Investigating How Robotics Activities Shape Elementary Students' Attitudes Toward Music Composition and Coding

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Abstract: This mixed methods sequential explanatory study explored how computational thinking influences elementary students' attitudes by engaging the students in coding a music composition with an autonomous robot. Pre and post tests were used to document students' attitudes toward music composition and coding over the course of six weeks. Eighty fifth-grade students participated in the music composition project, coding for one hour each week in an engineering class. The students were randomly organized into four study groups: individualized, collaborative, traditional, and Use-Modify-Create (UMC). Findings indicate that students experienced a significant increase in positive attitudes toward music composition after the robotics coding activity. Both the individualized and collaborative groups reported enhanced enthusiasm for music composition, while the UMC group showed increased positivity towards coding and greater confidence in their coding abilities. These results suggest that music educators can enhance student attitudes toward both computational thinking and music composition by integrating robotics into the music curriculum. The main contributions of this study include: (1) empirical evidence of positive attitude changes toward music and coding through robotics; (2) comparative analysis of four instructional modes; and (3) a practical framework for integrating robotics into elementary music education.

Keywords: Computational thinking, Robotics music programming, Attitudes towards coding, Attitudes toward music composition.

1. INTRODUCTION

The field of educational robotics continues to see the expansion of various new and complex robotics platforms (Baek & Taylor, 2020). In these platforms, some robots are relatively simple and ready to be programmed out of the box, while others can be composed of multiple parts and require some assembly depending upon the build language (Chung *et al*., 2014; Eguchi, 2012; Karim *et al*., 2015). Similarly, programming languages also range from basic instructional directions entered directly on the top of a robot through a graphical user interface, to a more sophisticated programming language (*i.e*., with complex syntax) being necessary for the robot to function. Existing studies identify numerous educational goals that can be achieved in a variety of areas when students program robots (Eguchi, 2012; Grandgenett *et al*., 2012; Hwang & Wu, 2014).

According to Erol (2020), research shows that robotics instruction improves student motivation and attitudes towards programming, increases their success at programming, and also reduces the dropout rate in programming courses. Programming instruction is considered functional particularly for learning skills like "creativity, critical thinking and problem solving, communication and cooperation, social and intercultural skills, productivity, leadership, and responsibility" (Durak *et al*., 2019). In robotic activities, students design solutions to complex problems and receive immediate feedback about the outputs of the programs they write by testing their solutions (Atmatzidou, Demetriadis, & Nika, 2018). A recent study by Durak *et al*. (2019) found that in this way, students learn how to cope with difficult situations within the context of the real world.

Integrating robotics and music provides an opportunity to bridge what are seemingly unconnected instructional areas, which can encourage more students to envision themselves as science, technology, engineering, and mathematics (STEM) students (Chung. *et al*., 2014). A recent study by Amri *et al*. (2022) states students' interaction with robotics facilitates learning and enhances students' positive interest in STEM (Ioannou & Makridou, 2018), both of which are crucial for engaging students in the STEM fields (Shen *et al*., 2020).

However, the convergence of STEM/STEAM, science, technology, engineering, art, and mathematics, disciplines in music education classrooms presents significant pedagogical challenges, especially for specialist music teachers. Music educators often work within frameworks that prioritize artistic expression, aesthetic experience, and historical or performance-based content. The introduction of coding, engineering, or robotics into these environments may be met with resistance due to unfamiliarity with the tools, lack of professional development, concerns

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about diluting core music content, or skepticism about the authenticity of interdisciplinary learning. For some educators, the shift toward STEM or STEAM can feel like a forced alignment with external educational mandates rather than a natural pedagogical evolution. Others may perceive it as a threat to the integrity of the music discipline, potentially reducing music's role to a functional vehicle for teaching non-arts content.

Moreover, logistical barriers, such as access to technology, time constraints in the curriculum, and a lack of integrated instructional resources, can hinder implementation. These challenges are compounded by the broader educational culture, in which the arts have historically been positioned as ancillary rather than central to STEM learning. As Pignato (2017) suggests, the integration of technology in music education exists within a complex web of cultural, social, and pedagogical influences, making any interdisciplinary innovation both promising and fraught with negotiation.

The intersection of robotics and music education is unique and innovative. Combining them offers opportunities for creativity, engagement, and learning. Similarities between the structure of music and features of programming languages such as sequencing and repetition create not only an enjoyable connection, but also the purposeful use of computational thinking skills to solve a given programming challenge (Chung *et al*., 2014).

