International Journal of Technology in Education and Science

www.ijtes.net

# Students' Experiences with Robotics Coding Activities

**Emine Turhal [1], Oktay Bektaş [2 *], Seyide Eroğlu [3]**

[1] Erciyes University, Kayseri, Türkiye, 0000-0002-7851-3047
[2] Mathematics and Science Education Department, Faculty of Education, Erciyes University, Kayseri, Türkiye, 0000-0002-2562-2864
[3] Nuh Mehmet Baldöktü Anatolian High School, Ministry of National Education, Kayseri, Türkiye, 0000-0002-7363-6638
* Corresponding author: Oktay Bektaş (obektas@erciyes.edu.tr)

## Article Info

***Article History***

Received:
2 July 2025

Revised:
14 November 2025

Accepted:
20 December 2025

Published:
1 January 2026

***Keywords***

Secondary education
Teaching/learning strategies
Robotic coding

## Abstract

Robotic coding activities help to concretize abstract scientific concepts, develop higher-order skills such as problem-solving and critical thinking, and provide students with opportunities to observe, formulate hypotheses, design experiments, and analyze data. Therefore, this study has chosen robotic coding activities as its research area. This study aimed to determine the opinions of eighth-grade middle school students on Arduino-based robotic coding activities integrated into science topics. This study employs a case study based on a qualitative research design. This research employed criterion sampling to select participants. The study group consists of five eighth-grade students studying at a public school. Researchers preferred a 13-question semi-structured interview as a data collection tool. The interviews were conducted face-to-face and online via Zoom by the third researcher. Interview data were analyzed using content analysis. Participants were informed about the activities under the guidance of the school and their families. Participants preferred Arduino-based robotic coding activities because of their connection to daily life. Five participants indicated they wanted to learn science topics through Arduino-based robotic coding activities because it facilitated meaningful learning. Participants stated increased motivation for science topics due to Arduino activities and noted that collaborative work improved their experiences. The authors argue that family guidance requires further research. Activities should be designed considering students' differences and interests. Interactive activities within the constructivist learning paradigm are necessary for students to manage their learning processes effectively. Additionally, conflicts that arise during group work enhance students' problem-solving and critical thinking skills.

***Citation:*** Turhal, E., Bektaş, O., & Eroğlu, S. (2026). Students' experiences with robotics coding activities. *International Journal of Technology in Education and Science (IJTES), 10*(1), 105-132. https://doi.org/10.46328/ijtes.5231

## Introduction

The advancement of technology in every field has made it mandatory in education (Mishra & Koehler, 2006). Integrating technology into lessons is a key way to educate students for the future in today's classrooms. This is why the importance of technology-based activities is increasing every day, and this increase particularly promotes the use of technology in education (Garrison & Vaughan, 2008). As a result, it is necessary to increase technology integration to enhance education quality and facilitate learning (Kirkwood & Price, 2014).

The integration of technology into education can take various forms (Davies, 2011). For example, robotics coding activities have emerged as a growing educational trend in recent years. Barak and Zadok (2009) utilized Lego Mindstorms, a robotic coding activity, while Sullivan and Bers (2016) employed robotic kits. This study chose Arduino-based activities because they are one of the least commonly addressed areas of robotic coding. Arduino kits are excellent for in-class use due to their low prices, widespread availability, and user-friendliness (Zhao & Kacprzyk, 2020). To ensure the continued growth of this use, the impact of these kits needs to be determined from the students' perspective. Therefore, this study aims to determine the perceptions of eighth-grade students regarding Arduino-based robotics coding activities. As a result of students' experiences with these tools, it is expected that the positive and negative aspects of Arduino-based robotics coding activities, the challenges encountered, and the proposed solutions to these challenges will be determined.

When examining the literature on studies attempting to reveal the effects of Arduino-based activities, it is noteworthy that the majority of the studies have been conducted at the high school level (Chung & Lou, 2021; Mellis & Buechley, 2012), while there are only a limited number of studies at the middle school level (Cakir & Guven, 2019). When examining the results of studies conducted at the high school level, it has been shown that Arduino-based activities contribute to the concretization of science concepts (Chung & Lou, 2021); support an increase in interest in science classes (Steidtmann et al., 2023); and develop students' skills such as problem-solving (Mellis & Buechley, 2012). Therefore, these findings reveal that the reflections of Arduino-based activities in education have been examined at a limited qualitative level. Further research is required to explore students' reflections on Arduino-based activities. The relevant literature has primarily focused on high school-level students and has been limited to specific skills (Soypak & Eskici, 2023). The rise in these studies will enable us to comprehend better how Arduino-based activities can provide students with a more comprehensive set of skills. On the other hand, there is a need to report similar or different results at the middle school level. The main reason for this need is the student's cognitive development at this level. Middle school students benefit from learning processes based on concrete, hands-on experiences (Piaget, 1952). Therefore, the qualitative investigation of reflections on Arduino-based activities at the middle school level may enable the development of effective learning strategies that help students acquire scientific and technological skills. The literature shows that activities involving technology at an early age enhance students' problem-solving and critical-thinking skills (e.g., Becker, 2000). Additionally, examining Arduino-based activities at different levels will enable a smooth transition process between educational levels (Kondaveeti et al., 2021). The healthy progression of the educational process involves supporting students with learning strategies that are appropriate to their cognitive development levels (Phun-Pat et al., 2021). A healthy transition reduces educational challenges for students, mitigates learning losses, and facilitates a smoother progression from middle school to high school (LaRocque et al., 2011).

Integrating Arduino-based robotics coding activities into science education makes the learning process interactive and engaging for students, but it also presents various challenges (Benitti, 2012; Papadakis et al., 2021). For example, having different levels of knowledge and skills in robotics coding among students can lead to issues of unequal opportunity in lesson presentation (Papadakis et al., 2021). Additionally, the lack of infrastructure for robotics coding activities, insufficient training support for teachers, and a limited variety of materials and activities for students are also among the challenges (Benitti, 2012). Therefore, this study has addressed the issue from various angles by examining students' thoughts on the mentioned difficulties and has offered solutions.

Students generally find robotic coding activities interesting in science classes and believe that these activities make abstract scientific concepts concrete (Mubin et al., 2013). On the other hand, some students struggle with complex coding processes or technical issues, which can negatively affect their motivation (Eguchi, 2014). Therefore, the literature emphasizes that students' robotic coding experiences should be supported with appropriate learning strategies and materials at different levels to make them more effective and inclusive (Bell et al., 2009; Bers, 2008). As a result, this study has examined the effects of utilizing various materials in Arduino-based STEM activities from the students' perspective.

## Theoretical Background and Related Studies

The authors identify and emphasize Constructivism or Experiential Learning as the fundamental guiding framework. According to Constructivist Learning Theory (Piaget, 1952; Vygotsky, 1978), learning is more effective when students actively construct their understanding, particularly through hands-on experiences and social interactions. Robotics activities offer a tangible context for learners to develop, test, and refine their scientific ideas. In addition, Experiential Learning Theory (Kolb, 1984) supports the idea that knowledge is created through the transformation of experience. Robotics projects involving problem-solving, trial-and-error, and applying abstract scientific concepts align closely with this learning model. In parallel, drawing on constructivism and experiential learning, the 21st Century Skills Framework emphasizes the importance of competencies such as collaboration, communication, critical thinking, and creativity. Arduino-based robotics coding activities grounded in constructivism and experiential learning engage students across all these areas, fostering teamwork, decision-making, digital literacy, and innovation (Ananiadou & Claro, 2009). When constructivism and experiential learning are considered together, Arduino-based robotics coding activities support meaningful learning because students relate abstract concepts to real-world applications. It develops higher-order thinking skills. It strengthens self-regulation and reflection skills, enabling students to monitor and evaluate their own learning processes. It increases motivation. Therefore, students experience intrinsic motivation because they can tangibly see and work with their own products (Ausubel, 1968; Kolb, 1984; Piaget, 1972; Vygotsky, 1978).

Previous studies have demonstrated the positive impact of robotics and coding activities on student motivation, science achievement, and 21st-century skills (Barak & Zadok, 2009; Chung & Lou, 2021; Sullivan & Bers, 2016). Most of this work has focused on high school students, often using Lego Mindstorm or pre-assembled kits (Benitti, 2012; Soypak & Eskici, 2023). Few studies have examined the use of Arduino at the middle school level, particularly in the context of science courses. One notable exception is Cakir and Guven (2019), who highlighted the potential of Arduino activities to develop engineering design skills in early adolescents. However, a detailed understanding of middle school students' experiences with Arduino-based science projects remains limited.

