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Science Teachers' Views on the Contributions of Robotics Coding Education to Scientific Reasoning and Problem-Solving Skills

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Abstract

This study aimed to examine science teachers' views on the contributions of robotics coding education to scientific reasoning and problem-solving skills. The study employed a basic qualitative research design with 19 science teachers who had previously received robotics coding training. Data were collected through a researcher-developed semi-structured written interview form and analyzed using inductive content analysis. The findings indicated that teachers associated robotics coding with hypothesis generation, causal reasoning, scientific observation, scientific interpretation, evidence use, and scientific thinking. Regarding problem-solving, teachers emphasized developing alternative solution strategies, algorithmic thinking, and prototype development. Participants also reported contributions to analytical thinking, technological literacy, motivation, collaboration, active participation, and meaningful learning, while identifying inadequate materials, technological infrastructure, limited instructional time, and crowded classrooms as major implementation challenges. Teachers recommended strengthening technological infrastructure, expanding in-service training, providing more inquiry- and project-based activities, and planning robotics coding activities progressively. Overall, the findings suggest that teachers perceive robotics coding as a learning environment with the potential to support scientific reasoning and problem-solving when implemented with appropriate pedagogical planning, sufficient technical resources, and sustained teacher support.

Keywords: Robotics coding, science education, teachers' views, scientific reasoning, problem-solving.

1. Introduction

Rapid advances in science and technology have substantially transformed the knowledge, skills, and competencies expected of individuals. Today, possessing scientific knowledge alone is no longer considered sufficient; individuals are also expected to critically evaluate scientific information, assess evidence, devise solutions to problems encountered in everyday life, and make informed decisions based on scientific evidence (National Research Council [NRC], 2012). This transformation has reshaped the goals of science education. Science instruction is no longer limited to the transmission of scientific concepts; it also aims to help students understand how scientific knowledge is generated and to enable them to apply this knowledge effectively across different contexts. Scientific thinking is defined as a multidimensional competence encompassing interrelated processes such as inquiry, experimentation, evidence evaluation, and drawing evidence-based conclusions (Zimmerman, 2007). Accordingly, scientific reasoning, problem-solving, and critical thinking are regarded as fundamental learning outcomes of contemporary science education. Scientific reasoning encompasses multidimensional competencies, including formulating investigable questions, developing hypotheses, selecting appropriate methods, generating evidence, evaluating the evidence obtained, and explaining conclusions based on scientific justification (Krell et al., 2022). The development of these competencies requires learning environments in which students are not merely passive recipients of knowledge but are actively engaged in processes of inquiry, experimentation, evaluation, and reflection.

The need to develop learning environments that enable students to employ higher-order thinking skills has increased interest in technology-enhanced and practice-oriented approaches to science education. Among these approaches, educational robotics has emerged as an interdisciplinary learning domain in which students design, construct, and program robotic systems (Schina et al., 2020). During robotics activities, students integrate their knowledge and skills in science, technology, engineering, and mathematics to develop a product or generate solutions to specific problems. These activities are reported to provide valuable learning opportunities that foster the development of a wide range of higher-order skills, including problem-solving, scientific inquiry, logical-mathematical thinking, creativity, collaboration, and learner autonomy (Arocena et al., 2022). Comprehensive reviews of educational robotics have demonstrated that these practices hold considerable potential for enhancing students' learning and knowledge transfer skills, motivation, creativity, and engagement in STEM disciplines (Anwar et al., 2019). However, educational robotics extends beyond the mere design, construction, and use of robots; it also encompasses the purposeful integration of these tools into the learning process in accordance with specific pedagogical objectives. Within this broader framework, robotics coding represents the practical dimension that focuses on controlling and regulating robot behaviors through algorithms and programming commands. Consequently, students do more than simply operate a technological tool; they plan how the robot should function, program its behavior, and evaluate the resulting outcomes by relating them to their own decisions.

During the robotics coding process, students analyze a problem, develop an algorithm to solve it, program the system, and test the resulting outcome (Eguchi, 2014). When the robot fails to exhibit the expected behavior, they are required to identify the source of the error, reconsider possible solution strategies, and revise their algorithms accordingly. This iterative process enables students to reconstruct their thinking based on the outcomes they obtain rather than adhering to their initial solutions. The processes involved in robotics coding activities—including observation, hypothesis generation, experimentation, evidence evaluation, inference, and drawing conclusions—closely align with the fundamental components of scientific reasoning (Topcubaşı et al., 2025). This process is also closely associated with problem-solving skills, as it requires students to decompose complex problems into smaller and more manageable steps, compare alternative solution strategies, and revise ineffective approaches. From this perspective, robotics coding provides a learning environment in which scientific reasoning and problem-solving function not as separate processes but as complementary components of the same learning experience. Nevertheless, participation in programming or robotics activities should not be assumed to lead automatically to improvements in problem-solving skills. For example, although students reported positive learning experiences in a programming intervention using Scratch, no significant improvement was found in their problem-solving scores (Kalelioğlu & Gülbahar, 2014). This finding suggests that the contributions of robotics coding to problem-solving skills should be evaluated in relation to the quality of the instructional intervention and the way the learning process is designed.

Research examining the effects of educational robotics on learning indicates that these benefits do not emerge consistently across all implementations. In a systematic review, Benitti (2012) reported that although robotics applications generally support learning, some studies found no significant improvements in learning outcomes. Therefore, the mere presence of robots in the classroom does not guarantee the achievement of the intended educational outcomes. Rather, the pedagogical value of robotics activities stems from learning experiences in which students engage with authentic real-world problems, develop tangible products, test their decisions, and reconstruct their thinking through iterative reflection (Alimisis, 2013).A more recent meta-analysis found that educational robotics has a moderate positive effect on students' STEM learning performance and attitudes toward learning, whereas its overall effect on computational thinking skills is not statistically significant (Ouyang & Xu, 2024). The same study further demonstrated that these outcomes are influenced by several factors, including the disciplinary context, instructional strategies, teacher support, intervention duration, and modes of interaction. These findings limit broad generalizations suggesting that robotics coding produces uniform effects across all students and all learning outcomes. Accordingly, the effectiveness of robotics coding depends not only on the characteristics of the technology itself but also on the pedagogical decisions that meaningfully integrate this technology with instructional objectives. In this regard, teachers play a pivotal role in transforming robotics coding from a purely technical activity into a meaningful and effective learning experience.