This study explores elementary students' attitudes towards music composition when combined with robotics and computational thinking. According to Bell and Bell (2018) there are some obvious connections between music and computation, but the idea of engaging with genuine computational thinking while also having authentic music learning experiences for students provides new opportunities. Implementing compositional algorithms as computer programs to create music directly has also been done for some time (Leach & Fitch, 1995), but there are now easily accessed systems available for school students to generate music algorithmically in a context that is intended to teach programming while at the same time building on their interest in music (Bell & Bell, 2018).

This study is important because it contributes new literature to an underexplored topic, identifies factors that encourage or hinder student engagement in music composition and computational thinking, promotes interdisciplinary connections between music and robotics, and supports the development of future STEM/STEAM career paths. It also raises critical considerations for music educators navigating the practical and philosophical implications of STEM/STEAM integration in their classrooms.

2. LITERATURE REVIEW

2.1. Music Composition and Robotics Coding Activities

This research study identified several common themes when exploring music composition and robotics coding activities. Educational robotics, computational thinking (CT), and science, technology, engineering, and math (STEM) emphasize hands-on problem solving utilizing the engineering design process. Students engaged in this study combined robotics, CT, and STEM by developing plans, testing their computations, and iterating their final projects to successfully complete their music compositions. A second theme to emerge was knowledge integration. Robotics, CT, and STEM provide interdisciplinary learning by combining coding, engineering principles, and mathematical reasoning to create real-world solutions. The last theme to be identified was the development of creativity by the students coding a music composition using robotics and computational thinking.

The use of educational robotics is increasing in elementary classrooms. Educational robotics enhances science, technology, engineering, arts, and mathematics (STEAM) curriculum into literature, social studies, dance, music, and art. According to Belbase *et al*. (2021) STEAM provides an approach to teach STEM by integrating the principles of each discipline with art as interdisciplinary learning critical to math and science. Misra *et al*. (2009) found that music can serve as a powerful means to engage students in introductory computer science courses, highlighting the creative as well as analytical sides of computing.

Robotics and computer programming offer a way to playfully engage students with the process of how motors, sensors, and electronics work (Elkin *et al*., 2016), and the use of a robot in programming education can help students understand computer-science concepts more easily (Noh & Lee, 2019). Sullivan *et al*. (2017) noted that the emerging domain of robotics can provide playful strategies for engaging children with the technology and engineering components of STEAM.

Komm *et al*. (2020) found that robotics is a strong motivator for engaging students in STEM fields with its direct feedback since robots are tangible machines. Ioannou and Makridou (2018) noted that educational robotics is increasingly appearing in educational settings for students of all ages, being considered a useful supporting tool for the development of cognitive skills, including Computational Thinking (CT). There is an overwhelming argument that CT will be a fundamental skill needed for all individuals by the middle of the twenty-first century and thus should be cultivated in early school years. According to Zhang *et al*. (2021) computer scientists recognize CT as a problem-solving skill which is broadly like mathematical problem-solving. Computational thinking along with educational robotics learning creates the scope for an integrated, multi-disciplinary approach that incorporates technical and social topics (Zhang *et al*., 2021).

Integrating robotics and computational thinking in elementary classrooms is an engaging way to introduce younger students to important STEM skills. Papadakis and Kalogiannakis (2020) noted that robotics can be an effective way to introduce CT to younger students since it involves being able to systematically process tasks and developing the step-by-step coding commands needed to program a robot. Khine (2018) found that educational robotics is rich with opportunities to integrate not only STEAM but also other disciplines such as literacy, social studies, dance, music, and art, while giving students opportunities to collaborate, express themselves using technological tools, solve problems, and think critically and innovatively.

In addition to academic research, several recent patents and industry developments highlight growing interest in robotics-based music composition tools (*e.g*., United States Patent Application, 2024, U.S. Patent Application No. US 2024/0371347 A1, which describes an automated music composition and generation system using virtual instrument libraries and parameter tables to produce digital music). News reports also indicate expanding use of programmable music robots in both formal and informal learning environments, suggesting potential for wider adoption in education.