This study aims to build upon and expand the existing literature by examining the experiences of eighth-grade students with Arduino-based science learning activities. In doing so, it seeks not only to confirm previous findings, such as increased engagement and motivation, but also to uncover unexpected challenges and nuances specific to younger learners and the use of Arduino technology in real science classroom settings.

**Study Contribution and Significance**

Evaluating every aspect of the Arduino-based activity process from the students' perspectives is crucial in providing feedback. Students' difficulties, motivations, and learning processes can be better understood with this input (Hattie & Timperley, 2007). When feedback is provided, teachers can more effectively adapt their learning strategies to meet the needs of students (Black & Wiliam, 1998). Additionally, it becomes possible for students to participate more effectively in their learning processes and to monitor their progress (Shute, 2008). In this way, the learning process is continuously improved, and as students gain skills, their interest in the lessons increases, and their motivation to learn strengthens (Hattie, 2009).

Collecting student feedback on robotic coding activities, assessing their influence on the learning process, and enhancing educational methodologies are crucial endeavors. The learning process encompasses stages in which students acquire knowledge, develop skills, and apply this knowledge (Bransford et al., 2000). Improving learning processes involves managing student interactions to promote efficiency and effectiveness, while fostering motivation and meaningful involvement. Developing methods that align with students' needs and interests in learning processes is crucial for fostering a deeper connection with learning (Ryan & Deci, 2000).

Arduino-based robotic activities are an effective educational resource that promotes theoretical knowledge and practical abilities in technology and engineering (Chou, 2018). A feedback process based on students' opinions is necessary for this process to achieve its goals and become more efficient, motivating, and meaningful (Barradas et al., 2024). Student feedback serves as a guide for organizing learning, acquiring desired knowledge and skills, and structuring the stages of activities. Organizing the learning process, effectively selecting learning materials, and adapting them to student levels can support students in deriving maximum benefit from their lessons (Dunlosky, 2013). Additionally, through student feedback, the difficulties students encounter in the flow of information can be identified, and based on this, learning methods can be reorganized to address these challenges. Given that students learn at varying rates, implementing a method that considers their perspectives might improve the effectiveness of the learning process (Dunlosky, 2013). Data obtained from student opinions enable the development of new learning models centered on Arduino-based robotic coding activities (Vega & Cañas, 2019). Furthermore, the feedback facilitates the identification of methods to enhance the effectiveness, motivation, and meaning of learning. For example, suppose a student sees their robotics coding project as a solution to a real-world problem. In that case, it increases their excitement, desire, and motivation, allowing them to explore other areas of interest. Additionally, it supports students in collaborating with their peers through group work and learning by facilitating interaction among them. Therefore, the feedback obtained from the students' opinions in this study will highlight how students and teachers can follow the knowledge, skills, and activity processes targeted by Arduino-based robotic coding activities, and emphasize the role and importance of this feedback in the learning process.

The literature emphasizes that student feedback on innovative practices in the learning process provides guiding information about the effectiveness of these practices (Kampylis et al., 2013). Feedback facilitates a deeper understanding of each other's strengths and limitations between teachers and students. Additionally, feedback enables students to adjust their learning strategies according to their individual needs. The learning process is thus guided more effectively, enabling students to address challenges, surmount motivational barriers, and improve their learning outcomes (Hsu & Ching, 2013). Additionally, activities can be more inclusive with student feedback, which can increase student participation (Papadakis et al., 2021). Consequently, collecting student feedback is essential for the sustainability and effective execution of innovative learning strategies.

While previous studies have examined the role of robotics and coding in science education, most of this research has focused on high school students or used commercially available kits such as LEGO Mindstorms. This study contributes to the existing literature by offering a rare perspective from eighth-grade students, specifically on Arduino-based activities integrated into real science classrooms. The study does not aim to replicate prior research. Instead, it explores students' direct experiences, highlighting unique insights such as how hands-on activities shape their career awareness, group dynamics, and meaningful learning.

Moreover, the study addresses a notable gap in middle school science education by demonstrating the potential of low-cost, open-source technologies, such as Arduino, to enhance motivation and learning, particularly in underrepresented educational contexts. These findings provide practical implications for curriculum designers and teachers, encouraging the inclusion of robotics-based project learning even at earlier educational levels. The study also reveals specific implementation challenges and student-suggested improvements, thus contributing new, learner-centered recommendations.

In doing so, the study contributes to the literature in four key ways:

1. Focus on a rarely studied age group (eighth-grade learners), addressing a documented gap in robotics education research.
2. Use of open-source Arduino platforms rather than commercial kits, highlighting cost-effective, scalable models for STEM education.
3. Collection of rich qualitative data that captures cognitive outcomes and learning's social, emotional, and motivational dimensions.
4. Student-centered recommendations that can inform curriculum development and classroom implementation strategies.

These contributions are particularly relevant for teachers and policymakers seeking to enhance science learning with technology-based pedagogies that are inclusive, scalable, and responsive to students' voices. The study offers insights into the benefits and limitations of integrating Arduino into middle school science, providing a foundation for future work on optimizing robotics instruction for younger learners.

### The Purpose of the Study

This study aimed to investigate the perspectives of eighth-grade middle school students on Arduino-based robotic coding activities integrated into science curricula. This study sought to obtain comprehensive insights via interviews and to augment the scant research on the impact of Arduino-based activities on the learning process at the middle and primary school levels (Chou, 2018), which are primarily concentrated on the high school level (Chung & Lou, 2021) and restricted to skills (Marín-Marín et al., 2024) in the existing literature.

The activities were thoroughly analyzed by collecting student feedback on the nature of the activities, procedural aspects, facilitator attributes, contributions to assessment and evaluation, and project preparation related to Arduino-based science activities. The insights derived from student perspectives on the advantages and disadvantages of Arduino-based activities, the challenges faced during implementation, and the suggested remedies aim to assist researchers and teachers in designing analogous lessons in activity planning, as well as program developers in creating science curricula. The inquiry "What are the experiences of eighth-grade students concerning Arduino-based robotic coding activities?" was formulated.

## Method

### Research Design

This study employs a case study based on a qualitative research design. A case study is a research methodology that analyzes one or more examples comprehensively "within a real-life context" (Yin, 2018). This study employed a case study to gain a deeper understanding of students' thoughts, feelings, and observations during robotic coding activities.

This study employed a case study design, despite the restricted sample size, as it facilitates a comprehensive and contextual analysis of a particular occurrence or process (Yin, 2018). The primary objective of qualitative research methodologies is not to achieve generalization, but to cultivate a nuanced, in-depth, and comprehensive understanding of the research subject (Merriam, 2009). Consequently, a limited sample does not diminish the study's validity; rather, it facilitates the generation of rich data through an in-depth examination of participants' experiences. Case studies are methodologies that aim to address "how" and "why" inquiries, wherein the researcher investigates the phenomena within its authentic setting (Yin, 2018). This design is considered the most suitable for context-sensitive research, which aims to conduct a detailed examination of the experiences of a limited number of participants. Furthermore, in studies with limited samples, the case study design enhances the reliability and validity of the research by utilizing a varied array of qualitative data and an epistemological framework that prioritizes depth, meaning, and interpretation over quantitative generalization (Creswell & Poth, 2018).

**Study Group**

This research employed criterion sampling, a type of purposive sampling, when selecting participants. The researcher may create the criterion from scratch or use an existing set of criteria as a starting point (Marshall & Rossman, 2014). The study group was selected from students with a background in robotic coding who had participated in robotic coding courses during the study period. The study group consists of five eighth-grade students studying at a public school in the Central Anatolia Region during the 2023-2024 academic year. Two participants are female (P3 and P4), and three are male. Table 1 shows the code names and genders of the students participating in the research. The limited participant count constrains the diversity and representativeness of students' perspectives on Arduino-based robotics coding activities. The qualitative data gathered from five students enhanced comprehension of the investigated phenomenon but restricted the transferability of the findings to other groups (Creswell & Poth, 2018).

**Data Collection Tool**

The study employed a semi-structured interview with 13 questions formulated by the researchers as a data-gathering instrument. To this end, research on robotic coding education has been reviewed (e.g., Lo, 2024; Yılmaz, 2021). An interview is a data collection instrument that involves posing and responding to questions for a specific, serious objective (Merriam & Tisdel, 2015). To evaluate the effectiveness, clarity, and applicability of the interview form developed by the researchers, we have sent it to two experts in science education for their feedback. Table 1 shows a sample of the responses.