Teachers are the primary implementers who align robotics coding activities with learning objectives, design appropriate instructional strategies, and provide guidance when students encounter learning difficulties. Therefore, the extent to which robotics coding contributes to students' scientific reasoning and problem-solving skills depends not only on teachers' technical knowledge and skills but also on their pedagogical expertise and practical teaching experience. Research has shown that teachers with experience in educational robotics perceive these practices as having the potential to enhance students' programming knowledge as well as a range of twenty-first-century skills, and they generally hold positive attitudes toward integrating educational robotics into the curriculum (Schina et al., 2020).Nevertheless, providing teachers with technical training on the use of robotic tools alone is insufficient to enable them to effectively integrate robotics applications into classroom practice. A systematic review of teacher education programs in educational robotics revealed substantial variation among existing programs in terms of duration, content, and theoretical foundations. The review further indicated that the most effective programs emphasize practice-based learning, collaboration, access to appropriate instructional materials, pedagogical guidance, and continuous feedback (Schina et al., 2021). Similarly, studies examining science teachers' perceptions of robotics coding have shown that these practices can support the development of students' diverse skills and promote lasting learning (Kurt & Anılan, 2024). However, insufficient knowledge and experience, limited instructional materials, inadequate technical infrastructure, time constraints, and the lack of sustained support continue to hinder the effective implementation of robotics coding in classroom settings. Therefore, teachers' perspectives are important not only for understanding the perceived benefits of robotics coding but also for identifying the conditions that facilitate or constrain its effective implementation in educational practice.

Studies examining teachers' and students' perceptions of robotics coding have identified problem-solving, creative thinking, analytical thinking, systematic thinking, and design skills as among the most prominent learning outcomes associated with these practices (Göksoy & Yılmaz, 2018). Similarly, a systematic review of robotics applications implemented at the primary school level in Türkiye found that improvements in problem-solving, collaboration, motivation, and students' interest in learning were among the primary benefits, whereas inadequate technological infrastructure and insufficient hardware constituted the major challenges to effective implementation (Yumbul & Bayraktar, 2022).These studies provide valuable insights into the general educational benefits of robotics coding and the conditions required for its effective implementation. Nevertheless, a substantial proportion of the existing literature has focused primarily on student achievement, motivation, technology integration, computational thinking, and teachers' general implementation experiences. Among the limited number of studies that have examined robotics coding in relation to both scientific reasoning and problem solving, one study explored the perspectives of academics and pre-service teachers (Topcubaşı et al., 2025). Consequently, there remains limited evidence regarding how teachers who have received robotics coding training evaluate these practices in terms of their contribution to the development of students' scientific reasoning and problem-solving skills. Furthermore, examining teachers' recommendations for fostering these skills alongside the challenges they encounter during implementation may contribute to a more comprehensive understanding of the pedagogical potential of robotics coding. Addressing this gap through the perspectives of practicing teachers constitutes the primary focus of the present study.

Accordingly, the aim of this study is to examine the views of teachers who have received robotics coding training regarding the contribution of this training to students' scientific reasoning and problem-solving skills. The study also investigates teachers' knowledge and competencies related to robotics coding, the educational contributions of these practices, the challenges encountered during implementation, and their proposed solutions to these challenges. In line with this aim, the following research questions were addressed:

1. What are teachers' views regarding the contribution of robotics coding education to the development of students' scientific reasoning skills?
2. What are teachers' views regarding the contribution of robotics coding education to the development of students' problem-solving skills?
3. What are teachers' views regarding robotics coding education, the challenges encountered during its implementation, and the proposed solutions to these challenges?

2. Method

The methodological details of the study are presented in the following subsections.

2.1. Research design

This study was conducted using a basic qualitative research design within the qualitative research approach to gain an in-depth understanding of teachers' views regarding the contribution of robotics coding to the development of scientific reasoning and problem-solving skills. Basic qualitative research is one of the qualitative research designs that aims to explore individuals' perceptions, experiences, interpretations, and perspectives concerning a particular phenomenon in depth (Merriam & Tisdell, 2016). The primary purpose of this design is to understand and interpret participants' experiences and perspectives from their own viewpoints (Creswell & Poth, 2018).

In this study, teachers' knowledge and competencies related to robotics coding education, their views on the use of robotics coding in educational settings, their evaluations of its contribution to scientific reasoning and problem-solving skills, their suggestions for fostering these skills, and the challenges they encountered during implementation together with their proposed solutions were examined. No experimental procedure was conducted to determine the effectiveness of an instructional intervention. Instead, the study sought to provide a detailed account of teachers' views and evaluations regarding robotics coding education. Therefore, the basic qualitative research design was considered appropriate for the purpose of the study and aligned well with the data collection process.

2.2. Participation

The participants were selected using criterion sampling, a purposive sampling method. Criterion sampling is a purposive sampling strategy in which participants with predetermined characteristics relevant to the study's purpose are intentionally selected (Patton, 2015). In the present study, the inclusion criteria were: (a) being employed as a science teacher, (b) having received robotics coding training, and (c) voluntarily agreeing to participate in the study.

A total of 19 science teachers who met these criteria participated in the study. To ensure participant confidentiality, each teacher was assigned a unique identifier (P1, P2, …, P19).

Direct quotations presented in the Findings section are reported using these identifiers to protect participants' identities.

2.3. Data collection instrument

The research data were collected using a semi-structured written interview form developed by the researchers. Semi-structured written interview forms enable researchers to collect data systematically through predetermined questions while allowing participants to express their views in detail using their own words (Creswell & Poth, 2018; Meho, 2006).

During the development of the interview form, the national and international literature on robotics coding, scientific reasoning, and problem-solving skills was first reviewed. Based on the purpose of the study and the research questions, a draft interview form consisting of eight open-ended questions was then prepared. To establish content and face validity, the draft form was submitted to three faculty members with expertise in science education and educational technology. The interview form was finalized following revisions made in accordance with the experts' comments and recommendations.

