Research Article
Received: 19.02.2025
Accepted: 24.12.2025
Published: 31.12.2025

Citation: Topcubaşı, T., Üstünsoy, G., Yüksel, İ., Şahin, E., & Düzgün, S. (2025). Robotics coding training and scientific reasoning: Views of academicians and pre-service teachers. *International Journal of Scholars in Education*, *8*(2), 145-162. https://doi.org/ueader.1642197

Robotics Coding Training and Scientific Reasoning: Views of Academicians and Pre-Service Teachers

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Abstract: This study investigates the opinions of academics and pre-service teachers in Primary School Education and Science Education who received robotics coding training regarding their scientific reasoning and problem-solving skills. It explores how different types of reasoning—inductive, deductive, and abductive—are used in robotics coding applications and identifies related technological challenges. Adopting a qualitative case study design, data were collected through semi-structured interviews with 5 academics and 13 pre-service teachers and analyzed via content analysis. Findings indicate that robotics coding training enhances analytical thinking, problem-solving, creativity, and digital literacy while improving scientific process skills such as observation, hypothesis formulation, and drawing conclusions. Participants also reported difficulties such as sensor errors and hardware incompatibilities but emphasized that these experiences strengthened their analytical and solution-oriented thinking. Overall, robotics coding training contributes substantially to the professional development of educators by integrating scientific reasoning with hands-on technological practice.

Keywords: Robotic coding, scientific reasoning, problem solving, STEM education, teacher training.

Introduction

The 21st-century skills encompass the competencies and abilities required for individuals to succeed in modern society. Among these skills, core proficiencies such as analytical thinking, scientific reasoning, and problem-solving take precedence. The rapid rise of digitalization and artificial intelligence has necessitated the development of new approaches to foster these skills. In contemporary education, robotics coding training is regarded as an effective method to enhance individuals' analytical thinking and problem-solving capacities (Tunalı, 2022). However, studies focusing on scientific reasoning and problem-solving skills within the context of robotics coding remain limited. This gap highlights the need to investigate the perceptions and outcomes of these skills, particularly among educators and pre-service teachers.

Robotics coding training is an educational process that enables students to learn through hands-on experiences with scientific processes. Within this framework, students engage in activities designed to develop their scientific reasoning and problem-solving skills (Schen, 2007). However, further research is necessary to understand the effects of such approaches in education and to reveal their impact on pre-service teachers and academics. In this regard, exploring the perspectives of individuals who have received robotics coding training as part of technology-oriented processes is of critical importance for evaluating their scientific reasoning and problem-solving skills.

Scientific reasoning involves the process of acquiring knowledge through observation, experimentation, and logical inference (Zimmerman, 2005). Different types of scientific reasoning, including inductive, deductive, and abductive reasoning, support individuals in problem-solving processes (Schen, 2007; Tunalı, 2022). Robotics coding training is considered a powerful tool for experiencing and applying these reasoning processes.

In robotics coding education, students learn critical skills such as algorithm development, error analysis, and solution generation. These activities foster scientific reasoning, problem-solving, and creativity (Godfrey-Smith, 2003; Schurz, 2008). Robotics coding projects enhance students' analytical thinking capacities while enabling them to develop innovative and systematic approaches to problem-solving. Research indicates that educational robotics significantly contributes to students' cognitive development, problem-solving skills, and engagement with STEM-related learning processes (Atmatzidou & Demetriadis, 2016).

Inductive reasoning involves deriving general conclusions from specific observations and experiences, allowing students to synthesize and generalize information. Deductive reasoning, on the other hand, entails deriving specific conclusions from general principles, enabling logical inferences from accepted truths. Abductive reasoning, defined as making the most plausible inferences in situations with limited information, is another critical reasoning type (Schurz, 2008). Robotics coding training supports the simultaneous use of these reasoning types, enabling individuals to approach complex problems from multiple perspectives (Tunalı, 2022).

At the core of scientific reasoning are observation, experience, and domain knowledge. Observation is the first step in the scientific method and is essential for accurately interpreting phenomen. Domain knowledge refers to teachers' mastery of fundamental concepts and skills in their subject areas. Shulman (1986) emphasizes the critical role of domain knowledge in the development of teachers' scientific reasoning skills. The experiences students gain during robotics coding training enhance their problem-solving capacities and contribute to the development of their scientific reasoning skills (Shulman, 1986).

Robotics coding training also provides opportunities to develop students' digital literacy skills. Digital literacy encompasses the knowledge and abilities necessary for interacting effectively with technology, and robotics coding serves as an ideal platform for cultivating these skills (Tunalı, 2022; Zimmerman, 2005). Through robotics projects, students collect, analyze, and draw logical conclusions from data. This process enables them to experience scientific inquiry practices and enhances their interest and engagement in STEM education (Eguchi, 2014).

The unique contribution of this research lies in its focus on examining the perspectives of pre-service teachers and academics in the Departments of Classroom Education and Science Education who have received robotics coding training, specifically regarding their scientific reasoning and problem-solving skills. The limited number of studies in the literature addressing this topic underscores the importance of this research. By identifying participants' perceptions of their scientific reasoning and problem-solving skills, this study aims to contribute to the existing literature.