Table 1. Changes Implemented when Formulating Questions for an Interview

| Question no | Researcher | Expert 1 | Expert 2 |
|---|---|---|---|
| 1 | What are your views on the necessity and importance of teaching robotic coding? | What do you think about robotic coding? Please explain. | - |
| 5 | Have robotics coding activities made a difference in your interest in science classes? Why? | Have robotics coding activities made a difference in your interest in science classes? Why? | Has working on Arduino-supported activities changed your perspective on science classes? Why? Please explain. |
| 9 | What daily life problems can be addressed through Arduino-supported robotic coding? Kindly explain. | - | Starting with question 5, it moves on to question 9. |

The feedback illustrated in the examples above has resulted in a reorganization of the questions. The definitive version of the semi-structured interview form has been presented. Table 2 presents the sample questions included in the semi-structured interview form.

Table 2. The Purpose of the Interview Questions and Example Questions

| Question Number | Purpose | Sample questions |
|---|---|---|
| 2 | Determining students' expectations for robotic coding activities | Which activity did you like the most during the activities? Why? |
| 11 | To identify students' expectations regarding new things through robotic coding. | Do you think that Arduino-supported robotic coding activities will contribute to your desire to prepare Arduino-supported scientific projects in the future? Why? |
| 12 | To determine students' perspectives on robotic coding activities in terms of career choice. | Did Arduino-based robotic coding activities influence your choice of profession? Why? Please explain. |

**Data Collection Process**

The authors obtained the approval document, numbered 292, from the Social Sciences Ethics Committee. The student's parents were informed in writing, and their consent was obtained. The interviews were conducted face-to-face and online via Zoom by the third researcher. The timing of the interviews was initially established with the students, and on the specified day, the interviews were carried out individually. Before the interviews, which lasted 20-30 minutes with each student, conversations were held to help relax the students. The interviews were recorded with the participants' consent. The classroom where the activities were conducted was suitable for group work. Although it was a classroom with fixed desks and stools, it had an atmosphere that allowed activities to be conducted efficiently. With the center of the classroom left empty, there were fixed tables on one side and two round tables where groups worked on the other side. Additionally, a small section at the back of the classroom, accessible to students, was designated for storing the necessary tools and materials. The activities were conducted by two different teachers for two different groups, one with eight participants and the other with six. Since the tables were fixed to the wall, there was an environment that allowed the teacher to move between the groups and manage the activity efficiently.

**Data Analysis**

Interview data were analyzed using content analysis (Erlingsson & Brysiewicz, 2017). Data analysis employed the categorical aggregation technique to identify patterns in the data and then present those patterns to the reader using predefined codes, themes, and categories. Initially, the first researcher entered the interview data into a computer for transcription. Secondly, the researchers created separate codes based on the participants' responses to the questions. The second and third researchers made reductions to the codes. Based on the final codes, categories were created and combined to reach themes. After reaching a consensus among the three researchers and relating the data to the data from other studies in the literature, the analysis process was concluded (Patton, 2015). The data analysis process, as described by Wellington (2015, p. 267), was followed precisely and is presented in Figure 1.

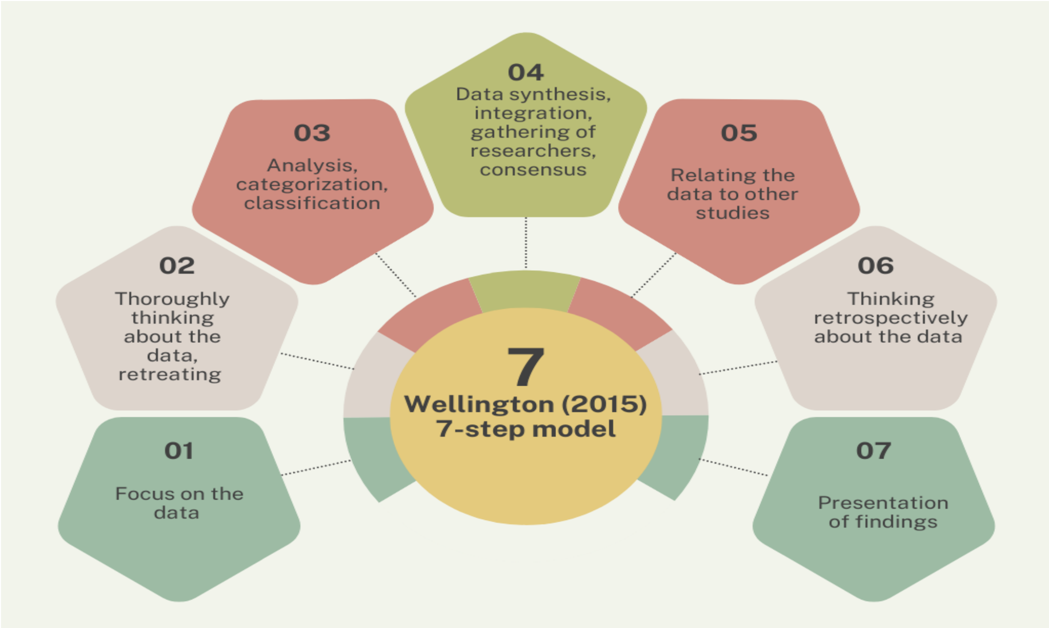


Figure 1. Data Analysis Process (Wellington, 2015, p. 267)

The development of the "Ways to Obtain Activity Information" category and codes, as outlined by Wellington (2015), proceeded as follows. The authors initially focused on the questions posed to participants to establish the category name and carefully analyzed the responses they provided. Later, consensus and consolidation were reached on the codes created by the researchers (school, family, teacher guidance, and individual orientation). Later, in studies related to robotic coding, the participants' perceptions of their education were examined, and similar code names were attempted to be assigned to these studies. In the findings section, the codes under the created category headings were presented through direct quotations. Figure 2 visualizes this example of the analysis process.

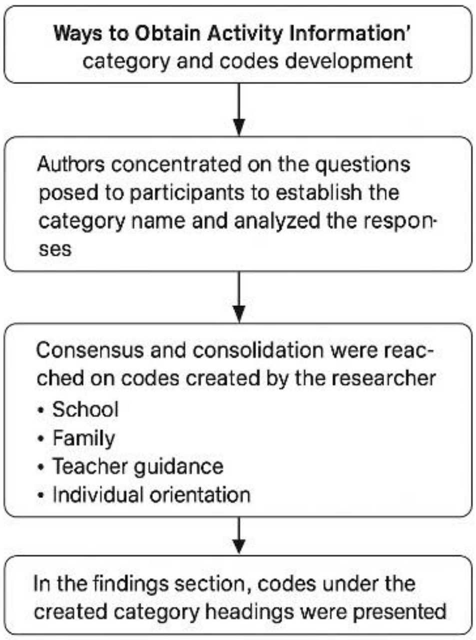


Figure 2. Example of the Analysis Process

**Validity and Reliability**

The researchers initially presented the interview form to experts for evaluation to enhance internal validity. Secondly, each question and the participants' responses were repeated during the interviews. After the confirmations, they were asked if they wanted to add anything, and any misunderstandings were corrected if present. Thirdly, prolonged interaction was ensured, and before the interview began, participants were informed about the interview content and questions. An environment was attempted to be created where the participant could feel comfortable for a natural conversation. The duration of the interviews averaged 30 to 35 minutes. Fourthly, the participants' responses to the questions were presented in the findings section as direct quotations. Due to the use of a single data collection tool, which limited the credibility of the data, data triangulation was not possible.

All study parts have been described in great detail to ensure external validity. The study participants were chosen based on the research objectives. The research indicates that a study's failure to achieve data saturation can constrain its external validity (Creswell, 2009). This study posited that data saturation was achieved with the involvement of five participants.

To ensure internal reliability, the conversations were recorded with a recording device during the interview after obtaining permission from the participants. Consequently, the authors have implemented measures to mitigate data loss and have sought to maintain alignment between the participants' statements and the researcher's documentation. Secondly, the participants' responses to the questions were presented directly in the findings section without interpretation. Thirdly, the researchers ensured the consistency of the analysis by reaching a consensus on codes, categories, and themes during the analysis process.

The findings have been appropriately discussed in the conclusion to ensure external reliability. An expert in scientific education has examined the findings and conclusion-discussion portions of the research. The expert has confirmed that the relevant sections are consistent.

## Results

The present research findings effectively address the research question. The authors have developed suitable titles for each category. Table 3 presents the codes, categories, and themes.

Table 3. Theme and Categories for Robotic Coding Education

| Theme | Categories |
|---|---|
| Robotic Coding Education | Ways to Obtain Activity Information |
| | Rationale for Selecting Activities |
| | Preferred Activities |
| | Instruments They Like to Use |
| | The Rationale for Favoring the Vehicles They Prefer Utilizing |

| Theme | Categories |
|---|---|
| | Level of Interest in Science Lessons |
| | Duration of the Activity |
| | Reasons for Learning Science Topics with Arduino |
| | Benefits for Daily Life Problems |
| | Events that Occurred During the Group Collaboration |
| | Adequacy in Terms of Evaluation |
| | Obstacles Encountered During the Activity Procedure |
| | Contribution to Writing Scientific Projects |
| | The Influence on Career Awareness |
| | Suggestions |

**Ways To Obtain Activity Information**

Table 4 indicates that four students were apprised of the activities via the school's direction. P3 stated: *"I commenced engaging in activities during the initial semester of seventh grade. My colleagues and I developed a TUBITAK project. We engaged in robotic coding, which is how I became acquainted with him"*.