The final semi-structured written interview form consisted of eight open-ended questions designed to elicit teachers' knowledge and competencies regarding robotics coding education, their views on the use of robotics coding in educational settings, their evaluations of its contribution to scientific reasoning and problem-solving skills, their suggestions for fostering these skills, and their perspectives on the challenges encountered during the implementation process.

2.4. Data collection procedure

The research data were collected using a semi-structured written interview form developed by the researchers. First, teachers who met the study's inclusion criteria were contacted and provided with detailed information regarding the purpose, scope, and data collection procedure of the study. Participants were informed that their participation was entirely voluntary, that the collected data would be used solely for scientific research purposes, and that the confidentiality of their personal information would be strictly maintained. Following this briefing, written informed consent was obtained from all participants.

The semi-structured written interview form was distributed to the participants via email, and they were asked to provide detailed responses to the questions based on their own knowledge and professional experiences. The written interview method was preferred because it facilitated access to teachers working in different institutions, allowed participants sufficient time to reflect on the questions and provide comprehensive responses, and enabled the researchers to obtain data directly in written form. Upon receipt, all interview forms were reviewed for completeness, and only the fully completed forms were included in the data analysis.

2.5. Data analysis

The data obtained from the study were analyzed using inductive content analysis. In this approach, the codes and categories were not predetermined; instead, they were generated inductively from the participants' responses (Patton, 2015).

The data analysis process was carried out in four stages. In the first stage, the interview transcripts were read repeatedly and examined in detail to develop an overall understanding of the data in relation to the purpose of the study. In the second stage, meaningful statements relevant to the research questions were identified and coded. In the third stage, codes with similar characteristics were grouped together to form categories. Finally, the categories were organized according to the research questions and interpreted with support from direct quotations drawn from the participants' responses.

Because participants were able to express more than one opinion in response to each question, an individual participant's response could be coded under multiple categories. Therefore, the frequency values presented in the tables indicate the number of participants who expressed a particular view rather than the total number of responses. To protect participants' confidentiality, teacher identification codes (T1, T2, …) were used when reporting direct quotations.

2.6. Credibility of the study

To ensure the trustworthiness of the study, the criteria proposed by Lincoln and Guba (1985)—namely credibility, transferability, dependability, and confirmability—were adopted.

To enhance credibility, the semi-structured interview form was reviewed by three faculty members with expertise in science education and educational technology. Based on their feedback and recommendations, the necessary revisions were made before the interview form was finalized. In addition, direct quotations from participants were included in the Findings section to support the researchers' interpretations and enhance the credibility of the findings.

To strengthen transferability, detailed descriptions were provided regarding the research design, participant selection process, data collection instrument, data collection procedure, and data analysis process. These detailed descriptions enable readers to determine the applicability of the findings to similar contexts.

To ensure dependability, the data analysis was conducted systematically, and each stage of the coding process was documented in detail. The resulting codes and categories were independently reviewed by two experts experienced in qualitative research. Following their feedback, the coding framework was refined and finalized.

To enhance confirmability, the findings were grounded in the participants' responses, and all categories and codes were supported by direct quotations. This approach helped ensure that the researchers' interpretations were firmly rooted in the participants' perspectives rather than the researchers' subjective assumptions.

3. Findings

This section presents the findings obtained in line with the research questions. The findings are systematically organized according to the categories and codes generated through inductive content analysis and are supported by direct quotations that reflect the participants' perspectives.

3.1. Teachers' Views on the Contribution of Robotics Coding to Scientific Reasoning Skills

The categories and codes derived from teachers' views regarding the contribution of robotics coding to scientific reasoning skills are presented in Table 1.

Table 1. Teachers' Views on the Contribution of Robotics Coding to Scientific Reasoning Skills

Category	Code	Illustrative Quotations
Developing Scientific Reasoning Skills	Hypothesis generation (n = 5)	P3: "It helps students develop observation and hypothesis-generation skills..." P16: "When students design an algorithm and run the robot, they experience the scientific method firsthand by observing how abstract hypotheses are transformed into concrete outcomes and by recognizing cause-and-effect relationships."
	Causal reasoning (n = 5)	P1: "They examine the process by establishing cause-and-effect relationships." P2: "When they encounter a problem, they can more easily establish cause-and-effect relationships and generate solutions." P5: "Developing cause-and-effect relationships..."
	Scientific observation (n = 4)	P1: "Robotics coding enhances students' abilities to make observations, interpret data, and establish cause-and-effect relationships. During the robotics coding process, students examine situations by identifying cause-and-effect relationships and drawing conclusions." P3: "It improves students' skills in observation, hypothesis generation, producing solutions through trial and error, and evaluating outcomes."
	Scientific interpretation (n = 3)	P1: "Students interpret the results they obtain..." P5: "Evaluating data..."
	Use of evidence (n = 3)	P1: "They draw evidence-based conclusions."
Supporting Scientific Thinking Processes	Experiential learning (n = 5)	P8: "Trial-and-error processes are essential during the R&D phase of a project."
	Scientific thinking (n = 4)	P5: "It supports scientific thinking and systematic reasoning processes."

***** Because a participant's response could be coded under more than one category, the total frequencies exceed the number of participants.

As shown in Table 1, teachers' views regarding the contribution of robotics coding to scientific reasoning skills were organized into two categories and seven codes. Within the category of developing scientific reasoning skills, the most frequently emphasized codes were hypothesis generation, causal reasoning, and scientific observation. Under the category of supporting scientific thinking processes, experiential learning and scientific thinking emerged as the most prominent codes. These findings indicate that teachers perceive robotics coding as an effective learning environment that can foster the development of students' scientific reasoning skills.

Teachers' recommendations for promoting scientific reasoning skills through robotics coding were also classified into categories and codes. The resulting findings are presented in Table 2.