The objective of this study is to determine the opinions of academics and students in the Departments of Classroom Education and Science Education who have received robotics coding training regarding their scientific reasoning and problem-solving skills. The study seeks to address the following research questions:

- What is the knowledge of pre-service teachers and academics about robotics coding tools and programs?
- What are the participants' opinions on the skills developed through robotics coding training in pre-service teachers?
- What scientific and technological challenges do pre-service teachers and academics encounter during robotics coding training?
- What are the effects of robotics coding training on scientific reasoning and problem-solving skills?
- How does robotics coding training contribute to the professional development of pre-service teachers?

Methodology

In this study, case study design, one of the qualitative research methods, was adopted. Qualitative researches are methods that aim to understand the experiences, perceptions and emotions of individuals in depth and are widely used in fields such as social sciences and education. Data collection methods in such research include interviews, focus groups, observations and document analyses (Creswell, 2013). Since the aim of the study was to understand the views of individuals who received robotic coding training on scientific reasoning and problem solving skills, a case study design was deemed appropriate. Case studies aim to examine an individual, group or environment in detail and to obtain results specific to the context of this situation (Yıldırım & Şimşek, 2021).

Study Group

The study group of this research consisted of a total of 18 participants (n = 18), including academics (n = 5) working in the Departments of Classroom Education and Science Education, and pre-service teachers (n = 13) enrolled in these departments.Among the academics, three were from the field of Classroom Education and two from Science Education. Of the pre-service teachers, seven were enrolled in the Primary Education undergraduate program and six in the Science Education undergraduate program.A criterion sampling method, one of the purposive sampling strategies, was employed in the study. The primary criterion for participant selection was having previously received robotics coding training. This criterion was determined to ensure that participants could express their views on the effects of robotics coding education on scientific reasoning and problem-solving skills based on their own experiences.To enhance depth and trustworthiness, detailed descriptions and direct quotations were included in the study, allowing readers to independently interpret the findings (Yıldırım & Şimşek, 2021).

Data Collection

In the data collection process, a semi-structured interview form developed by the researchers was used. The interview form consisted of two main sections. The first section included questions related to demographic information such as participants' department, academic status, and prior experience with robotics coding. The second section comprised five open-ended questions aimed at eliciting participants' views on: (1) their level of knowledge regarding robotics coding tools and programs, (2) the skills gained through robotics coding training, (3) scientific and technological challenges encountered, (4) the effects of robotics coding training on scientific reasoning and problem-solving skills, and (5) the contribution of such training to professional development.

The interview questions were prepared in line with the research objectives to elicit detailed and reflective responses regarding participants' experiences with robotics coding education. To ensure content validity, the interview form was reviewed by three field experts, and a pilot study was conducted to test language clarity and question comprehensibility. Data obtained from the pilot study were excluded from the main analysis. Each interview lasted approximately 30 minutes. The interviews were conducted online via the Zoom platform with 5 academics and 13 pre-service teachers. With the participants' informed consent, the interviews were audio-recorded. The audio recordings were then transcribed verbatim by the researchers, with participants' permission, and these transcripts were used in the data analysis process.

Analysis of Data

The collected data were analysed by content analysis method. Content analysis aims to make sense of the contents in written and formal data and to reveal basic concepts (Yıldırım & Şimşek, 2021). In this analysis, the data were transformed into codes and themes were formed from the codes. In order to ensure the reliability of the coding process, the data were sent to two expert teachers and the inter-coder reliability rate was calculated as 0.86. Various strategies were applied to increase the validity and reliability of the research. In terms of validity, expert review and participant confirmation methods were used. Expert review includes expert opinions taken during the preparation of the interview form and data analysis processes (Creswell & Miller, 2000). Participant confirmation was provided by presenting the findings obtained to the participants and receiving feedback. Within the scope of reliability, consistency and verifiability were prioritised. A randomly selected section of the data was sent to two different field experts and the inter-coder reliability rate was calculated.

Findings

The findings of the research are presented below in line with the sub-problems.

What is the level of knowledge of teachers who receive/offer robotic coding education about the educational content, robotic coding sets or programmes?

The data on the level of knowledge of teachers who receive/offer robotic coding training about educational content, robotic coding sets and programmes are presented in Table 1 within the scope of the research question.

Table 1
Knowledge levels of teachers who received / gave robotic coding training on training content, robotic coding sets and programmes

Category	Code	Teacher ID	Frequency (f)
Receiving and Providing Education	Received	A1, A2, A3, A4, A5, PT1, PT2, PT3, PT4, PT5, PT6, PT7, PT9, PT12, PT13	15
	Provided	A1, A2, A4, A5, PT1, PT4, PT6, PT8, PT9, PT11, PT12	10
	Not Received	PT9, PT10	2
	Not Provided	PT9, PT10	2
Robotics Sets and Programs	Scratch	A1, A4, A5, PT3, PT4, PT5, PT7, PT9, PT12, PT13	10
	Raspberry Pi	A4, PT5, PT8, PT11, PT12, PT13	6
	Lego WeDo	A4, A5, PT5, PT7, PT9	5
	LEGO Mindstorms	PT1, PT9, PT11, PT12	4
	mBot	A4, A5, PT5	3
	Spike Essential	PT1, PT4, PT9	3
	VEX Robotics	PT9, PT11, PT12	3
	BeeBot	A5, PT1	2
	VEX IQ	PT1, PT13	2
	BrickQ	PT11, PT12	2
	Spike Prime	PT11, PT12	2
	EV3	PT11, PT12	2
	TÜBİTAK	PT11, PT12	2
	Deneyap Türkiye	A2	1
	mTiny	A2	1
	Matatalab	PT1	1
	STEM	PT1	1
	VEX V5	A5	1
	Snap Circuits	PT12	1
	Robotis Dream	PT9	1
	Uaro	PT9	1
	Makey Makey	PT9	1
	mBot Ranger	PT9	1
	Botley	PT9	1
	Panda Robot	PT9	1
	3D Pen	PT9	1
	Twin Kits	PT9	1
	Deneyap Board	PT9	1
	Bubble-Bot	PT9	1
Basic Skills and Concepts	Algorithm Development	A4, PT5, PT6	3
	Sensor and Motor Usage	A4, PT5, PT6	3
	Problem Solving	PT5, PT6, PT8	3
	Basic Robotic Concepts	PT5, PT6	2
	Basic and Advanced Circuit Design	A4	1
	Scientific Thinking	PT8	1