Table 4. Participant Codes related to the Category of Ways to Obtain Activity Information

| Participants | Codes |
|---|---|
| P1, P3, P4, P5 | School guidance |
| P2 | Family's guidance |

Furthermore, P2 stated that he received information about the incidents from his family's counsel. P2 stated: *"My brother-in-law ran a company called Teknotest. I attended that school in eighth grade. I have some computer abilities, so I am enrolled here."*

**The Rationale for Selecting Activities**

Table 5 indicates that three students favored Arduino-based robotic coding exercises due to their relevance to daily life.

Table 5. Participant Codes related to the Category of the Rationale for Selecting Activities

| Participants | Codes |
|---|---|
| P1, P3, P4 | Having a contribution to daily life |
| P1, P2, P5 | Given that it is a novel subject |
| P2, P3, P5 | Appealing to your area of interest |
| P1, P3 | Being instructive |
| P3 | Being fun |

For instance, P4 expressed, *"I advocate for emphasizing subjects that will benefit individuals in their daily lives."* Secondly, three people (P1, P2, and P5) stated that the novelty of robotic coding jobs appealed to them. P5 elucidated: *“If it pertains to a novel subject that captivates my interest or piques my curiosity, I want to engage with it. If the topic has been previously addressed, we can forgo it.”*

P1 and P3 preferred the activities due to their educational value. P1 stated: *“The planetary project necessitated significant coding work. Furthermore, it was a commendable project as it enhanced individuals' learning.”*

**The Preferred Activities**

Four participants preferred the "attention; there is a gas leak" activity. P4 stated: *“I liked the gas sensors because they were both instrumental and a nice activity. I liked it the most.”*

Table 6. Participant Codes related to the Categories of Preferred Activities

| Participants | Codes |
|---|---|
| P1, P2, P3, P4 | Attention: There is a gas leak. |
| P1, P3, P5 | Plants have a tongue. |
| P1, P2, P3 | Super universe |

Three attendees favored the activities concerning the tongue of plants (Table 6). P1 contemplated: *“The tongue of plants was among my foremost interests. I encountered a device that gauges the water level of plants, as I had observed it multiple times online. I was intrigued by the circuit but had not researched it, so it was pleasant to discover it.”*

**The Instruments They Like to Use**

Four students have stated that they enjoy using Arduino materials. P4 stated: *“I enjoy using Arduino cables.”* Table 7 indicates that three participants enjoyed using the software tools. P2 stated: *“I enjoy using coding software.”*

Table 7. Participant Codes related to the Category of Instruments They Like to Use

| Participants | Codes |
|---|---|
| P1, P2, P3, P4 | Arduino materials |
| P1, P3, P5 | Coding software |

**The Rationale for Favoring the Vehicles They Prefer to Utilize**

As seen in Table 8, four participants stated that they liked the tools they enjoyed using the most because they found them fascinating. For example, P5 emphasized: *“I liked the gas sensor the most; it was a sensor I used myself. I had used the pH meter before, but it caught my interest. The planet weight activity was also something I* *had never done before, and it caught my attention quite a bit."*

Table 8. Participants' Codes for the Category of the Rationale for Favoring the Vehicles They Prefer to Utilize

| **Participants** | **Codes** |
|---|---|
| P1, P2, P4, P5 | Having an area of interest |
| P1, P3 | Being functional |
| P5 | The increase in the feeling of curiosity |
| P3 | Increasing creativity |

P3 claimed that she preferred the tools because they enhance creativity. She explained: *"The coding part of the job attracts me more because it appeals to my imagination. Coding can be thought of as creating a new entity."*

**Interest Level in Science Class**

Table 9 shows that three participants increased their interest in science classes through Arduino-based robotic coding activities. Regarding this topic, P5 said: *"These activity types played a significant role in my liking for science classes. We could not visualize things like planetary weights or biology-related topics before; it helped me to imagine them in my mind...."*

Table 9. Participant Codes related to the Interest Level in Science Subjects

| **Participants** | **Codes** |
|---|---|
| P3, P4, P5 | It increased. |
| P1, P2 | It has not changed. |

P1 and P2, on the other hand, stated that Arduino-based robotics coding activities did not change their interest in science classes. For example, P1 stated: *"It can facilitate my learning, but since I only deal with that circuit, there will not be any science-related change for me. It is not just about utilizing the circuit; the instruction on the circuit holds significant value."*

**Activity Duration**

Table 10 indicates that three students found the allocated time for the activities to be sufficient. Regarding this issue, P1 emphasized: *"The time allocated for the three activities was sufficient."*

Table 10. Participant Codes related to The Activity Duration Category

| **Participants** | **Codes** |
|---|---|
| P1, P4, P5 | Sufficient |
| P2, P3 | Insufficient |

Conversely, P3 is one of the two participants who expressed that the activity's allotment of time was inadequate.

P3 stated: *"It was not enough. These activities need to be held with more people. It could be a weekly class. Considering that we are in the technology age and schools are preparing us for the future, this system needs to be more intensive, and the time allocated should be greater."*

**The Reasons for Learning Science Topics with Arduino**

Table 11 shows that five participants indicated they wanted to learn science topics through Arduino-based robotic coding activities because it facilitated meaningful learning. P1 stated: *"We hardly forget what we learn, which I think is important."* Secondly, three participants mentioned that they wanted to learn science topics through Arduino-based activities because they found them fascinating. For example, P3 explained: *"In science class, our attention can inevitably wander, but in such activities, it is almost impossible for our attention to drift... I think it can enhance my performance based on my interest."*

Table 11. Participant Codes Related to the Category of Reasons for Learning Science Topics with Arduino

| Participants | Codes |
|---|---|
| P1, P2, P3, P4, P5 | Ensuring meaningful learning |
| P2, P3, P4 | Being interesting |
| P3, P5 | Providing the opportunity for the integration of science and technology |
| P4 | Ensuring learning through experience |
| P2 | Increasing awareness of career development |

P4, on the other hand, stated that they wanted to learn science classes through Arduino-based robotic coding activities because it facilitates learning through experience. P4 emphasized: *"We experience it ourselves; learning something by trying it out is already the best and most effective way of learning, in my opinion...."* Finally, P2 wanted to learn science topics with Arduino because it increases career awareness, stating: *"...someone who can make a career choice. He can organize his future life, in my opinion."*

**Benefits for Daily Life Problems**

Table 12 indicates the participant codes related to the benefits of Arduino-based robotic coding activities for daily life problems. Five participants stated that these activities benefit everyday problems because they save lives. P4 mentioned: *"The gas sensor, for example, to warn people in case of a fire... let us think of a large venue, let us say a fire broke out there; I think it is a significant development for warning people and ensuring their safety."*

Table 12. Participant Codes for the Category of Benefits to Daily Life Problems

| Participants | Codes |
|---|---|
| P1, P2, P3, P4, P5 | Life-saving |
| P2, P3, P4, P5 | Serving daily needs |

Additionally, four participants mentioned that they wanted to learn these activities because they serve daily needs.

P3 said: *"…the activities we do can be used as solutions in our daily lives. For example, we have a vineyard house where we use a stove. Here, the gas sensor allows us to detect the toxic gases emitted by the stove."*

**Events that Occurred During the Group Collaboration**

Table 13 presents the participant codes related to the category of experiences in group work. Four participants indicated that group work contributed to peer learning during Arduino-based robotic coding activities. P1 said: *"It was efficient because people could understand the work* (principles) *and logic of those next to them and maybe learn more efficiently."* Secondly, P5 thought that Arduino-based robotics coding activities should be conducted as individual rather than group work. P5 mentioned: *"Within the group, some people do not participate, while others are very active. I think some people learn less... it could have been more beneficial if it were individual, with more time and productivity allocated to each person."*

Table 13. Participant Codes related to the Category of Experiences in Group Work

| **Participants** | **Codes** |
|---|---|
| P1, P2, P3, P4 | Being peer learning |
| P5 | Conducting individual work |
| P3 | Experiencing a clash of ideas |
| P1 | Working in harmony |

P3, on the other hand, stated that conflicts of ideas can arise during group work, but these conflicts can also contribute to the learning process. P3 spoke: *"In group work, there can sometimes be conflicts of ideas. There may be discussions, but since discussions advance brain development, I think this is not a minus but rather a plus. I think it is more memorable."*

**Adequacy in terms of Evaluation**

Table 14 presents the participant codes related to teachers' competencies in assessment. Three participants stated that the teachers did not evaluate students during the activities. Students rated these teachers as inadequate in their evaluations. For example, P1: *"Yes, there was no evaluation. Watching the circuits work taught us science, but there was no questioning with questions, etc."*

Table 14. Participant Codes related to the Competence Category in terms of Evaluation

| **Participants** | **Codes** |
|---|---|
| P1, P2, P3 | Insufficient |
| P4, P5 | Sufficient |

On the other hand, two participants stated that teachers conducted assessments during the activities and found them to be sufficient. For example, *P5: "It tested our learning because we went through a question-and-answer format during the activities…Yes, it was done by asking individually what this is, and what that is, and the* *evaluation of what the sensors and the materials mean and how they are used was conducted."*

**Obstacles Encountered during the Activity Procedure**

Table 15 indicates that only P2 experienced difficulties during the implementation process of Arduino-based robotic coding activities, primarily due to a lack of preparedness and technical problems. P2: *"We had our materials, but they did not work; we encountered a technical problem...I did not know what to do, and because I seemed like I did not know, that might have been a bit of a difficulty."* The other four participants stated that they did not experience any difficulties.