Table 2. Teachers' Recommendations for Promoting Scientific Reasoning Skills Through the Robotics Coding Process

Category	Code	Illustrative Quotations
Recommendations Regarding the Scientific Inquiry Process	Providing opportunities for hypothesis generation (n = 4)	P7: "Students should be provided with real-life problems and given opportunities to formulate hypotheses, plan solutions, conduct trials, evaluate results, and correct errors."
	Focusing on real-world problems (n = 2)	P5: "More emphasis should be placed on real-world problems."
	Providing opportunities for conducting research (n = 1)	P4: "Children can be engaged in hands-on activities that encourage them to conduct research."
Recommendations Regarding Teaching and Learning Processes	Including hands-on activities (n = 4)	P7: "Collaborative, hands-on, and progressive activities should be included."
	Including project-based activities (n = 3)	P1: "Project-oriented instruction should be planned." P5: "Project-based studies should be incorporated." P8: "Continuing these types of activities would be beneficial for project development."
	Structuring instruction progressively (n = 3)	P7: "Progressive activities should be included." P10: "Instruction should begin with unplugged coding activities and then proceed to computer-based coding."
	Implementing the instructional process systematically (n = 2)	P6: "Robotics coding should be integrated into the curriculum in a systematic and planned manner." P11: "The process needs to be well planned."

*Because a participant's response could be coded under more than one category, the total frequencies exceed the number of participants.

As presented in Table 2, teachers' recommendations for supporting scientific reasoning skills were grouped into two categories: the scientific inquiry process and teaching and learning processes. Within the category of the scientific inquiry process, teachers emphasized providing students with opportunities to formulate hypotheses, conduct research, and engage with real-world problems. Recommendations related to teaching and learning processes focused on incorporating hands-on and project-based activities and structuring instruction in a progressive and systematic manner. These findings indicate that teachers associate the development of scientific reasoning not only with the use of robotics tools but also with the design of inquiry-based and pedagogically structured learning experiences.

3.2. Teachers' Views on the Contribution of Robotics Coding to Problem-Solving Skills

Teachers' views regarding the contribution of robotics coding to problem-solving skills were classified into categories and codes through inductive content analysis. The findings are presented in Table 3.

Table 3. Teachers' Views on the Contribution of Robotics Coding to Problem-Solving Skills

Category	Code	Illustrative Quotations
Developing Problem-Solving Skills	Developing alternative solution strategies (n = 6)	P15: "It also improves students' ability to evaluate different solution strategies."
	Algorithmic thinking (n = 6)	P19: "Algorithmic thinking involves being able to construct the next step and analyze what is needed to achieve a solution."
	Prototype development (n = 4)	P8: "It is necessary for conducting trial-and-error processes during the R&D phase of a project." P10: "Robotics coding is a tool for designing products through which we can create prototypes."
Accompanying Gains in the Problem-Solving Process	Developing analytical thinking (n = 2)	P7: "I think it enables children to approach situations more analytically." P11: "It contributes to students' ability to analyze problems and develop different solution strategies."
	Developing self-confidence (n = 1)	P1: "It provides students with self-confidence after engaging in problem-solving behaviors."
	Developing technological literacy (n = 1)	P12: "Students gain a deeper understanding of technology and its operating principles."

*****Because a participant's response could be coded under more than one category, the total frequencies exceed the number of participants.

As shown in Table 3, teachers' views regarding the contribution of robotics coding to problem-solving skills were grouped under two categories. Within the category of developing problem-solving skills, teachers primarily emphasized generating alternative solution strategies, algorithmic thinking, and the process of prototype development. Within the category of outcomes accompanying the problem-solving process, the most prominent themes were the development of analytical thinking, self-confidence, and technological literacy. These findings indicate that teachers perceive robotics coding as a learning environment that supports the development of problem-solving skills while also contributing to the acquisition of cognitive and personal competencies associated with this process.

Teachers' suggestions for improving problem-solving skills during the robotics coding process were classified into categories and codes. The findings obtained are presented in Table 4.

Table 4. Teachers' Recommendations for Improving Problem-Solving Skills Through the Robotics Coding Process

Category	Code	Illustrative Quotations
Suggestions for supporting the problem-solving process	Providing opportunities to develop alternative solution strategies (n = 2)	P4: "Students can be encouraged to generate different solution strategies." P1: "Originality should be prioritized in the planned activities."
	Providing opportunities to plan the solution process (n = 2)	P7: "Opportunities should be provided for planning the solution process."
	Supporting learning from mistakes (n = 1)	P7: "Students should be given opportunities to correct their mistakes."
Suggestions related to the design process	Providing opportunities for project development (n = 3)	P1: "Project-based instruction should be planned."
	Supporting three-dimensional thinking (n = 1)	P8: "It will be beneficial for developing three-dimensional thinking skills."
Suggestions related to the teaching–learning process	Incorporating group work (n = 4)	P3: "Group work should be incorporated into the learning process." P14: "I create collaborative learning environments based on peer guidance that enable students to perceive debugging as an integral stage of the learning process."
	Incorporating real-life problems (n = 2)	P5: "Greater emphasis should be placed on real-life problems."

*****Because a participant's response could be coded under more than one category, the total frequencies exceed the number of participants.

As shown in Table 4, teachers' suggestions for improving problem-solving skills during the robotics coding process were grouped into three categories. Within the category of suggestions for supporting the problem-solving process, teachers emphasized providing students with opportunities to develop alternative solution strategies, plan the solution process, and learn from their mistakes. Under the category of suggestions related to the design process, promoting project development and supporting three-dimensional thinking emerged as the most prominent themes. Regarding suggestions related to the teaching–learning process, teachers highlighted the importance of incorporating real-life problems and encouraging group work. These findings indicate that teachers associate the development of problem-solving skills with inquiry-based, practice-oriented, and collaborative learning processes.

3.3. Teachers' Views on Robotics Coding Education

Teachers' views on robotics coding education were classified into categories and codes through inductive content analysis. The findings are presented in Table 5.

Table 5. Teachers' Views on Their Knowledge Levels and Technical Competencies Regarding Robotics Coding Education

Category	Code	Illustrative Quotations
Knowledge level	Beginner level (n = 8)	P4: "I have a basic level of knowledge about robotics coding. I know that it involves sensors and contributes to the development of problem-solving skills."
	Good level (n = 6)	P13: "Robotics coding is offered as a course in my classroom."
	Intermediate level (n = 5)	P12: "I would say my knowledge is slightly above the intermediate level."
Technical competency	Block-based programming skills (n = 5)	P10: "I can use block-based programming with MEBKİT, Twiset, and Arduino."
	Knowledge of sensors (n = 4)	P4: "I know about sensors."
	Programming skills (n = 2)	P13: "I know how to write programming commands."