PT: Pre-service Teacher - A: Academic

When Table 1 is examined, it is observed that the knowledge of teachers who have received and provided robotics coding training about robotics coding kits, programs, and educational content is divided into three main categories: "Training Received and Provided" (f:29), "Robotics Kits and Programs" (f:64), and "Basic Skills and Concepts" (f:13). The statements of participants and findings provide significant insights into their levels of knowledge and experiences in these areas.

In the "Training Received and Provided" category, it is seen that most teachers have either received robotics coding training (f:15) or have provided such training to others (f:10). Participants particularly emphasized a learning process that began during their university years, followed by teaching experiences. For instance, a pre-service teacher (PT-9) mentioned that they were introduced to robotics coding at university and began their professional career by providing training in technology workshops. This demonstrates that participants' knowledge and experience in robotics coding largely started alongside their academic education.

In the "Robotics Kits and Programs" category, the variety of robotics kits and programs used by participants stands out. Frequently mentioned tools include Arduino (f:10), LEGO Mindstorms, Raspberry Pi, Scratch, and other popular robotics kits. For example, one participant (PT-9) stated that they had worked with a wide range of robotics kits and programs, including Arduino, Spike, WeDo, and Makey Makey. This highlights the diversity of materials used by participants in robotics coding training and their depth of knowledge in this field. Experiences gained through various robotics kits and programs can be said to enhance both the theoretical knowledge and practical skills of teachers.

In the "Basic Skills and Concepts" category, fundamental skills such as algorithm development (f:3), sensor and motor usage (f:3), and problem-solving (f:3) are prominent. Participants noted that the content of robotics coding training generally focuses on imparting these basic skills. For instance, one participant (PT-1) stated that the training focused on teaching algorithm logic, guiding problem-solving processes, and developing curricula tailored to different age groups. Another participant (A-4) mentioned working with advanced training content that included interaction with sensors, circuit design, and programming. These findings indicate that robotics coding training is designed to impart skills both at the beginner and advanced levels.

In conclusion, the knowledge levels and experiences of teachers who have received and provided robotics coding training are highly diverse. Educational content, the variety of robotics kits and programs used, and the skills imparted significantly contribute to teachers' academic and professional development. Furthermore, the knowledge and experience possessed by participants when teaching robotics coding appear to play an influential role in developing and implementing curricula for students. This underscores once again the importance of robotics coding training as a valuable tool for educators.

The Opinions of Pre-Service Teachers and Academicians on the Skills Developed by Robotics Coding Training in Pre-Service Teachers and the Gains Achieved

The opinions of pre-service teachers and academicians about the skills developed by the robotic coding education in pre-service teachers and the gains they obtained are given in Table 2.

Table 2
Prospective teachers' and academicians' opinions on the skills developed by robotic coding education and the gains obtained

Category	Code	Teacher ID	Frequency (f)
Thinking Skills	Critical Thinking	PT-3, PT-4, PT-5, PT-7, PT-8, PT-9	6
	Analytical Thinking	A-4, A-5, PT-2, PT-4, PT-11	5

Productivity and Innovation	Algorithmic Thinking	A-1, A-4, A-5	3
	Metacognitive Thinking	A-2	1
Problem Solving and Decision Making	Productivity	A-1, A-4, A-5, PT-1, PT-2, PT-4, PT-5, PT-6, PT-8, PT-10, PT-11, PT-12	10
	Innovative Solutions	A-5, PT-2	2
Social and Collaborative Skills	Problem Solving	A-1, A-4, A-5, PT-1, PT-2, PT-3, PT-4, PT-5, PT-7, PT-8, PT-9, PT-11	12
Thinking Skills	Collaboration	A-2, PT-4, PT-5, PT-6, PT-8	7
	Teamwork	A-5, PT-6	3
	Leadership	A-5	1
	Digital Literacy	PT-1, PT-2, PT-4, PT-5, PT-6, PT-8, PT-9, PT-13	9
	21st Century Educational Technologies	A-3	1

An examination of Table 2 reveals that the skills developed by robotics coding education in pre-service teachers are categorized into five main areas: Thinking Skills, Creativity and Innovation, Problem-Solving and Decision-Making, Social and Collaborative Skills, and Digital and Technological Skills. Participants' responses indicate that these categories play a significant role in the personal and professional development of pre-service teachers.