Table 15. Participant Codes related to the Category of Difficulties Experienced during the Implementation Process

| **Participants** | **Codes** |
|---|---|
| P2 | Preparedness<br>Technical problems |

**Contribution to Writing Scientific Projects**

Table 16 displays the participants' views on the contribution category to scientific project writing. Four participants stated that it contributes to writing scientific projects because it provides a theoretical foundation. For example, P4 stated: *"I think it will contribute to project writing; after all, we learned to do something by combining a few circuit components. This could indicate that we can create something by combining more circuit components."*

Table 16. Participant Codes related to the Category of Contribution to Scientific Project Writing

| **Participants** | **Codes** |
|---|---|
| P1, P2, P3, P5 | Providing a theoretical foundation |
| P1, P5 | Being applicable in daily life |
| P4 | Providing experience |
| P3 | Building self-confidence |

The participants stated that the activities contributed to the writing of scientific projects, as they provided valuable experience and self-confidence. The opinions of P4 and P3 on the subject are provided below, respectively:

> *"...yes, professor, it will happen because it was a preliminary experience, let me put it that way. We saw what we would do and how we would do it... We learned how to distribute tasks in a team on any project. We experienced learning where individuals are better first and distributing tasks accordingly."* (P4)

> *"It created a confidence that we could do it. For example, the gas sensor activity initially did not work. Because we had misconnected some wires, we had to remove and reconnect all of them later. This also*

*boosted our self-confidence because it showed us that these mistakes could be corrected again."* (P3)

**The Influence on Career Awareness**

As shown in Table 17, the participants reported that Arduino-based robotic coding activities had a positive impact on their career awareness. For example, P3 said, " It *contributed to my career choice because it helped me understand myself. It showed me which fields interest me and which areas I could succeed in. This, of course, has an impact on my career choice."*

Table 17. Participant Codes related to the Category of Influence on Career Awareness

| Participants | Codes |
|---|---|
| All participants | Positive |

**Suggestions**

Table 18 shows the participants' suggestions regarding Arduino-based robotic coding activities. Four participants suggested that the training process related to the activities should be planned. For example, P4 said, *"If we think about what we do every week, the teacher could explain the topic one week and have us work on that topic the following week. If he always leaves it to us, it would not be very nice because our knowledge has its limits. I think a teacher should teach us. He should also leave it to us, but he needs to balance both equally."*

Table 18. Participant Codes related to the Recommendations Category

| Participants | Codes |
|---|---|
| P2, P3, P4, P5 | The education process should be planned. |
| P3 | Integration into the lesson should be ensured.<br>Activities should also be held in the university environment. |
| P1 | Ready-made codes should not be used. |

P1 suggested not using pre-written code. P1's thoughts on this matter have been explored in the dialogue below:

*P1: Being active in the algorithm written for the circuit could have been helpful. We just ended up creating a circuit there.*

*Researcher-3: Shouldn't we have avoided using ready-made codes?*

*P1: Yes, we used ready-made codes, probably because the codes were more complex. Projects can be further simplified, and an exchange of information can be facilitated in the algorithm.*
*Researcher-3: You think we could have learned something if you had created the code, right?*

*P1: Yes.*

## Discussion and Conclusion

The authors concluded that students became aware of robotic coding activities due to the support of the school and family members. This situation illustrates the substantial impact of school and family support on students' engagement in scientific activities (Ragusa & Leung, 2023). The literature suggests that teachers play a crucial role in promoting activities and encouraging students (Nugent, 2010). Nugent et al. (2010) assert that robotics coding activities implemented in schools are more effective in fostering student engagement and enhancing interest. This study aligns with existing literature findings on this matter. The authors of this study argue that school-based initiatives are essential for the widespread implementation of robotic coding education. The school's proactive engagement in robotic coding activities, where the research was conducted, has proven effective. The authors assert that schools must provide appropriate environments for robotic coding activities. The authors assert that schools with suitable environments will have a significant influence on educational policies related to Arduino-based robotic coding activities. Conversely, research concerning parental guidance in robotic coding activities is underrepresented in the literature (Relkin et al., 2020). Limited family support may be associated with family dynamics and the technological awareness of students within the home environment (Tosun & Mihci, 2020). The authors contend that family guidance warrants further investigation.

This research concludes that students enjoy robotic coding activities due to their relevance to daily life, novelty, educational value, alignment with their interests, and perceived enjoyment. This scenario illustrates that students select activities that fulfill their academic requirements while resonating with their interests. The literature suggests that students prefer activities with significant real-life relevance and educational value (Samperio Sanchez, 2017). Eguchi (2014) asserted that robotic coding education allows students to address real-world challenges, enhancing their motivation. Consequently, the authors emphasize the importance of selecting activities that relate to real-life scenarios for science educators seeking to develop Arduino-based robotic coding tasks. The authors contend that activities must be designed considering students’ variations and interests.

The study determined that students favor Arduino-based robotic coding activities due to their enjoyment. The research has accorded less focus to this rationale for student preference (Gokce et al., 2024). Consequently, the authors contend that engaging activities within the constructivist learning paradigm are essential for students to effectively oversee their learning processes. Including factors that enhance students’ enjoyment of activities facilitates the constructivist learning process (Machumu et al., 2018). Consequently, the authors underscore the necessity of considering the entertainment aspect to enhance students’ engagement in the activities. Integrating components that enhance students’ engagement in creating Arduino-based instructional content will substantially enrich the literature.

The study concluded that students favored all three activities that generated solutions to tangible, real-world issues. Kafai and Burke (2015) indicated that students preferred activities that generated solutions to real-world problems. Literature suggests that students frequently engage in activities that offer practical benefits (Roblyer & Edwards, 2005). Students perceive robotic coding activities relevant to daily life as more engaging (Gokce et al., 2024). These preferences indicate that students may have been affected by their surroundings. The gas leak detection activity, designed for emergencies such as fires, demonstrates students' initiative to address potential environmental challenges. The authors assert that robotic coding activities effectively enhance problem-solving and life skills.

The research indicates that students appreciated using Arduino materials and software tools in robotic coding activities. Research indicates that Arduino is favored by students engaged in robotic coding activities and that software tools play a crucial role in enhancing technical skills (Benitti, 2012; Lee, 2020). Students prefer Arduino materials due to their capacity for direct interaction with technology (Kirikkaya & Basaran, 2019). Conversely, students favor software tools because they improve their ability to solidify abstract concepts and support learning (Winne, 2006). The authors contend that Arduino and software tools effectively develop technical skills and enhance students' enjoyment of the learning process.

Students appreciated the tools for their practicality, aesthetic appeal, and characteristics that foster innovation. The research indicates a scarcity of evidence suggesting that students favor tools that enhance creativity and engagement (Haymana & Özalp, 2020). The survey participants asserted that they utilized technologies that augmented their creativity and were stimulating. This outcome suggests that the design of tools used in robotic coding education should incorporate additional elements that foster innovation.

The authors concluded that Arduino-based robotic coding activities increase students' interest in science subjects. This result is consistent with the study by Atmatzidou and Demetriadis (2016). The authors believe that students' interest in science classes may increase when they actively participate in the learning process, which aligns with the constructivist paradigm's emphasis on active learning. From this perspective, this study is important because it advocates for the use of Arduino-based robotic coding activities to enhance students' interest in science, enabling them to engage in active learning through hands-on experience.