*****Because a participant's response could be coded under more than one category, the total frequencies exceed the number of participants.

As shown in Table 5, teachers' knowledge levels regarding robotics coding varied across beginner, intermediate, and good levels. While most participants evaluated their knowledge as being at the beginner level, the remaining participants described themselves as having intermediate or good levels of knowledge. Regarding technical competencies, the most prominent themes were block-based programming skills, knowledge of sensors, and programming skills. These findings indicate that teachers possess varying levels of knowledge and technical competency related to robotics coding. Teachers' views on the use of robotics coding in the educational process were classified into categories and codes through inductive content analysis. The findings are presented in Table 6.

Table 6. Teachers' Views on the Use of Robotics Coding in the Educational Process

Category	Code	Illustrative Quotations
Development of cognitive skills	Problem-solving skills (n = 6)	P12: "It is highly beneficial for teamwork and problem-solving learning."
	Analytical thinking (n = 5)	P4: "I believe it contributes to the development of children's analytical thinking skills."
	Algorithmic thinking (n = 2)	P19: "When solving a problem, they first organize the steps to be followed and then implement each step one by one to reach a solution."
	Creative thinking (n = 1)	P7: "It develops creativity skills."
Personal outcomes	Developing patience (n = 1)	P3: "They learn to be patient, not give up, and try different solution strategies."
Contributions to the learning process	Increasing interest and motivation toward the lesson (n = 3)	P17: "It also increases students' interest in and motivation toward the lesson."
	Learning through trial and error (n = 3)	P6: "Learning through trial and error makes the learning process more meaningful and long-lasting."

	Transforming theoretical knowledge into practice (n = 2)	P5: "It enables students to transform theoretical knowledge into practical applications."
	Promoting long-term retention (n = 2)	P3: "It enables students to learn through enjoyment and makes learning more permanent."
	Encouraging active participation (n = 1)	P3: "It encourages students' active participation in the lesson."
Development of social skills	Developing collaboration skills (n = 3)	P1: "It promotes teamwork."
	Developing communication skills (n = 1)	P4: "I believe it contributes to the development of communication skills."
Development of design and production skills	Productivity (n = 2)	P6: "I think it actively contributes to the development of students' productivity skills."
	Prototype and product development (n = 1)	P10: "It should be used for developing products and prototypes."
Development of technological competencies	Improving technological literacy (n = 3)	P7: "It improves technology use skills."
	Adapting to the requirements of the digital age (n = 1)	P11: "I think it is one of the most beneficial tools for keeping up with the modern era and making our lives easier."

*****Because a participant's response could be coded under more than one category, the total frequencies exceed the number of participants.

As shown in Table 6, teachers' views on the use of robotics coding in the educational process were grouped into six categories. Within the category of the development of cognitive skills, the most prominent themes were problem-solving, analytical thinking, algorithmic thinking, and creative thinking. Under the category of personal outcomes, teachers emphasized the development of patience. In the category of contributions to the learning process, the identified themes included increasing students' interest in and motivation toward lessons, learning through trial and error, transforming theoretical knowledge into practice, promoting long-term retention, and encouraging active participation. Within the category of the development of social skills, collaboration and communication skills emerged as key themes. In the category of the development of design and production skills, productivity as well as prototype and product development were highlighted. Finally, within the category of the development of technological competencies, improving technological literacy and adapting to the requirements of the digital age were identified as important outcomes. These findings indicate that teachers perceive robotics coding as a multifaceted learning environment capable of supporting a wide range of cognitive, personal, social, technological, and practice-oriented learning outcomes.

Teachers' views on the challenges encountered during the robotics coding process and their proposed solutions were classified into categories and codes through inductive content analysis. The findings are presented in Table 7.

Table 7. Teachers' Views on the Challenges Encountered During the Robotics Coding Process and Proposed Solutions

Category	Code	Representative Quotations
Hardware-related challenges	Insufficient instructional materials (n = 6)	P3: "One of the biggest challenges I encounter is the lack of equipment."
	Inadequate technological infrastructure (n = 5)	P6: "Insufficient technical infrastructure..."
	Hardware malfunctions (n = 2)	P10: "Equipment and hardware failures..."
Challenges related to the educational process	Time constraints (n = 6)	P3: "The lengthy planning and implementation process leads to insufficient time."
	Overcrowded classrooms (n = 1)	P3: "It is very difficult to manage the process effectively in overcrowded classrooms."
Student-related challenges	Lack of motivation and tendency to give up (n = 4)	P18: "Students tend to give up after their first mistake."
	Differences in students' readiness levels (n = 2)	P7: "Students have different levels of readiness..."
	Lack of programming knowledge (n = 1)	P8: "We experience difficulties when we write code incorrectly or do not know how to code."
Proposed solutions	Strengthening technological infrastructure (n = 5)	P3: "The technological infrastructure in schools should be strengthened."
	Planning the learning process effectively (n = 4)	P3: "The process should be systematically planned and implemented with small groups."
	Increasing in-service training opportunities (n = 2)	P4: "More in-service training should be provided for teachers."
	Designing activities appropriate to students' levels (n = 2)	P7: "Activities should be designed according to students' readiness levels."
	Allocating sufficient instructional time (n = 1)	P4: "Sufficient time should be allocated for lessons."

*Because a participant's response could be coded under more than one category, the total frequencies exceed the number of participants.

As shown in Table 7, teachers' views on the challenges encountered during the robotics coding process and their proposed solutions were grouped into four categories. Within the category of hardware-related challenges, the most frequently emphasized issues were insufficient instructional materials, inadequate technological infrastructure, and hardware malfunctions. Under the category of challenges related to the educational process, time constraints and overcrowded classrooms emerged as the primary concerns. In the category of student-related challenges, teachers highlighted students' lack of motivation and tendency to give up, differences in readiness levels, and insufficient programming knowledge. Regarding proposed solutions, teachers recommended strengthening technological infrastructure, systematically planning the learning process, increasing in-service training opportunities, designing activities appropriate to students' readiness levels, and allocating sufficient instructional time. These findings indicate that the challenges encountered during the robotics coding process stem not only from hardware-related limitations but also from instructional processes and student-related factors. Furthermore, the proposed solutions primarily focus on improving educational environments and enhancing teaching and learning processes.