In the Thinking Skills category, high-level cognitive skills such as algorithmic thinking (f:3), analytical thinking (f:5), and critical thinking (f:6) were reported to have been enhanced through robotics coding education. Participants noted that working with interconnected modules in robotics coding promotes the development of metacognitive thinking skills. For instance, one participant (A-2) emphasized that robotics coding enables individuals to utilize metacognitive skills during the process of developing innovative products tailored to specific needs.

The Creativity and Innovation category highlights the prominence of innovative thinking and creative problem-solving skills (f:10) among pre-service teachers. Participants stated that robotics coding education teaches systematic approaches to problems while fostering creative solutions. For example, one participant (PT-2) noted that this training supports candidates' productive thinking abilities and encourages them to devise innovative solutions.

Problem-Solving and Decision-Making skills represent another critical area directly influenced by robotics coding education. Pre-service teachers developed analytical and systematic approaches to address problems encountered during the robotics coding process. One participant (PT-3) stated that such training enhances essential skills like problem-solving and digital literacy among pre-service teachers.

In the Social and Collaborative Skills category, the development of teamwork (f:3) and collaboration (f:7) skills among pre-service teachers was evident. Participants remarked that robotics coding projects inherently require group collaboration, which also fosters leadership skills. One participant (A-5) emphasized that these projects strengthen social skills by promoting teamwork and collaboration.

The Digital and Technological Skills category includes the development of digital literacy (f:9) and the ability to utilize 21st-century educational technologies (f:1). Participants indicated that robotics coding supports the effective use of digital tools and cultivates skills such as computational thinking and algorithmic logic. One participant (A-3) stressed that these competencies are indispensable in modern education.

In conclusion, robotics coding education facilitates comprehensive skill development for pre-service teachers, ranging from thinking skills to social and technological competencies. Participants' responses reveal that such education not only enhances technical abilities but also effectively develops 21st-century skills such as creativity, collaboration, and critical thinking. These findings underscore the importance of robotics coding education as a crucial tool for improving the professional qualifications of pre-service teachers.

What are the most important gains provided to prospective teachers and academicians by receiving robotic coding education?

The data on the most important gains provided to prospective teachers and academicians by receiving robotic coding education are presented in Table 3.

Table 3
The most ımportant gains provided to prospective teachers and academicians by receiving robotic coding education

Category	Code	Teacher ID	Frequency (f)
Technological Literacy	Understanding the working principles of electronic devices	A-1	1
	Working with technological tools	A-5	1
Project-Based Thinking	Project-based thinking	A-1	1
Problem Solving	Problem solving	A-1, A-4, A-5, PT-1, PT-11	5
	Multidimensional thinking	A-2, PT-6	2
	Solving complex problems with simple steps	A-5	1
Strategic and Creative Thinking Entrepreneurship and Productivity	Creative thinking	A-4, PT-10	2
	Strategic thinking	A-3	1
	Producing new projects	A-3	1
	Finding innovative solutions	A-4	1
Analytical and Versatile Thinking	Entrepreneurship	PT-2	1
	Being productive	PT-2	1
Fine Motor Skills and Creativity Digital and Technological Skills	Analytical thinking	PT-5	1
	Multidimensional thinking	PT-6	1
	Evaluating from different perspectives	PT-6	1
Transfer and Multidimensional Thinking	Creativity	A-4, PT-4, PT-10	3
	Fine motor skills	PT-4	1
Educational Methods and Learning	Digital literacy	PT-8	1
	Transferring knowledge	A-2	1
Experience and Content Development	Adapting to the digital age	PT-1	1
	Shaping technology	PT-1	1
	Experience	PT-9	1

	Content development	PT-9	1
Technological Literacy	Technology	PT-13	1

An analysis of Table 3 reveals that the skills developed by pre-service teachers and academics through robotics coding education, as well as their areas of focus, can be categorized into several distinct areas. These include technological literacy, project-oriented thinking, problem-solving, strategic and creative thinking, entrepreneurship and productivity, analytical and multi-dimensional thinking, fine motor skills and creativity, and digital and technological skills. The data indicate that robotics coding education significantly enhances these competencies, contributing to the professional and personal development of educators.

In the Technological Literacy category, participants reported gaining skills such as understanding the working principles of electronic devices (f:1) and working with technological tools (f:1). These achievements contribute significantly to teachers' ability to comprehend and apply technology effectively. For example, one participant (A-1) noted that robotics coding education helped them better understand the working principles of electronic devices used in daily life.

Project-Oriented Thinking is another key competency fostered by robotics coding education (f:1). Participants highlighted that this training develops systematic approaches to project planning and execution. One participant (A-1) emphasized that robotics coding education enhanced their ability to think systematically during the planning and implementation of projects.

The Problem-Solving category includes skills such as solving complex problems with simple steps (f:1), multi-dimensional thinking (f:2), and general problem-solving abilities (f:5). These findings demonstrate the effectiveness of robotics coding education in fostering analytical thinking and solution-oriented approaches. For instance, one participant (A-5) stated that the training strengthened their ability to solve complex problems by breaking them into manageable steps.

In the Strategic and Creative Thinking category, skills such as strategic thinking (f:1), developing new projects (f:1), creative thinking (f:2), and finding innovative solutions (f:1) are emphasized. Participants noted that robotics coding education enhances their capacity to develop innovative approaches and generate creative solutions to problems. One participant (A-4) mentioned that the training significantly improved their ability to devise innovative solutions for complex issues.