The authors have determined that students consider the activity time adequate. The literature suggests that the designated time for robotic coding activities is typically sufficient; however, some students express concerns about the duration due to individual variations (Nam et al., 2019). The sufficiency of the activity durations suggests that the program design was executed correctly (Sullivan & Bers, 2016). The authors contend that the duration of meticulously designed Arduino-based robotic coding education programs will enhance students' learning outcomes. The authors of this study argue that students should be allocated additional time for complex and comprehensive tasks.

This study has correlated students' enthusiasm for science themes with the capacity of Arduino-based robotic coding activities to facilitate meaningful learning, foster engagement, create interdisciplinary linkages, and prepare for future endeavors. The pertinent literature indicates that Arduino-based activities facilitate a more tangible and comprehensible understanding of scientific concepts for students (Barak & Zadok, 2009; Kim et al., 2020). The authors of this study argue that incorporating Arduino-based robotic coding activities into science classes can facilitate meaningful learning, as these activities align with the constructivist learning paradigm. Furthermore, Arduino-based robotic coding activities should be incorporated into the educational process as they facilitate transdisciplinary studies (Sarı et al., 2022). The capacity of students to link science and technology, together with their proficiency in using technology in everyday life, underscores the significance of these activities in their scientific education. Furthermore, Arduino-based robotic coding activities enhance experiential learning and promote the comprehension of scientific subjects (Koray & Duman, 2022). Consequently, the authors of this study contend that Arduino-based activities have to be incorporated into the science learning process for the reasons stated above.

Students deemed robotic coding exercises beneficial as they generated solutions to practical issues. Students have consistently highlighted the potential of gas sensors to save lives and meet daily needs. The literature suggests that linking robotic coding assignments to real-life challenges can enhance students' interest and motivation (Ragusa & Leung, 2023). Our research aligns with the existing literature on this matter. The results indicate that pupils are developing an awareness of surrounding issues and enhancing their problem-solving capabilities. Consequently, the authors argue that Arduino-based robotic coding exercises that address real-world issues enhance students' learning experiences.

Students participated in peer learning and collaborated effectively during Arduino-based robotic coding tasks. Conversely, ideological disagreements have arisen among students during collaborative tasks. Research indicates that collaborative efforts in robotic coding tasks improve students' social and teamwork abilities. (Yuen et al., 2014). The present investigation is consistent with the existing literature on this matter. The students in this study saw concept clashes as a beneficial learning experience. Consequently, the authors assert that dialogues informed by diverse viewpoints augment students' critical thinking abilities. The authors assert that disagreements during group work enhance students' problem-solving and critical thinking abilities, enriching the literature with a more thorough comprehension of group dynamics.

Some students indicated that teachers were deficient in their evaluative methods throughout activities, while others asserted that individual assessments were satisfactory. The varying impressions in the evaluation process suggest that students engage with their learning experiences from distinct viewpoints. The varying opinions may stem from professors' assessment methodologies and the caliber of student feedback. Sure, students may have encountered the evaluation systems more beneficially. The literature emphasizes the importance of a structured evaluation procedure in robotic coding activities and underscores the need for teacher training in assessment within robotic coding education (Alimisis, 2013; Lee & Park, 2019). Consequently, the authors of this study corroborate the literature in these respects. The authors assert that evaluation processes for Arduino-based robotic coding instruction should be consistent and comprehensive.

Students faced no challenges during the activity procedure; however, some students experienced unpreparedness and technical issues. This scenario suggests that students' technological resources and personal learning proficiencies are critical to the activity's effectiveness. Technical issues and insufficient preparedness are commonly cited obstacles in robotic coding endeavors, as noted in the literature. Furthermore, it is evident that when a conducive learning environment is established to address these issues, students overcome these hurdles with greater ease (Gokce et al., 2024).

The onset of technical challenges may stem from pupils' insufficient experience in analogous activities and inadequate preparation for equipment usage. Conversely, collaborative efforts across groups and help from educators have proven effective in alleviating these issues. The authors of this study argue that student readiness levels should be taken into account when planning Arduino-based robotic coding activities. They also contribute to the literature by offering practical recommendations to mitigate challenges faced during implementation.

Robotic coding activities enhance students' abilities in scientific project writing. Students reported acquiring theoretical knowledge in project writing, formulating practical ideas for daily life, and enhancing self-confidence. Research indicates that robotic coding exercises improve students' project writing skills (Lee et al., 2020). Our research is predominantly aligned with the existing literature on this matter. The practical expertise acquired by students through individual and collaborative project work has facilitated this achievement. Consequently, the authors argue that Arduino-based robotic coding activities enhance technical and theoretical competencies, thereby increasing participants' self-confidence.

Arduino-based robotic coding activities enhance students' career awareness and motivation. Students have indicated that these activities have enhanced their understanding of their areas of interest and potential subjects for success. Research indicates that robotic coding activities influence students' job decisions (Ayar, 2015). Our study's results indicate that experiential learning approaches that facilitate self-understanding among students effectively enhance their professional awareness. The experiences students acquired during the activities have bolstered their confidence in future career decisions.

Participants have proposed incorporating Arduino-based robotic coding activities into science curricula. Furthermore, the participants asserted that pre-existing codes should not be utilized throughout these actions. The literature consistently emphasizes the importance of incorporating robotic coding tasks into teaching (Kim et al., 2015). Nevertheless, critiques regarding the use of pre-existing code are infrequently discussed (Gokce et al., 2024). Our study provides a novel perspective that addresses the existing literature's deficiency on this topic. These proposals are based on the student's aspiration to gain greater benefits from the activities. The focus on developing algorithms rather than utilizing pre-existing code signifies that students aspire to engage more actively in learning. This outcome suggests that student-centered methodologies should be implemented in the design of robotic coding activities. This study offers recommendations to enhance Arduino-based robotic coding activities in the literature.

**Data-Based Implications and Original Contributions**

This study offers insights that extend beyond confirming existing literature, revealing dimensions of the student experience that are rarely addressed in robotics education research at the middle school level. One such contribution is the impact of Arduino-based activities on students' career awareness. Several participants noted that these experiences influenced their interest in future professions related to science and technology. This outcome has been underexplored in prior studies, which typically emphasize short-term engagement or cognitive skills, such as problem-solving and coding (e.g., Chung & Lou, 2021; Sullivan & Bers, 2016). This suggests that robotics education may play a formative role in identity development and long-term motivation, especially during early adolescence (Bandura et al., 2001).

Additionally, students' reflections on group collaboration revealed both benefits and challenges. While many valued peers learning, others noted issues such as unequal participation or idea conflicts. Rather than undermining learning, these tensions often contributed to deeper thinking and enhanced problem-solving, underscoring the importance of structured cooperative strategies in technology-based learning environments (Johnson & Johnson, 1994).

Notably, the study generated student-informed recommendations rooted in lived experience. Participants advocated for increased session time, including individual work options, and the design of activities based on real-life scenarios. These suggestions were consistently expressed across interviews, highlighting their practical value for educators seeking to create inclusive and engaging robotics curricula.

By addressing not only what students experienced but also why and how those experiences shaped their perceptions, the study responds directly to its research question. It illustrates how Arduino-based activities support meaningful learning, foster real-world relevance, and influence academic engagement and personal growth. These findings enrich the theoretical foundations of constructivist and experiential learning by connecting them to students' authentic voices and classroom realities. In contrast to recent studies that have mainly emphasized skill development, computational thinking, or entrepreneurship outcomes through Arduino-based STEM implementations (Barradas et al., 2024; Topcubaşi & Tiryaki, 2023), this study foregrounds the affective and interpretive dimensions of learners' experiences. By focusing on how students construct meaning and reflect on their engagement, the study contributes to a more holistic understanding of robotics-based learning that integrates emotional, motivational, and contextual factors alongside technical proficiency.

The contemporary educational paradigm seeks to develop persons capable of adapting to evolving global situations, proficiently utilizing technology, and possessing essential 21st-century competencies (Ananiadou & Claro, 2009). In this context, current educational programs that equip students with 21st-century skills have made technology integration into lessons one of their primary goals. Consequently, technology integration in education has become essential to address contemporary demands and enhance the efficacy of the learning environment (Voogt & Pareja Roblin, 2012).

The authors analyzed and explored the challenges of Arduino-based activities. They proposed solutions based on the study findings and limitations. Therefore, this study differs from similar studies in the literature in this aspect (Mellis & Buechley, 2012; Steidtmann et al., 2023).

