.51702>

- Feldman-Maggor, Y., Tuvi-Arad, I., & Blonder, R. (2022). Development and evaluation of an online course on nanotechnology for the professional development of chemistry teachers. *International Journal of Science Education*, 44(16), 2465–2484. <https://doi.org/10.1080/09500693.2022.2128930>
- Feri, A., & Zulherman. (2021). Development of nearpod-based e module on science material “energy and its changes” to improve elementary school student learning achievement. *International Journal of Education and Learning*, 3(2), 165–174. <https://doi.org/10.31763/ijele.v3i2.400>
- Filippov, S. A., Ten, N. G., & Fradkov, A. L. (2017). Teaching robotics in secondary school: Examples and outcomes. *IFAC-PapersOnLine*, 50(1), 12167–12172. <https://doi.org/10.1016/j.ifacol.2017.08.2147>
- 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), 64. <https://doi.org/10.3390/educsci11020064>
- Gavrilas, L., & Kotsis, K. T. (2024). Investigating perceptions of primary and preschool educators regarding incorporation of educational robotics into STEM education. *Contemporary Mathematics and Science Education*, 5(1), 24003. <https://doi.org/10.30935/conmaths/14384>
- Glezou, K. V. (2021). Robotics as a powerful vehicle toward learning and computational thinking in secondary education of 21st century. In: *Research Anthology on Computational Thinking, Programming, and Robotics in the Classroom*. IGI Global. pp. 716-755. <https://doi.org/10.4018/978-1-7998-6717-3.ch001>
- Gonzales, M., Andal, E., Ching, D., Gaffud, M., & Tabo, E. (2021). Assessing the efficacy of RoboTeach extension project on public school teachers. *International Journal of Educational Management and Development Studies*, 2(3), 78–100. <https://doi.org/10.53378/348742>
- Gunadi, G., Haryono, H., & Purwanti, E. (2022). The analysis of 21st century learning implementation and competency achievement of junior high school students in 3T regions. *Innovative Journal of Curriculum and Educational Technology*, 11(1), 10–18. <https://doi.org/10.15294/ijcet.v11i1.44847>
- Hallström, J., & De Vries, M. J. (2024). *Programming and computational thinking in technology education* (Vol. 20). Brill Publishers. <https://doi.org/10.1163/9789004687912>
- Hasanah, U. (2024). Gaining science teachers’ perceptions toward STEM education in Indonesia. In *Proceedings of 2nd 2024 Education, Science, and Technology International Conference* (Vol. 2, No. 1, pp. 278-296). <http://103.97.100.158/index.php/eduscience/tech/article/view/607>
- Hennesy, S., D’Angelo, S., McIntyre, N., Koomar, S., Kreimeia, A., Cao, L., Brugha, M., & Zubairi, A. (2022). Technology use for teacher professional development in low- and middle-income countries: A systematic review. *Computers and Education Open*, 3, 100080. <https://doi.org/10.1016/j.caeo.2022.100080>
- Huang, B., Jong, M. S.-Y., Tu, Y.-F., Hwang, G.-J., Chai, C. S., & Jiang, M. Y.-C. (2022). Trends and exemplary practices of STEM teacher professional development programs in K-12 contexts: A systematic review of empirical studies. *Computers & Education*, 189, 104577. <https://doi.org/10.1016/j.compedu.2022.104577>
- Hughes, C. E., Dieker, L. A., Glavey, E. M., Hines, R. A., Wilkins, I., Ingraham, K., Bukaty, C.A., Ali, K., Shah, S., Murphy, J., & Taylor, M. S. (2022). RAISE: Robotics & AI to improve STEM and social skills for elementary school students. *Frontiers in Virtual Reality*, 3, 968312. <https://doi.org/10.3389/frvir.2022.968312>
- Hursen, C., Paşa, D., & Keser, H. (2023). High school students’ use of information, media, and technology skills and multidimensional 21st-century skills: An investigation within the context of students, teachers, and curricula. *Sustainability*, 15(16). <https://doi.org/10.3390/su151612214>

- Ibrahim, M. F., Huddin, A. B., Hashim, F. H., Abdullah, M., Abd Rahni, A. A., Mustaza, S. M., Hussain, A., & Zaman, M. H. M. (2020). Strengthening programming skills among engineering students through experiential learning based robotics project. *International Journal of Evaluation and Research in Education*, 9(4), 939–946. <https://doi.org/10.11591/ijere.v9i4.20653>