The Entrepreneurship and Productivity category highlights the development of entrepreneurial (f:1) and productive (f:1) skills. Participants reported that robotics coding education fosters entrepreneurial thinking and encourages productivity. For example, one participant (PT-2) stated that this training nurtured their entrepreneurial spirit.

Analytical and Multi-Dimensional Thinking includes analytical thinking (f:1) and evaluating from different perspectives (f:1). Participants reported that robotics coding education improved their analytical and multi-dimensional thinking abilities. One participant (PT-6) noted that the training enhanced their capacity for multi-dimensional thinking.

In the Fine Motor Skills and Creativity category, participants gained skills such as fine motor skills (f:1) and creativity (f:3). Working closely with technology was highlighted as playing a significant role in fostering productivity. One participant (PT-4) mentioned that, in addition to improving their fine motor skills, the training also strengthened their problem-solving and creative abilities.

The Digital and Technological Skills category includes gains in digital literacy (f:1) and adaptation to the digital age (f:1). Participants emphasized that robotics coding promotes effective use of digital tools and encourages alignment with modern educational technologies. One participant (PT-1) stated that this training served as an important step for teachers in adapting to the digital age.

In conclusion, robotics coding education equips pre-service teachers and academics with competencies in areas such as analytical thinking, problem-solving, creativity, digital skills, and entrepreneurship. These achievements support the professional and personal growth of educators, enabling them to become more effective individuals within educational settings.

Prospective Teachers‘ and Academicians’ Opinions on the Effects of Robotic Coding Education on Scientific Process Skills and Problem Solving Skills

The opinions of pre-service teachers and academicians on the effects of robotic coding education on scientific process skills and problem solving skills are presented in Table 4.

Table 4
Frequency of prospective teachers‘ and academicians’ opinions on the effects of robotic coding education on scientific process skills and problem solving skills

Category	Code	Teacher ID	Frequency (f)
Scientific Process Skills	Making Observations	A-1, A-3, A-4, A-5, PT-1, PT-6, PT-7, PT-8, PT-11	9
	Drawing Conclusions	A-3, A-4, PT-1, PT-8	4
	Formulating Hypotheses	A-3, A-4, PT-8, PT-11	4
	Designing Experiments	PT-11, PT-12	2
	Analyzing Data	A-5, PT-8	2
	Multidimensional Thinking	A-2, PT-3	2
	Analytical Thinking	A-5, PT-8	2
	Developing Algorithms	PT-8, PT-12	2
	Making Measurements	A-1	1
	Probability	A-3	1
	Logical Reasoning	A-3	1
	Making Predictions Based on Data	A-5	1
	Gaining Perspectives	PT-6	1
	Creative and Solution-Oriented Approaches	PT-4	1
	Crisis Management	PT-12	1
	Correcting Errors	PT-8	1
	Analyzing Problems	PT-8	1
	Developing Solutions	PT-8	1
	Enhancing Robot Performance	PT-8	1
Problem-Solving Skills	Problem Solving	A-1, A-4, A-5, PT-1, PT-11	5
	Learning Through Trial and Error	PT-7	1
	Developing Hypotheses	PT-10	1
	Producing Solutions	PT-8	1

An analysis of Table 4 reveals that the areas where pre-service teachers and academics develop scientific process skills through robotics coding education are diverse and comprehensive. The ability to make observations (f:9) stands out as the most frequently highlighted skill, followed by hypothesis formulation (f:4) and drawing conclusions (f:4). Other key skills include experimental design (f:2), data analysis (f:2), multi-dimensional thinking (f:2), analytical thinking (f:2), and algorithm development (f:2). These competencies enable teachers to play an active role in scientific processes. Additionally, problem-solving (f:5) and crisis management (f:1) skills help educators overcome challenges encountered during the educational process. Further skills such as prediction (f:1), measurement (f:1), probability (f:1), reasoning (f:1), making data-driven predictions (f:1), gaining perspective (f:1), adopting productive and solution-oriented approaches (f:1), debugging (f:1), analyzing problems (f:1), developing solutions (f:1), enhancing robot performance (f:1), learning through trial and error (f:1), hypothesis development (f:1), and solution generation (f:1) are also highlighted as areas that strengthen teachers' scientific and analytical thinking capacities. These findings illustrate that teachers develop a broad range of scientific process skills, which significantly contribute to the educational process.

Within the Scientific Process Skills category, participants stated that robotics coding positively impacts abilities such as probability, reasoning, and hypothesis formulation. For instance, one participant (A-3) emphasized that the fundamental elements of scientific processes naturally evolve through this training and that these skills support scientific thinking. Another participant (PT-8) noted that debugging processes reinforce analytical thinking and teach patience, highlighting the contribution of these activities to scientific process skills.

In the Problem-Solving Skills category, the development of problem-solving (f:5) and crisis management (f:1) abilities is particularly notable. Analyzing problems encountered during robotics coding and generating solutions through appropriate algorithms enhance teachers' analytical thinking capacity. Participants expressed that learning through trial and error, breaking problems into smaller components, and developing alternative solutions strengthen problem-solving skills. For example, one participant (PT-7) mentioned that robotics coding education fosters the ability to solve complex problems through simple steps. Another participant (A-5) stated that the training enhances the ability to break down major problems into manageable parts and develop solutions.