**Suggestions**

Arduino-based robotic coding exercises promote significant learning. Consequently, it is advisable to incorporate Arduino-based robotic coding education within the science curriculum. Participants have indicated that teachers are deficient in assessment and evaluation during the activities. Consequently, teachers must receive instruction in measurement and evaluation while implementing Arduino-based robotic coding activities. Students have said that they appreciate hands-on activities. As a result, students should select practical robotic coding exercises that provide hands-on exposure. Based on the study results, when planning Arduino-based robotic coding activities, it is recommended to place more emphasis on daily activities that students can relate to. Students have reported experiencing difficulties during collaborative robotic coding sessions. To address these challenges, educators should facilitate peer learning. Based on the study results, students should be encouraged to write their own code instead of using pre-written code during Arduino-based robotic coding activities. The authors propose that the existing curriculum should enhance robotic coding activities in middle schools to facilitate the development of technological competencies in students from an early age. The authors advocate for encouraging teachers to utilize visual and practical resources to facilitate students' comprehension of coding procedures, catering to diverse learning styles. Training instructors in robotic coding and Arduino use will ensure they have the necessary knowledge and expertise in their teaching methods. The authors suggest organizing seminars and workshops for teachers. Consistently collecting student feedback on activities and incorporating this input into educational practices will enhance the overall learning experience. Projects should be created that allow students to work in groups, and opportunities for collaborative learning should be provided to facilitate this approach. This will also develop the student's social skills. Robotic coding tasks should be integrated with real-world challenges encountered in everyday life. This would enhance students' drive to learn and expand the domains of their knowledge activities.

This study was limited to the participation of only five students. It is recommended that similar studies be conducted with larger participant groups that possess different demographic characteristics (e.g., age, gender, socioeconomic status, robotics coding background). The authors propose conducting comparative studies to examine the effects of Arduino-based activities across various educational levels, including primary and high school.

## References

Alimisis, D. (2013). Educational robotics: Open questions and new challenges. *Themes in Science and Technology Education, 6*(1), 63–71.

Ananiadou, K., & Claro, M. (2009). 21st-century skills and competencies for new millennium learners in OECD countries. *OECD Education Working Papers*, No. 41. OECD Publishing.

Atmatzidou, S., & Demetriadis, S. (2016). Advancing students' computational thinking skills through educational robotics: A study on age and gender relevant differences. *Robotics and Autonomous Systems*, 75, 661–670. https://doi.org/10.1016/j.robot.2015.10.008

Ausubel, D. P. (1968). *Educational psychology: A cognitive view.* Holt, Rinehart & Winston.

Ayar, M. C. (2015). First-hand experience with engineering design and career interest in engineering: an informal STEM education case study. *Educational Sciences: Theory and Practice*, *15*(6), 1655–1675. https://doi.org/10.12738/estp.2015.6.0134

Bandura, A., Barbaranelli, C., Caprara, G. V., & Pastorelli, C. (2001). Self-efficacy beliefs as shapers of children's aspirations and career trajectories. *Child Development, 72*(1), 187–206. https://doi.org/10.1111/1467-8624.00273

Barak, M., & Zadok, Y. (2009). Robotics projects and learning concepts in science, technology, and problem-solving. *International Journal of Technology and Design Education, 19*(3), 289-307. https://doi.org/10.1007/s10798-007-9043-3

Barradas, R., Lencastre, J. A., Soares, S. P., & Valente, A. (2024). Arduino-based mobile robotics for fostering computational thinking development: an empirical study with elementary school students using problem-based learning across Europe. *Robotics*, *13*(11), 159. https://doi.org/10.3390/robotics13110159

Becker, H. J. (2000). Findings from the teaching, learning, and computing survey: Is Larry Cuban right? *Education Policy Analysis Archives, 8*(51). 1–31. https://doi.org/10.14507/epaa.v8n51

Bell, T., Wedege, T., & Bowers, A. (2009). *The role of robotics in education: A strategy for the development of skills and knowledge in STEM education*. Proceedings of the International Conference on Robotics and Automation. https://doi.org/10.1109/robot.2009.5150505

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

Bers, M. U. (2008). *Blocks to robots: Learning with technology in the early childhood classroom.* Teachers College Press.

Black, P., & Wiliam, D. (1998). Assessment and classroom learning. *Assessment in Education: Principles, Policy & Practice*, *5*(1), 7–74.

Bransford, J., Brophy, S., & Williams, S. (2000). When computer technologies meet the learning sciences: Issues and opportunities. *Journal of Applied Developmental Psychology*, *21*(1), 59–84. https://doi.org/10.1016/S0193-3973(99)00051-9

Cakir, N. K., & Guven, G. (2019). Arduino-Assisted robotic and coding applications in science teaching: Pulsimeter activity in compliance with the 5E learning model. *Science Activities*, *56*(2), 42–51. https://doi.org/10.1080/00368121.2019.1675574

Chou, P. N. (2018). Skill development and knowledge acquisition cultivated by maker education: Evidence from Arduino-based educational robotics. *EURASIA Journal of Mathematics, Science and Technology Education*, *14*(10), em1600. https://doi.org/10.29333/ejmste/93483

Chung, C. C., & Lou, S. J. (2021). Physical computing strategy to support students' coding literacy: an educational experiment with Arduino boards. *Applied Sciences*, *11*(4), 1830. https://doi.org/10.3390/app11041830

Creswell, J. W. (2009). *Research design, qualitative, quantitative, and mixed methods approach* (Third Edition). SAGE Publications.

Creswell, J. W., & Poth, C. N. (2018). *Qualitative inquiry and research design: Choosing among five approaches* (4th ed.). SAGE Publications.

Davies, R. S. (2011). Understanding technology literacy: A framework for evaluating educational technology integration. *TechTrends*, *55*, 45–52.

Dunlosky, J., Rawson, K. A., Marsh, E. J., Nathan, M. J., & Willingham, D. T. (2013). Improving students' learning with effective learning techniques: Promising directions from cognitive and educational psychology. *Psychological Science in the Public Interest*, *14*(1), 4–58. https://doi.org/10.1177/15291006124532

Eguchi, A. (2014). *Robotics as a learning tool for educational transformation*. In Proceedings of 4th International Workshop Teaching Robotics, Teaching with Robotics & 5th International Conference Robotics in Education (pp. 27–34).

Erlingsson, C., & Brysiewicz, P. (2017). A hands-on guide to doing content analysis. *African Journal of Emergency Medicine, 7*(3), 93–99. https://doi.org/10.1016/j.afjem.2017.08.001

Garrison, D. R., & Vaughan, N. D. (2008). *Blended learning in higher education: Framework, principles, and guidelines*. Jossey-Bass.

Gokce, H., Gokce, Z., Bektas, O., & Kırmızıgül, A. S. (2024). Robotic coding perceptions of middle school students. *Journal of Education and Future*, (25), 31–44. https://doi.org/10.30786/jef.1274671

Hattie, J. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. Routledge.

Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research*, *77*(1), 81–112. https://doi.org/10.3102/003465430298487

Haymana, İ., & Özalp, D. (2020). The effect of robotics and education on the creative thinking of primary school 4th graders. *Istanbul Aydin University Faculty of Education Journal, 6*(2), 247–274.

Hsu, Y. C., & Ching, Y. H. (2013). Mobile app design for teaching and learning: Educators' experiences in an online graduate course. *International Review of Research in Open and Distributed Learning*, *14*(4), 117–139. https://doi.org/10.19173/irrodl.v14i4.1542

Johnson, D. W., & Johnson, R. T. (1994). *Learning together and alone: Cooperative, competitive, and individualistic learning* (5th ed.). Allyn & Bacon.

Kafai, Y. B., & Burke, Q. (2015). Constructionist gaming: Understanding the benefits of making games for learning. *Educational psychologist*, *50*(4), 313–334. https://doi.org/10.1080/00461520.2015.1124022

Kampylis, P., Law, N., Punie, Y., Bocconi, S., Brecko, B., Han, S., ... & Miyake, N. (2013). *ICT-enabled innovation for learning in Europe and Asia. Exploring conditions for sustainability, scalability, and impact at the system level* (No. JRC83503). Joint Research Centre.

Kim, C., Kim, D., Yuan, J., Hill, R. B., Doshi, P., & Thai, C. N. (2015). Robotics to promote elementary education pre-service teachers' STEM engagement, learning, and teaching. *Computers & Education*, *91*, 14–31. https://doi.org/10.1016/j.compedu.2015.08.005

Kim, S. Y., & Hyun, Y. S. (2020). The effect of STEAM program using Arduino on preservice science teachers' STEAM core competencies. *Journal of Science Education*, *44*(2), 183–196. https://doi.org/10.21796/jse.2020.44.2.183

Kirikkaya, E. B., & Basaran, B. (2019). Investigation of the effect of the integration of Arduino to electrical experiments on students' attitudes towards technology and ICT by the mixed method. *European Journal of Educational Research,* 8(1), 31–48. https://doi.org/10.12973/eu-jer.8.1.31

Kirkwood, A., & Price, L. (2014). Technology-enhanced learning and teaching in higher education: What is 'enhanced' and how do we know? *Learning, Media and Technology, 39*(1), 6–36. https://doi.org/10.1080/17439884.2013.770404

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development.* Prentice-Hall.