Teachers' overall evaluations of robotics coding education, their views on professional development, and their recommendations for the wider implementation of robotics coding education were classified into categories and codes through inductive content analysis. The findings are presented in Table 8.

Table 8. Teachers' Overall Evaluations of Robotics Coding Education and Their Recommendations

Category	Code	Representative Quotations
Educational contributions	Developing 21st-century skills (n = 2)	P3: "Robotics coding is a practice-oriented educational approach that contributes to the development of 21st-century skills such as creativity, problem-solving, and logical thinking."
	Promoting long-term retention (n = 2)	P4: "I believe it is essential for today's education system. It makes lessons more enjoyable and promotes long-term retention."
	Making learning enjoyable (n = 1)	P3: "It enables students to learn through enjoyment."
	Transforming theoretical knowledge into practice (n = 1)	P7: "This type of education also helps students transform theoretical knowledge into practical applications."
	Fostering productive individuals (n = 1)	P5: "I believe it contributes to raising individuals who not only consume technology but also produce it."
Contributions to professional development	Enhancing professional competence (n = 3)	P11: "It was a highly productive training program, including content that I can integrate into my teaching."
Recommendations for wider implementation	Expanding the use of robotics coding in education (n = 3)	P13: "I believe robotics coding education should definitely be incorporated into the educational process."
	Increasing in-service training opportunities (n = 1)	P6: "I think the Ministry of National Education should organize more seminars and in-service training programs on this topic."

*Because a participant's response could be coded under more than one category, the total frequencies exceed the number of participants.

As shown in Table 8, the teachers' overall evaluations of robotics coding education were grouped into three categories: educational contributions, contributions to professional development, and recommendations for the wider dissemination of robotics coding education. Within the educational contributions category, the most prominent themes included the development of twenty-first-century skills, the promotion of meaningful and enjoyable learning, the transformation of theoretical knowledge into practical application, and the cultivation of productive individuals. Under the contributions to professional development category, teachers emphasized that robotics coding education enhanced their professional knowledge and competencies. Regarding recommendations for wider dissemination, participants suggested expanding the implementation of robotics coding education within educational settings and increasing the availability of in-service training opportunities. Overall, these findings indicate that teachers perceive robotics coding education as an important educational practice that supports both students' cognitive and practice-based learning while also contributing to teachers' professional development. Furthermore, they believe that such educational oppotunities should be implemented more widely across educational contexts.

4. Discussion

The findings related to the first research question indicate that teachers perceive robotics coding as an important learning environment for fostering the development of scientific reasoning. Among the components of scientific reasoning, hypothesis generation, causal reasoning, and scientific observation were the most frequently emphasized by the participants, while scientific interpretation and the use of evidence also emerged as prominent themes. These findings may be explained by the nature of robotics coding activities, in which students analyze problems, formulate predictions about potential solutions, test the algorithms they develop, and refine their solution processes based on the outcomes they obtain. Scientific reasoning comprises a set of interconnected cognitive processes, including hypothesis generation, evidence evaluation, inference, and the establishment of cause-and-effect relationships (Krell et al., 2022; Zimmerman, 2007). Likewise, robotics coding activities support these processes by enabling students to observe whether their solutions produce the intended robot behaviors, evaluate the resulting evidence, and revise their solution strategies whenever necessary. Consistent with the present findings, Topçubaşı et al. (2025) also reported that robotics coding supports the development of scientific reasoning processes such as observation, hypothesis generation, and concluding.

Teachers' views regarding scientific observation, scientific interpretation, and the use of evidence can also be explained by the practice-oriented nature of robotics coding. Data obtained from the robot's sensors, program outputs, and the robot's behaviors during task execution provide students with tangible sources of evidence. By evaluating this evidence, students interpret why a particular solution succeeds or fails and subsequently revise their algorithms based on the evidence they have gathered. The National Research Council (NRC, 2012) emphasizes that scientific practices involve observing phenomena, analyzing data, and constructing evidence-based explanations. Similarly, Bers et al. (2014) argue that the processes of observation, testing, debugging, and revision embedded in robotics activities foster the development of students' scientific thinking skills. From this perspective, robotics coding provides a learning environment that encourages students not only to reach correct solutions but also to critically examine how those solutions are achieved and to reflect on the reasoning underlying their problem-solving processes.

The teachers in this study also reported that robotics coding promotes experiential learning and scientific thinking. During robotics coding activities, students do not passively receive knowledge; rather, they design, implement, test, and revise their solutions whenever necessary. This process encourages active participation in learning and makes students' scientific thinking processes more explicit and meaningful. Alimisis (2013) argued that educational robotics provides structured learning experiences in which students engage with authentic real-world problems and develop tangible products.

Similarly, Eguchi (2014) emphasized that robotics activities support the development of twenty-first-century skills, including critical thinking, problem solving, and scientific thinking. Furthermore, Schina et al. (2021) reported that effective educational robotics programs are characterized by practice-based activities, project-based learning, and strong teacher guidance. These findings are consistent with the views expressed by the teachers in the present study, who perceived robotics coding as an effective instructional tool for fostering experiential learning and scientific thinking.

Nevertheless, the teachers' recommendations for fostering scientific reasoning suggest that robotics coding alone is not sufficient as an instructional approach. The participants emphasized the importance of incorporating authentic real-world problems, encouraging students to engage in inquiry, providing more opportunities for hypothesis generation, and implementing hands-on activities in a planned and systematic manner. These recommendations indicate that the pedagogical value of robotics coding depends less on the technology itself than on how the learning process is designed. Consistent with this interpretation, Benitti's (2012) systematic review reported that educational robotics generally produces positive educational outcomes; however, the magnitude of these effects varies according to factors such as the duration of the intervention, instructional design, and characteristics of the learning environment. Similarly, Ouyang and Xu (2024) concluded that educational robotics has positive effects on STEM achievement, although these effects differ depending on instructional strategies and implementation conditions. Therefore, the findings of the present study do not suggest that robotics coding directly improves scientific reasoning. Rather, they indicate that teachers perceive robotics coding as an effective learning environment capable of supporting scientific reasoning processes when implemented under appropriate pedagogical conditions.