- Javaid, M., Haleem, A., Singh, R. P., & Suman, R. (2021). Substantial capabilities of robotics in enhancing industry 4.0 implementation. *Cognitive Robotics*, 1, 58–75. <https://doi.org/10.1016/j.cogr.2021.06.001>
- Jones, M., Geiger, V., Falloon, G., Fraser, S., Beswick, K., Holland-Twining, B., & Hatisaru, V. (2024). Learning contexts and visions for STEM in schools. *International Journal of Science Education*, 47(3), 337–357. <https://doi.org/10.1080/09500693.2024.2323032>
- Jung, S. E., & Won, E.-S. (2018). Systematic review of research trends in robotics education for young children. *Sustainability*, 10(4), 1–24. <https://doi.org/10.3390/su10040905>
- Kaygısız, G. M., Üzümcü, Ö., & Ucar, F. M. (2020). The case of prospective teachers' integration of coding-robotics practices into science teaching with STEM approach. *İlköğretim Online*, 19(3), 1200–1213. <https://doi.org/10.17051/ilkonline.2020.728020>
- Khanlari, A. (2016). Teachers' perceptions of the benefits and the challenges of integrating educational robots into primary/elementary curricula. *European Journal of Engineering Education*, 41(3), 320–330. <https://doi.org/10.1080/03043797.2015.1056106>
- Khwaengmek, V., & Faikhamta, C. (2023). Perceptions of pre-service science teachers toward teaching STEM from suburb university in Thailand. *Kasetsart Journal of Social Sciences*, 44(1), 223–230. <https://doi.org/10.34044/j.kjss.2023.44.1.25>
- Kim, C., Kim, D., Yuan, J., Hill, R. B., Doshi, P., & Thai, C. N. (2015). Robotics to promote elementary education pre-service teachers' STEM engagement, learning, and teaching. *Computers & Education*, 91, 14–31. <https://doi.org/10.1016/j.compedu.2015.08.005>
- Kurup, P. M., Li, X., Powell, G., & Brown, M. (2019). Building future primary teachers' capacity in STEM: Based on a platform of beliefs, understandings and intentions. *International Journal of STEM Education*, 6, Article 10. <https://doi.org/10.1186/s40594-019-0164-5>
- Lavi, R., Tal, M., & Dori, Y. J. (2021). Perceptions of STEM alumni and students on developing 21st century skills through methods of teaching and learning. *Studies in Educational Evaluation*, 70, 101002. <https://doi.org/10.1016/j.stueduc.2021.101002>
- Li, Z., Yan, Z., Chan, K. K. Y., Zhan, Y., & Guo, W. Y. (2023). The role of a professional development program in improving primary teachers' formative assessment literacy. *Teacher Development*, 27(4), 447–467. <https://doi.org/10.1080/13664530.2023.2223595>
- Mallik, A., Liu, D., & Kapila, V. (2023). Analyzing the outcomes of a robotics workshop on the self-efficacy, familiarity, and content knowledge of participants and examining their designs for end-of-year robotics contests. *Education and Information Technologies*, 28(6), 7225–7264. <https://doi.org/10.1007/s10639-022-11400-1>
- Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: A systematic literature review. *International Journal of STEM Education*, 6(2), 1–16. <https://doi.org/10.1186/s40594-018-0151-2>
- Mason, S. L., & Rich, P. J. (2020). Development and analysis of the elementary student coding attitudes survey. *Computers & Education*, 153, 103898. <https://doi.org/10.1016/j.compedu.2020.103898>

- McCarthy, A. M., Maor, D., McConney, A., & Cavanaugh, C. (2023). Digital transformation in education: Critical components for leaders of system change. *Social Sciences & Humanities Open*, 8(1), 100479. <https://doi.org/10.1016/j.ssaho.2023.100479>
- Meral, M., Yalçın, S. A., Çakır, Z., & Samur, E. (2024). The effect of STEM-based robotic coding education on primary school students' decision-making skills. *Journal of Theoretical Educational Science*, 17(2), 478–498. <https://doi.org/10.30831/akukeg.1355818>
- Miller, J. (2019). STEM education in the primary years to support mathematical thinking: Using coding to identify mathematical structures and patterns. *ZDM - Mathematics Education*, 51(6), 915–927. <https://doi.org/10.1007/s11858-019-01096-y>