Kondaveeti, H. K., Kumaravelu, N. K., Vanambathina, S. D., Mathe, S. E., & Vappangi, S. (2021). A systematic literature review on prototyping with Arduino: Applications, challenges, advantages, and limitations. *Computer Science Review*, *40*, 100364. https://doi.org/10.1016/j.cosrev.2021.100364

Koray, A., & Duman, F. G. (2022). Subject-oriented educational robotics applications with Arduino in science teaching: digital dynamometer activity in accordance with the 5E instructional model. *Science Activities*, *59*(4), 168–179. https://doi.org/10.1080/00368121.2022.2093824

LaRocque, M., Kleiman, I., & Darling, S. M. (2011). Parental involvement: The missing link in school achievement. *Preventing School Failure*, *55*(3), 115–122. https://doi.org/10.1080/10459880903472876

Lee, E. (2020). A Meta-analysis of the effects of Arduino-based education in Korean primary and secondary schools in engineering education. *European Journal of Educational Research, 9*(4), 1503–1512. https://doi.org/10.12973/eu-jer.9.4.1503

Lo, N. P. K. (2024). From theory to practice: Unveiling the synergistic potential of design and maker education in advancing learning. *SN Computer Science*, *5*(4), 360. https://doi.org/10.1007/s42979-024-02726-3

Machumu, H., Zhu, C., & Almasi, M. (2018). Students' motivational factors and engagement strategies in constructivist-based blended learning environments. *Afrika Focus, 31*(1), 13–34.

Marín-Marín, J. A., García-Tudela, P. A., & Duo-Terrón, P. (2024). Computational thinking and programming with Arduino in education: A systematic review for secondary education. *Heliyon*. *10*/ 8, 29177. https://doi.org/10.1016/j.heliyon.2024.e29177

Marshall, C., & Rossman, G. B. (2014). *Designing qualitative research*. Sage Publications.

Martín-Gutiérrez, J., Mora, C. E., Añorbe-Díaz, B., & González-Marrero, A. (2017). Virtual technologies trends in education. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(2), 469–486. https://doi.org/10.12973/eurasia.2017.00626a

Mellis, D. A., & Buechley, L. (2012, June). Case studies in the personal fabrication of electronic products. In *Proceedings of the Designing Interactive Systems Conference* (pp. 268–277). https://doi.org/10.1145/2317956.2317998

Merriam, S. B. (2009). *Qualitative research: A guide to design and implementation.* Jossey-Bass.

Merriam, S. & Tisdel, E.J. (2015). *Qualitative research: A guide to design and implementation*. (Fourth edition). Jossey-Bass.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record, 108*(6), 1017–1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x

Mubin, O., Stevens, C. J., Shahid, S., Al Mahmud, A., & Dong, J. J. (2013). A review of the applicability of robots in education. *Technology for Education and Learning, 1*(1), 1–7. https://doi.org/10.2316/Journal.209.2013.1.209-0015

Nam, K. W., Kim, H. J., & Lee, S. (2019). Connecting plans to action: The effects of a card-coded robotics curriculum and activities on Korean kindergartners. *The Asia-Pacific 28*(5), 387–397. https://doi.org/10.1007/s40299-019-00438-4

Nugent, G., Barker, B., Grandgenett, N., & Adamchuk, V. I. (2010). Impact of robotics and geospatial technology interventions on youth STEM learning and attitudes. *Journal of Research on Technology in Education*, *42*(4), 391–408. https://doi.org/10.1080/15391523.2010.10782557

Papadakis, S., Vaiopoulou, J., Sifaki, E., Stamovlasis, D., & Kalogiannakis, M. (2021). Attitudes towards the use of educational robotics: Exploring pre-service and in-service early childhood teacher profiles. *Education Sciences*, *11*(5), 204. https://doi.org/10.3390/educsci11050204

Patton, M. Q. (2015). Qualitative research and evaluation methods (Fourth Edition). Sage Publications.

Phun-Pat, Y., Chauca, C., Mayurí, M. A., & Curro-Urbano, O. (2021). Cognitive Development, Learning Strategies, and Academic Performance in the First Stage of University Education. *International Journal of Emerging Technologies in Learning (iJET)*, *16*(20), 35–50. https://www.learntechlib.org/p/220551/

Piaget, J. (1952). *The origins of intelligence in children*. International Universities Press.

Piaget, J. (1972). *The psychology of the child.* Basic Books.

Ragusa, G., & Leung, L. (2023). The impact of early robotics education on students' understanding of coding, robotics design, and interest in computing careers. *Sensors, 23*(23), 9335, 1–10. https://doi.org/10.3390/s23239335

Relkin, E., Govind, M., Tsiang, J., & Bers, M. (2020). How parents support children's informal learning experiences with robots. *Journal of Research in STEM Education, 6*(1), 39–51. https://doi.org/10.51355/jstem.2020.87

Roblyer, M., & Edwards, J. (2005). *Integrating educational technology into teaching* (4th edition). Prentice-Hall.

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*(1), 68–78. https://doi.org/10.1037/0003-066X.55.1.68

Samperio Sanchez, N. (2017). Discovering students' preference for classroom activities and teachers' frequency of activity use. *Colombian Applied Linguistics Journal, 19*(1), 51–66.

Sarı, U., Pektaş, H. M., Şen, Ö. F., & Çelik, H. (2022). Algorithmic thinking development through physical computing activities with Arduino in STEM education. *Education and Information Technologies*, *27*(5), 6669-6689. https://doi.org/10.1007/s10639-022-10893-0

Shute, V. J. (2008). Focus on formative feedback. *Review of Educational Research*, *78*(1), 153–189. https://doi.org/10.3102/0034654307313795

Soypak, B., & Eskici, M. (2023). Examining research on robotic coding applications in high secondary school mathematics and science courses: A content analysis study. *Journal of Science, Mathematics, Entrepreneurship and Technology Education*, *6*(3), 214–229.

Steidtmann, L., Kleickmann, T., & Steffensky, M. (2023). Declining interest in science in lower secondary school classes: Quasi-experimental and longitudinal evidence on the role of teaching and teaching quality. *Journal of Research in Science Teaching*, *60*(1), 164–195. https://doi.org/10.1002/tea.21794

Sullivan, A., & Bers, M. U. (2016). Robotics in the early childhood classroom: Learning outcomes from an 8-week robotics curriculum. *International Journal of Technology and Design Education, 26*(1), 3–20. https://doi.org/10.1007/s10798-015-9304-5

Topcubasi, T., & Tiryaki, A. (2023). The effect of Arduino-based E-STEM education on students' entrepreneurial skills and STEM attitudes. *Journal of Science Learning*, *6*(4), 424–434.

Tosun, N., & Mihci, C. (2020). An examination of digital parenting behavior in parents with preschool children in the context of lifelong learning. *Sustainability*, *12*(18), 7654. https://doi.org/10.3390/su12187654

Vega, J., & Cañas, J. M. (2019). PyBoKids: an innovative Python-based educational framework using real and simulated Arduino robots. *Electronics*, *8*(8), 899. https://doi.org/10.3390/electronics8080899

Voogt, J., & Pareja Roblin, N. (2012). 21st-century skills. *Curriculum Studies, 44*(3), 299–321.

https://doi.org/10.1080/00220272.2012.668938

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes.* Harvard University Press.

Wellington J (2015). *Educational Research: Contemporary Issues and Practical Approaches,* 2nd ed. Bloomsbury.

Winne, P. H. (2006). How software technologies can improve research on learning and bolster school reform. *Educational Psychologist, 41*(1), 5–17. https://doi.org/10.1207/s15326985ep4101_3

Yılmaz, A. (2021). The effect of technology integration in education on prospective teachers' critical and creative thinking, multidimensional 21st-century skills, and academic achievements. *Participatory Educational Research*, *8*(2), 163–199. https://doi.org/10.17275/per.21.35.8.2

Yin, R. K. (2018). *Case study research and applications: Design and methods* (6th ed.). Sage Publications.

Yuen, T., Boecking, M., Stone, J., Tiger, E. P., Gomez, A., Guillen, A., & Arreguin, A. (2014). Group tasks, activities, dynamics, and interactions in collaborative robotics projects with elementary and middle school children. *Journal of STEM Education, 15*(1), 39–45. https://www.learntechlib.org/p/148284/.

Zhao, Y., & Kacprzyk, J. (2020). Cost-effective educational robotics: Arduino as a tool for teaching STEM subjects. *International Journal of STEM Education, 7*(1), 1–12. https://doi.org/10.1186/s40594-020-00222-2