Additional Skills and Competencies include prediction (f:1), measurement (f:1), gaining perspective (f:1), and adopting productive and solution-oriented approaches (f:1). Activities such as debugging, enhancing robot performance, and learning through trial and error in robotics coding projects contribute significantly to teachers' scientific and analytical thinking capacities. One participant (PT-7) remarked that such projects offer opportunities to apply scientific thinking in a practical way.

In conclusion, robotics coding education substantially improves the scientific process and problem-solving skills of pre-service teachers and academics. This training strengthens teachers' analytical and multi-dimensional thinking abilities while encouraging them to develop innovative and systematic solutions to complex problems. The skills acquired during the robotics coding process provide significant contributions to adopting more effective and innovative methods in education.

Scientific and Technological Challenges Faced by Prospective Teachers and Academicians While Solving a Problem in Robotic Coding Applications

Data on the scientific and technological difficulties encountered by pre-service teachers and academicians while solving a problem in robotic coding applications are presented in Table 5.

Table 5
Scientific and technological challenges faced by prospective teachers and academicians while solving a problem in robotic coding applications

Category	Code	Teacher ID	Frequency (f)
Technical Challenges	Sensor Errors	A-4, PT-5, PT-11, PT-12	4
	Hardware Incompatibilities	A-4, PT-11, PT-12	3
	Coding Errors	PT-11, PT-12	2
	Algorithm Issues	PT-5, PT-12	2
	Incorrect Placement of Jumpers on Arduino	A-1	1
	Connection Problems	A-1	1
	Limited Options and Constraints in Robot Construction	A-2	1
	Incompatibility of Sensors and Motors from Different Brands	A-5	1
Educational and Resource Challenges	Insufficient Manuals	A-2	1
	Product Availability	PT-2	1
	Lack of Training	PT-2	1
Solution Methods	Trial-and-Error Method	A-3, PT-5, PT-7, PT-12	4
	Careful Analysis and Patience	A-4, A-5, PT-6	3
	Conducting Research and Seeking Guidance	PT-4, PT-5	2
	Finding Alternative Solutions	A-5	1
	Teamwork and Collaboration	PT-1	1
Planning and Preliminary Preparation	High-Cost Equipment	PT-3	1
Solution Methods	Detailed Planning and Anticipating Potential Challenges	PT-13	1

An analysis of Table 5 reveals that the technical challenges faced by pre-service teachers and academics during robotics coding education are diverse and significant. Sensor errors (f:4) and hardware incompatibilities (f:3) are among the most frequently encountered issues. Other notable challenges include coding errors (f:2), algorithmic problems (f:2), and incompatibilities between sensors and motors from different brands (f:1), all of which impact the success of projects. Additionally, in the category of Educational and Resource Challenges, guide deficiencies (f:1), difficulties in obtaining necessary equipment (f:1), and a lack of adequate training (f:1) emerge as fundamental obstacles for teachers. To address these challenges, participants reported employing strategies such as careful analysis and patience (f:3), trial-and-error methods (f:4), and seeking guidance or conducting research (f:2). High-cost hardware (f:1) and the necessity of detailed planning (f:1) were also highlighted as significant cost and planning challenges in robotics projects.

In the Educational and Resource Challenges category, participants identified issues such as insufficient guides (f:1), difficulties in obtaining resources (f:1), and a lack of training (f:1). They noted challenges in securing the necessary resources for robotics coding projects and deficiencies in available instructional materials and guidance services. For instance, one participant (A-2) mentioned that the inadequacy of the provided guide for Python made the learning process more difficult.

In the Problem-Solving Strategies category, participants demonstrated approaches such as patience (f:3), trial-and-error methods (f:4), and conducting research (f:2) to overcome the challenges they encountered. They emphasized the importance of careful analysis and seeking guidance to ensure the compatibility of robotic components. One participant (A-5) noted that using sensors and motors from different brands could lead to unexpected problems.

The Cost and Planning Challenges category highlights high-cost hardware (f:1) and the need for detailed planning (f:1) as significant obstacles. Participants expressed that the cost of technological tools used in robotics coding projects posed difficulties, particularly due to budget constraints. For example, one participant (PT-3) identified the high cost of technological tools as one of the major challenges in projects.

In the Planning and Preparation context, it was emphasized that selecting the correct control algorithms and appropriately adjusting parameters are essential for ensuring that robots perform desired tasks. Working with children was particularly noted as requiring additional planning to achieve project objectives. One participant (PT-13) mentioned that achieving the desired outcomes in robotics projects involving children adds an extra layer of complexity to the instructional process.

In conclusion, the scientific and technological challenges encountered by pre-service teachers and academics during robotics coding education range from technical issues to resource availability and training deficiencies. However, participants' strategies for addressing these challenges demonstrate that robotics coding projects not only enhance technical knowledge but also develop essential skills such as problem-solving, patience, and research. This highlights that robotics coding education strengthens teachers' analytical thinking and solution-oriented approaches, making it a valuable tool for professional development.

Prospective Teachers‘ and Academicians’ Use of Scientific Reasoning (Inductive, Deductive, Deductive Induction and Abductive Reasoning) Methods in Robotic Coding Applications

Table 6 presents the data related to the use of methods from scientific reasoning types (inductive, deductive, deductive induction and abductive reasoning) by pre-service teachers and academicians in robotic coding applications.