- Mu, S., Xu, K., He, W., Hu, X., & Chiu, T. K. F. (2024). Teaching behaviors in problem-oriented instruction for robotics education. *Education and Information Technologies*, 29(14), 17943–17964. <https://doi.org/10.1007/s10639-024-12578-2>
- Mumcu, F., Uslu, N. A., & Yıldız, B. (2022). Investigating teachers' expectations from a professional development program for integrated STEM education. *Journal of Pedagogical Research*, 6(2), 44–60. <https://doi.org/10.33902/JPR.202213543>
- Mury, S. R., Negrini, L., Assaf, D., & Skweres, M. (2022). How to support teachers to carry out educational robotics activities in school? The case of Roteco, the Swiss robotic teacher community. *Frontiers in Education*, 7. <https://doi.org/10.3389/educ.2022.968675>
- Mwangi, P. N., Muriithi, C. M., & Agufana, P. B. (2022). Exploring the benefits of educational robots in STEM learning: A systematic review. *International Journal of Engineering and Advanced Technology*, 11(6), 5–11. <https://doi.org/10.35940/ijeat.f3646.0811622>
- Negrini, L., Giang, C., Bonaiuti, G., Cascalho, J. M., Primo, T. T., & Eteokleous, N. (2023). Editorial: Educational robotics as a tool to foster 21st century skills. *Frontiers in Education*, 8. <https://doi.org/10.3389/educ.2023.1186029>
- Ortega-Ruipérez, B., & Alcalde, M. L. (2023). Teachers' perception about the difficulty and use of programming and robotics in the classroom. *Interactive Learning Environments*, 31(10), 7074–7085. <https://doi.org/10.1080/10494820.2022.2061007>
- Ou, Q., Liang, W., He, Z., Liu, X., Yang, R., & Wu, X. (2023). Investigation and analysis of the current situation of programming education in primary and secondary schools. *Heliyon*, 9(4), e15530. <https://doi.org/10.1016/j.heliyon.2023.e15530>
- Ouyang, F., & Xu, W. (2024). The effects of educational robotics in STEM education: A multilevel meta-analysis. *International Journal of STEM Education*, 11, Article 7. <https://doi.org/10.1186/s40594-024-00469-4>
- Papadakis, S., Kalogiannakis, M., & Gözü, A. İ. C. (2022). Editorial: STEM, STEAM, computational thinking, and coding: Evidence-based research and practice in children's development. *Frontiers in Psychology*, 13. <https://doi.org/10.3389/fpsyg.2022.1110476>
- Paucar-Curasma, R., Cerna-Ruiz, L. P., Acra-Despradel, C., Villalba-Condori, K. O., Massa-Palacios, L. A., Olivera-Chura, A., & Esteban-Roblado, I. (2023). Development of computational thinking through STEM activities for the promotion of gender equality. *Sustainability*, 15(16), 12335. <https://doi.org/10.3390/su151612335>
- Ring, E. A., Dare, E. A., Crotty, E. A., & Roehrig, G. H. (2017). The evolution of teacher conceptions of STEM education throughout an intensive professional development experience. *Journal of Science Teacher Education*, 28(5), 444–467. <https://doi.org/10.1080/1046560X.2017.1356671>
- Şahin, E., Sarı, U., & Şen, Ö. F. (2024). STEM professional development program for gifted education teachers: STEM lesson plan design competence, self-efficacy,

- computational thinking and entrepreneurial skills. *Thinking Skills and Creativity*, 51. <https://doi.org/10.1016/j.tsc.2023.101439>
- Samara, V., & Kotsis, K. T. (2023). The use of new technologies and robotics (STEM) in the teaching of sciences in primary education: The concept of magnetism: A bibliographic review. *European Journal of Education Studies*, 10(2). <https://doi.org/10.46827/ejes.v10i2.4652>
- Scherer, R., Siddiq, F., & Sánchez-Scherer, B. (2021). Some evidence on the cognitive benefits of learning to code. *Frontiers in Psychology*, 12. <https://doi.org/10.3389/fpsyg.2021.559424>
- Seckin-Kapucu, M. (2023). Studies on robotic coding education in science education: A systematic literature review. *Journal of Education in Science, Environment and Health*, 9(1), 74–84. <https://doi.org/10.55549/jeseh.1239093>
- Silva, R., Costa, C., & Martins, F. (2024). Pre-service teachers' perceptions towards integrating educational robotics in the primary school. *Eurasia Journal of Mathematics, Science and Technology Education*, 20(4), Article em2419. <https://doi.org/10.29333/ejmste/14356>