The findings related to the second research question indicate that teachers perceive robotics coding as an effective learning environment for supporting the development of problem-solving skills. The participants particularly emphasized the processes of generating alternative solution strategies, algorithmic thinking, and prototype development. These findings may be explained by the nature of robotics coding activities, in which students decompose problems into smaller sub-tasks, plan solution procedures, test the algorithms they develop, and revise ineffective solution steps when necessary. Bers et al. (2014) noted that robotics coding integrates the interconnected processes of problem identification, solution development, implementation, testing, and debugging. Similarly, Çakıcı and Özdemir (2022) reported that coding education positively supports students' problem-solving and algorithmic thinking skills. Likewise, Kılıçkıran et al. (2020) found that robotics coding education contributes significantly to the problem-solving processes of gifted students. Therefore, teachers' perceptions of problem solving appear to be closely associated with the iterative nature of robotics coding, which requires students not only to generate solutions but also to test, evaluate, and refine them whenever necessary.

Teachers' views regarding algorithmic and analytical thinking may be explained by the structured and sequential nature of problem solving in robotics coding. For a robot to perform a desired task successfully, students must determine the order in which operations should be executed and evaluate how each command influences the final outcome. Consequently, students are required not only to generate a solution to a problem but also to systematically plan how that solution should be constructed. Eguchi (2014) argued that educational robotics can foster higher-order thinking skills through the interconnected processes of planning, programming, testing, and revising. Similarly, Doğan and Korkmaz (2025) demonstrated that project-based educational robotics activities are positively associated with students' computational thinking skills and programming self-efficacy. However, the meta-analysis conducted by Ouyang and Xu (2024) found that the overall effect of educational robotics on computational thinking was not significant across all implementations. Therefore, the present findings should not be interpreted as evidence that robotics coding automatically improves algorithmic and analytical thinking. Rather, they suggest that teachers perceive robotics coding as a learning environment capable of supporting these cognitive processes when implemented through appropriate instructional design and learning conditions.

Prototype development emerged as another important finding that teachers associated with problem-solving skills. In robotics coding, the proposed solution is tested through a tangible product or a functioning system, and when the product does not perform as expected, students revisit their designs or programs and make the necessary revisions. Within this process, errors are viewed not as indicators of failure but as valuable sources of feedback that contribute to improving the solution. Alimisis (2013) argued that developing tangible products to address authentic real-world problems in educational robotics supports students' solution generation and iterative refinement processes. Similarly, Kılıçkıran et al. (2020) reported that robotics coding activities contribute to students' product development experiences and their ability to generate solutions to the problems they encounter. From this perspective, teachers' emphasis on prototype development may be explained by the fact that robotics coding places the iterative cycle of designing, testing, and refining at the core of the problem-solving process.

The teachers recommended that students should be provided with opportunities to explore alternative solution strategies, plan their solution processes, identify and correct their own errors, develop projects, work on authentic real-world problems, and participate in collaborative group activities to foster problem-solving skills. These recommendations suggest that robotics coding should not be reduced to the execution of technical commands; rather, it should be designed as a pedagogical learning environment in which students actively engage in thinking, inquiry, and solution generation. Chevalier et al. (2021) argued that making the stages of understanding the problem, generating ideas, designing solutions, programming, and evaluating outcomes explicit within robotics activities supports creative problem solving. Similarly, Schina et al. (2021) emphasized that effective educational robotics practices should integrate pedagogical guidance, collaboration, hands-on activities, and continuous feedback. Therefore, the development of problem-solving skills appears to depend less on the mere presence of robots in the classroom than on providing students with open-ended problems, opportunities to explore multiple solution pathways, and systematic teacher guidance throughout the learning process.

Overall, the findings related to the second research question indicate that teachers perceive robotics coding as an effective learning environment capable of supporting the development of alternative solution strategies, algorithmic thinking, and prototype development. In addition, analytical thinking, self-confidence, and technological literacy were identified as important outcomes that accompany and support the problem-solving process. However, because the present study is based solely on teachers' perspectives, these findings should not be interpreted as evidence of directly measured improvements in students' problem-solving skills. Rather, they reflect teachers' evaluations that robotics coding has the potential to foster problem-solving skills when learning activities are structured around the processes of planning, testing, debugging, and iterative refinement.

The findings related to the third research question indicate that teachers possess varying levels of knowledge and technical competence in robotics coding. While some participants perceived themselves as having beginner-level competence, others reported possessing intermediate or advanced levels of knowledge and expertise. In terms of technical competencies, block-based programming, the use of sensors, and the ability to write programming commands emerged as the most prominent skills. These differences suggest that robotics coding training programs based on a standardized curriculum may not adequately address teachers' diverse professional learning needs. Schina et al. (2021) emphasized that effective teacher education programs should integrate technical knowledge with pedagogical practice, be structured progressively from basic to advanced levels, and provide sustained support following formal training. Similarly, Chevalier et al. (2021) found that teachers generally feel more confident implementing pre-designed activities than designing their own activities, assessing student learning, or adapting instruction to students' individual needs. Therefore, teachers need not only to learn how to operate robotics tools but also to develop the ability to integrate these tools effectively with science curriculum objectives and students' learning characteristics.

Teachers reported that robotics coding can support the development of a wide range of skills and attributes, including problem solving, analytical and algorithmic thinking, creative thinking, technological literacy, productivity, and perseverance. In addition, increased interest and motivation toward lessons, active participation in the learning process, learning through trial and error, the transformation of theoretical knowledge into practical application, and the promotion of meaningful and lasting learning were identified as important educational benefits of robotics coding. Göksoy and Yılmaz (2018) found that both teachers and students associate robotics coding with problem solving, analytical thinking, systematic thinking, creative thinking, and design skills. Similarly, Doğan and Korkmaz (2025) reported a positive relationship between project-based educational robotics activities and students' computational thinking skills. Furthermore, Anwar et al. (2019), in their comprehensive review of educational robotics research, concluded that these practices have considerable potential to enhance learning, motivation, creativity, student engagement, and teachers' professional development. However, because the findings of the present study are based solely on teachers' perspectives, these reported outcomes should be interpreted as perceived educational benefits of robotics coding rather than as directly measured effects.