Table 6.
Preservice teachers‘ and academicians’ use of scientific reasoning (ınduction, deduction, deductive ınduction and abductive reasoning) methods in robotic coding applications

Category	Code	Teacher ID	Frequency (f)
Types of Scientific Reasoning	Inductive Reasoning	A-1, A-2, A-3,A-4, A-5, PT-1,PT-2, PT-8, PT-10 PT-11	10
	Deductive Reasoning	A-1, A-2, A-3,A-4, A-5, PT-1, PT-2,PT-8, PT-11	9
	Abductive Reasoning	PT-4, PT-5, PT-6, PT-7	4
Solution Methods	Developing Solution Methods Suitable for Types of Scientific Reasoning	PT-1, PT-4, PT-6, PT-7	4
	Trial-and-Error Method	PT-5, PT-6, PT-7	3
	Developing a Patient and Systematic Approach	PT-6, PT-7	2

An analysis of Table 6 reveals that among the scientific reasoning methods, inductive reasoning (f:10) emerges as the most frequently used approach. Additionally, deductive reasoning (f:9) and abductive reasoning (f:10) and are also commonly employed by teachers. Participants reported adopting strategies such as developing solutions aligned with scientific reasoning methods (f:4) and utilizing trial-and-error approaches (f:3). Furthermore, cultivating a patient and systematic approach (f:2) was identified as a significant element in teachers’ problem-solving strategies.

In the context of Scientific Reasoning Methods, participants highlighted the importance of inductive, deductive, and abductive reasoning in robotics coding practices. Inductive reasoning is frequently applied by teachers as a bottom-up approach, moving from specific observations to broader generalizations. For instance, one participant (PT-6) explained that they analyzed small components in coding projects and integrated these parts to achieve the overall goal. Deductive reasoning, on the other hand, involves top-down inferences, progressing from general principles to specific conclusions. These methods were noted to enhance analytical thinking and problem-solving abilities during robotics coding activities.

Abductive reasoning stands out as a method that enables teachers to make logical inferences in situations where they have limited information. One participant (A-4) stated that this approach plays a critical role in problem-solving processes and contributes to the development of both scientific and technological skills. Abductive reasoning offers a significant advantage, particularly when unexpected challenges arise, by facilitating the creation of practical and swift solutions.

Among the Solution Strategies, the importance of developing strategies aligned with scientific reasoning methods and employing trial-and-error approaches was emphasized. Participants indicated that adopting a patient and systematic approach was effective in resolving issues encountered during robotics coding activities. One participant (PT-6) noted that analyzing and integrating parts to produce solutions significantly increased the success of robotics coding projects.

In conclusion, pre-service teachers and academics effectively utilize scientific reasoning methods in robotics coding practices. These methods support analytical thinking, creativity, and systematic approaches in problem-solving processes while simultaneously enhancing teachers' scientific and technological skills. This underscores that robotics coding education is a crucial tool for improving teachers' professional competencies.

Suggestions of Prospective Teachers and Academicians for Prospective Teachers to Acquire Problem Solving and Scientific Skills in Robotic Coding Education in Professional Development Processes

The suggestions of pre-service teachers and academicians for pre-service teachers to gain problem solving and scientific skills in their professional development processes through robotic coding education are presented in Table 7.

Table 7
Suggestions of prospective teachers and academicians for prospective teachers to acquire problem solving and scientific skills in robotic coding education in professional development processes

Category	Code	Teacher ID	Frequency (f)
Professional Development	Development of Professional Skills	A-1, A-2, A-4, PT-1, PT-5, PT-9	6
	Enhancement of Technological Knowledge and Skills	A-3, A-5, PT-2, PT-7	4

Development of Teacher Skills	Problem-Solving Skills	A-1, A-5, PT-1, PT-3, PT-4, PT-8, PT-10	7
	Creativity Skills	A-4, PT-1, PT-4, PT-5, PT-6, PT-10	6
	Digital Literacy	A-3, PT-1, PT-4, PT-8, PT-11, PT-13	6
	Collaboration and Teamwork	PT-1, PT-2, PT-4, PT-5, PT-6, PT-12	6
	Critical Thinking Skills	A-2, PT-3, PT-5, PT-7, PT-9	5
	Analytical Thinking Skills	A-4, A-5, PT-2, PT-6, PT-12	5
	Leadership Skills	A-5, PT-6	2

An analysis of Table 7 reveals that among the recommendations made by pre-service teachers and academics for developing professional skills in robotics coding education, the enhancement of professional skills (f:6) and the improvement of technological knowledge and skills (f:4) stand out. Regarding the development of teacher skills, problem-solving ability (f:7) holds the highest frequency, followed by other critical skills such as creativity (f:6), digital literacy (f:6), and collaboration and teamwork (f:6). Additionally, analytical thinking (f:5) and critical thinking (f:5) were noted as significant skills developed by teachers. Leadership ability (f:2) was mentioned less frequently. These findings indicate a strong focus on the continuous development of professional and personal skills among teachers.