- Surahman, E., & Wang, T.-H. (2023). In-service STEM teachers professional development programmes: A systematic literature review 2018–2022. *Teaching and Teacher Education*, 135, 104326. <https://doi.org/10.1016/j.tate.2023.104326>
- Teidla-Kunitsõn, G., Sisask, M., & Põlda, H. (2023). A bridge or a wall: Teachers mediating ICT in the classroom. *Education Sciences*, 13(10), 979. <https://doi.org/10.3390/educsci13100979>
- Tiryaki, A., & Adıgüzel, S. (2021). The effect of STEM-based robotic applications on the creativity and attitude of students. *Journal of Science Learning*, 4(3), 288–297. <https://doi.org/10.17509/jsl.v4i3.29683>
- Tran, Y. (2018). Computer programming effects in elementary: Perceptions and career aspirations in STEM. *Technology, Knowledge and Learning*, 23(2), 273–279. <https://doi.org/10.1007/s10758-018-9358-z>
- Tuomi, P., Multisilta, J., Saarikoski, P., & Suominen, J. (2018). Coding skills as a success factor for a society. *Education and Information Technologies*, 23(1), 419–434. <https://doi.org/10.1007/s10639-017-9611-4>
- Ufnar, J. A., & Shepherd, V. L. (2019). The scientist in the classroom partnership program: An innovative teacher professional development model. *Professional Development in Education*, 45(4), 642–658. <https://doi.org/10.1080/19415257.2018.1474487>
- Uğur-Erdoğan, F. (2021). How do elementary childhood education teachers perceive robotic education in kindergarten? A qualitative study. *Participatory Educational Research*, 8(2), 421–434. <https://doi.org/10.17275/PER.21.47.8.2>
- Uslu, N. A., Yavuz, G. O., & Usluel, Y. K. (2022). A systematic review study on educational robotics and robots. *Interactive Learning Environments*, 31(9), 5874–5898. <https://doi.org/10.1080/10494820.2021.2023890>
- Wahono, B., & Chang, C.-Y. (2019). Assessing teacher's attitude, knowledge, and application (AKA) on STEM: An effort to foster the sustainable development of STEM education. *Sustainability*, 11(4), 950. <https://doi.org/10.3390/su11040950>
- Wahono, B., Hariyadi, S., & Subiantoro, A. W. (2022). The development of an online STEM teacher professional development package with the DECODE model: An innovative teacher's quality maintenance. *Eurasia Journal of Mathematics, Science and Technology Education*, 18(12), Article em2191. <https://doi.org/10.29333/ejmste/12647>
- Wahono, B., Hariyadi, S., Subiantoro, A. W., Bravo, J. A. M., & Manalu, M. S. (2025a). Empowering STEM teachers with TPACK: Insights from the DECODE online professional development program. *Eurasia Journal of Mathematics, Science and Technology Education*, 21(1), Article em2570. <https://doi.org/10.29333/ejmste/15896>

- Wahono, B., Purmanna, A., Ramadhani, R., & Manalu, M. S. (2025b). Strengthens the student collaboration and decision-making skills through integrated STEM education: A research and development study. *Science Education International*, 36(1), 86–93. <https://doi.org/10.33828/sei.v36.i1.9>
- Wang, K., Sang, G. Y., Huang, L. Z., Li, S. H., & Guo, J. W. (2023). The effectiveness of educational robots in improving learning outcomes: A meta-analysis. *Sustainability*, 15(5), 4637. <https://doi.org/10.3390/su15054637>
- Yang, Y. F., Tseng, C. C., & Lai, S. C. (2024). Enhancing teachers' self-efficacy beliefs in AI-based technology integration into English speaking teaching through a professional development program. *Teaching and Teacher Education*, 144, 104582. <https://doi.org/10.1016/j.tate.2024.104582>
- Yildirim, B., Akcan, A. T., & Ocal, E. (2022). Teachers' perceptions and STEM teaching activities: Online teacher professional development. *Journal of Baltic Science Education*, 21(1), 84–107. <https://doi.org/10.33225/jbse/22.21.84>
- Yuldashevna, I. A., & Khurana, K. (2024). The impediments to the process of implementing robotics in the school education system in Uzbekistan. *SAGE Open*, 14(2). <https://doi.org/10.1177/21582440241254595>
- Zhang, J., Zhou, M., & Zhang, X. (2023). Interventions to promote teachers' perceptions about STEM education: A meta-analysis. *Education and Information Technologies*, 28(6), 7355–7390. <https://doi.org/10.1007/s10639-022-11492-9>