The findings identified insufficient instructional materials, inadequate technological infrastructure, hardware malfunctions, limited instructional time, and overcrowded classrooms as the major challenges encountered during the implementation of robotics coding activities. In addition, students' low motivation, their tendency to give up after initial failures, differences in prior readiness levels, and insufficient coding knowledge were identified as important factors that complicated the implementation process. Yumbul and Bayraktar (2022) similarly reported that inadequate technological infrastructure and limited hardware resources are among the primary challenges affecting robotics education practices in Türkiye. Likewise, Ceylan and Gündoğdu (2018) demonstrated that the implementation of coding education is shaped by contextual factors, including schools' technological infrastructure, students' readiness levels, classroom conditions, and time constraints. Dikbaş and Polat (2022) also highlighted challenges related to inadequate infrastructure, financial costs, teachers' lack of knowledge, and insufficient in-service training opportunities in robotics coding workshops. Collectively, these findings suggest that the successful implementation of robotics coding depends not only on teachers' willingness or the availability of robotics equipment but also on the technical, physical, and organizational conditions of schools, all of which play a critical role in determining the quality of the implementation process.

Teachers' recommendations to strengthen technological infrastructure, systematically organize the learning process, expand in-service training opportunities, develop activities appropriate to students' developmental levels, and allocate sufficient instructional time are directly related to the implementation challenges identified in this study. Schina et al. (2021) emphasized that effective robotics teacher education programs should adopt a comprehensive approach that integrates technical practice, pedagogical guidance, instructional material support, collaboration, and continuous feedback. Similarly, the findings of Ceylan and Gündoğdu (2018) and Dikbaş and Polat (2022) highlight the importance of providing teachers with both technical and pedagogical support, improving school infrastructure, and implementing robotics coding activities through well-planned instructional processes. Therefore, in-service training programs should not focus solely on the operation of robotics hardware and software. Rather, they should also address competencies related to instructional activity design, integration into science teaching, classroom management, differentiated instruction, and the assessment of student learning.

Overall, the findings related to the third research question indicate that teachers perceive robotics coding as a multifaceted learning environment capable of supporting students' cognitive, personal, social, and technological development. However, the successful realization of this potential appears to depend on several interrelated factors, including teachers' knowledge and competence, the adequacy of technological infrastructure, the amount of instructional time available, classroom conditions, and the extent to which learning activities are designed to meet students' developmental needs. Therefore, the broader implementation of robotics coding in educational settings should not be limited to the provision of robotics equipment alone. Rather, it should be supported through a comprehensive approach that integrates teacher education, technical support, pedagogical planning, and sustainable implementation practices.

5. Conclusion and recommendations

This study examined science teachers' views on the contributions of robotics coding to the development of students' scientific reasoning and problem-solving skills. The findings indicate that teachers perceive robotics coding not merely as a technical programming activity but as an applied, student-centered learning environment in which students test their ideas, observe outcomes, develop alternative solution strategies, and revise their solutions whenever necessary. However, because the findings are based solely on teachers' perspectives, they should not be interpreted as evidence of directly measured improvements in students' scientific reasoning or problem-solving skills.

Teachers reported that robotics coding can support the development of hypothesis generation, causal reasoning, scientific observation, scientific interpretation, the use of evidence, and scientific thinking. With respect to problem-solving skills, the most prominent outcomes identified were generating alternative solution strategies, algorithmic thinking, and prototype development. In addition, analytical thinking, self-confidence, and technological literacy were considered important competencies that accompany and support the problem-solving process. These findings suggest that teachers perceive robotics coding as an applied learning environment that enables students to develop solutions, test their proposed solutions, and refine them based on the feedback obtained throughout the learning process.

The findings also suggest that robotics coding can support students' interest and motivation toward science lessons, active participation in the learning process, collaboration and communication skills, productivity, and technological competence. Teachers further reported that robotics coding training made meaningful contributions to their own professional competence and helped them integrate newly acquired knowledge and skills more effectively into their science teaching practices. However, the variation observed in teachers' knowledge and technical competence indicates that robotics coding training programs should be designed progressively and tailored to participants' prior knowledge and professional learning needs.

The study identified insufficient instructional materials, inadequate technological infrastructure, hardware malfunctions, limited instructional time, overcrowded classrooms, and differences in students' prior readiness levels as the primary factors hindering the implementation of robotics coding. Therefore, efforts to expand the use of robotics coding in educational settings should not be limited to the provision of robotics kits alone. Instead, successful and sustainable implementation requires a comprehensive approach that simultaneously addresses technological infrastructure, teacher education, instructional time, classroom organization, and students' developmental characteristics.

Based on the findings of this study, robotics coding activities are recommended to be integrated with authentic real-world problems, scientific inquiry, project-based learning, and collaborative group work. Students should be provided with opportunities to formulate hypotheses, plan solution processes, explore alternative solution strategies, evaluate outcomes, and analyze and correct their own errors. Learning activities should be designed using a progressive sequence from simple to complex and should focus not only on the execution of programming commands but also on encouraging students to articulate their thinking processes, justify their decisions, and explain the rationale underlying their proposed solutions.

In-service teacher education programs should address not only the technical operation of robotics tools but also instructional activity design, integration with science curriculum objectives, teaching strategies that promote problem-solving and scientific reasoning, classroom management, and assessment practices. Furthermore, providing teachers with ongoing support through sample instructional activities, lesson plans, technical assistance, and professional collaboration with colleagues may enhance both the sustainability and the classroom effectiveness of robotics coding implementations.

Future research could examine the contributions of robotics coding to scientific reasoning and problem-solving skills through the direct assessment of student performance using multiple data sources, such as classroom observations, student-generated artifacts, and process-based learning records. Studies conducted across different grade levels, school contexts, and larger participant samples may provide a broader understanding of the findings and enhance their applicability across diverse educational settings. Furthermore, comparative studies examining robotics coding programs of varying durations and instructional approaches could help identify the pedagogical conditions under which these interventions are most effective.

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