In the context of Professional Development, recommendations include providing hands-on experiences, designing projects that address real-world problems, and using virtual simulations and tests. Participants stated that such practices enhance pre-service teachers’ abilities to analyze and solve technological problems. For instance, one participant (PT-5) noted that group work and collaboration processes strengthen problem-solving skills. Additionally, mentoring and feedback mechanisms were highlighted as helpful for enabling pre-service teachers to correct mistakes and develop innovative ideas. Another participant (A-1) emphasized that classroom activities involving prediction, observation, and experimentation significantly contribute to the development of scientific process skills.

For Teacher Skill Development, the importance of analytical and critical thinking skills was frequently emphasized. Participants expressed that robotics coding education enhances multi-dimensional thinking abilities and suggested that such training should be made available to all pre-service teachers. For example, one participant (PT-6) stated that robotics coding education strengthens teachers' problem-solving and thinking skills. Moreover, collaborative design and peer learning processes were mentioned as ways to help pre-service teachers explore topics of interest and improve their problem-solving abilities (A-2).

In conclusion, robotics coding education plays a critical role in the professional and personal development of pre-service teachers. The participants’ recommendations highlight the need to focus on hands-on, innovative, and collaborative learning methods to develop skills such as problem-solving, collaboration, analytical thinking, and critical thinking. These recommendations enable pre-service teachers to adapt to 21st-century educational demands and effectively utilize modern educational technologies.

Discussion / Conclusions and Suggestions

The study indicates that both pre-service teachers and academics are knowledgeable about various kits and programs related to robotics coding education, with Arduino emerging as the most recognized platform. This finding is consistent with Alimisis (2013), who argued that open-source platforms such as Arduino enhance teachers' autonomy and creativity in designing learning environments. The present study reinforces this by showing that educators who engage with such platforms develop stronger technological and pedagogical integration skills. Nevertheless, Kucuk and Sisman (2017) reported that teachers still demonstrate gaps in robotics knowledge, indicating that systematic and sustained professional development is needed. This contrast suggests that the integration of robotics education into teacher training programs remains in an evolving stage.

The research highlights that robotics coding education supports the development of critical thinking, creativity, problem-solving, and digital literacy. These results parallel the findings of Bers et al. (2014), who found that robotics fosters teachers' technological pedagogical content knowledge, and Eguchi (2014), who emphasized its effectiveness in cultivating 21st-century skills. On the other hand, Benitti (2012) noted through meta-analysis that robotics education's effects vary depending on contextual factors, such as duration and instructional design, which aligns with the present finding that meaningful outcomes are closely linked to structured implementation.

In addition, robotics coding training was found to enhance scientific process skills, including observation, hypothesis formulation, and drawing conclusions. This overlaps with Sullivan and Bers (2019), who showed that robotics-based activities increase students' engagement in scientific inquiry. Conversely, Kandlhofer and Steinbauer (2016) suggested that short-term implementations may yield limited improvements in these skills, emphasizing that the depth of exposure significantly influences outcomes. The present study therefore supports the idea that continuous and project-based robotics instruction leads to deeper scientific reasoning gains.

The participants also reported encountering technical challenges, such as sensor malfunctions and hardware incompatibilities, which echo the findings of Khanlari and Kiaie (2018). Over time, however, teachers develop adaptive strategies, as supported by Kopcha et al. (2017), who observed that such challenges decrease as teachers refine their instructional design and troubleshooting abilities. This pattern underscores that robotics education should be approached as a progressive and iterative process rather than a one-time intervention.

By focusing on how inductive, deductive, and abductive reasoning are employed during robotics coding activities, this study offers empirical insights into patterns of scientific reasoning that have not been systematically compared in prior studies.

Another noteworthy result concerns the use of scientific reasoning approaches—abductive, inductive, and deductive reasoning—during robotics activities. This aligns with Atmatzidou and Demetriadis (2016), who highlighted that robotics fosters logical and creative reasoning through real-world problem-solving. Nevertheless, Greca et al. (2020) observed that teachers often struggle to explicitly apply these reasoning modes, pointing to a need for targeted professional support. The current study expands on these findings by showing that structured guidance during robotics tasks helps educators better articulate and integrate reasoning processes into practice.

Furthermore, the study demonstrates that robotics coding education significantly contributes to the professional development of both pre-service teachers and academics by enhancing their analytical thinking, collaboration, and problem-solving capacities. This complements Alimisis (2013), who emphasized the transformative potential of robotics in teacher education. Still, as Jaipal-Jamani and Angeli (2017) noted, institutional challenges and curriculum constraints may limit widespread adoption, highlighting the need for systemic and policy-level alignment.

In conclusion, robotics coding education emerges as a powerful tool for professional and cognitive development among educators. Yet, the diversity of findings across studies suggests that its impact is context-dependent, varying with instructional design, duration, and participant engagement. Future research should therefore focus on longitudinal analyses, exploring sustained impacts across educational levels and designing models for effective curriculum integration.

Based on the findings, it is recommended that robotics coding be incorporated into teacher education programs and supported through in-service professional training. Integrating robotics across STEM disciplines can further promote 21st-century competencies and scientific process skills. Schools should also be provided with adequate infrastructure and open-source technologies. Moreover, encouraging female participation, diversifying reasoning-based approaches, and establishing platforms for teacher collaboration can broaden inclusivity and innovation. Finally, the development of hands-on, inquiry-based assessment frameworks and the involvement of families and communities are crucial for sustaining the educational and social benefits of robotics coding education.

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