2.2. Attitudes Toward Music Composition and Coding Activities

Integrating computational thinking (CT) into artistic fields has been shown to increase participation in computer science (Gorson *et al*., 2017). One of the greatest strengths of programming music in an introductory computer science class is that it provides a broader perspective earlier on of what can be done with computers (Misra *et al*., 2009). A creative learning environment, fueled by a meaningful and personally relevant curriculum, drives improvements in students' attitudes and intent to persist in computing (Engelman *et al*., 2017). STEAM practices derived from STEM, with an additional subject art being included can complement early childhood STEM education, wherein the “A” in STEAM covers the area of visual art and crafts, liberal arts, linguistic arts, social studies, music, and culture (Ng *et al*., 2022). According to Pandey *et al*. (2023) music and robotics integrated with computer programming are approaches to engage students in computer science (CS) by prioritizing personal expression, creativity, and aesthetics. Research has shown that combining CS with music and robotics in elementary education can make learning more engaging and effective (Pandey *et al*., 2023).

The purpose of this study was to explore the effects of robotics activities on students’ attitudes toward music composition and coding, and was guided by the following two research questions:

RQ1: Does music programming using robotics increase positive attitudes toward music composition in elementary students?

RQ2: Does programming a music composition increase students’ positive attitude toward coding with elementary students?

The two research variables are of interest to quantify attitude shifts towards music composition and coding following robotics activities. Research on attitudes towards music programming and coding can be transferred from the elementary engineering classroom to music classrooms.

Robotics programming for this study included students using C programming language, a text-based coding language, to develop a music composition on an autonomous robot. C coding language was utilized in this research study because the autonomous robots used in the engineering classroom use C. Starting in fourth grade, students are introduced to C coding language and develop their programming skills through coding the autonomous robots in the engineering classroom. Robotics music programming includes typing the musical notes into a coding program to run the completed musical composition. This approach combines robotics with music, programming physical robots to perform or interact with music. In comparison, coding music, also known as algorithmic or generative music coding, involves using software to write code that generates or manipulates music. The practice of live coding involves writing and modifying computer programs that generate music in real time (Brown & Sorensen, 2009). Platforms like Sonic Pi, Supercollider, and Tidal Cycles allow users to create music through algorithms, live-coding patterns, and manipulating sounds digitally (Magnusson, 2011). Live coding is a form of musical composition in which music is improvised on the spot through coding, which was created in search of new forms of expression in computer music (Sonoyama & Nakajima, 2023). Robotics music programming uses code to allow the robot to interact with music, while coding music involves creating or performing music purely in a digital space.

While this study highlights positive student attitudes toward interdisciplinary learning, it is important to acknowledge the pedagogical challenges that arise when integrating robotics into music education. Resistance from educators may stem from a perceived dilution of musical rigor or discomfort with unfamiliar technologies. Additionally, despite the relevance of the STEAM framework, which explicitly includes the arts in STEM education, it remains curiously absent from much of the discourse surrounding educational robotics. Emphasizing the "A" in STEAM especially through projects like musical robotics can help foster creativity, cultural relevance, and holistic engagement. Music educators may need targeted professional development and curricular support to embrace such interdisciplinary teaching strategies without feeling their domain is being overshadowed.

Recent studies have continued to explore interdisciplinary approaches combining robotics, coding, and the arts. For example, Liu et al. (2025) found that integrating flow-based music programming increased learner engagement and motivation in K-12 settings, while Fanchamps et al. (2024) demonstrated that music production using technology stimulates computational thinking—particularly around loops, conditionals, and functions—across age groups. These emerging studies reinforce the relevance of STEAM integration for fostering both technical and artistic competencies.

3. METHODS

3.1. Research Design

This study employed a mixed-methods sequential explanatory design. This design undertakes the sequential approach where the quantitative phase is followed by the qualitative phase, the core component is quantitative, the supplemental component is qualitative (Creswell, 2009), and the qualitative findings are used to contextualize the quantitative data (Nooraie *et al.*, 2020). Figure **1** shows the mixed-methods sequential explanatory design.

Phase 1 involved implementing attitudes towards computational thinking and music composition pretests to determine attitudes toward coding and music composition. Phase 2 involved qualitative interviews, and class notes collection. Phase 3 involved the attitudes towards computational thinking and music composition posttest collection to quantitatively answer the research questions and elaborate on the qualitative results. Phase 4 involved statistical analysis. Phase 5 involved triangulation of data and contextualizing quantitative findings with qualitative data.

Qualitative data derived from in-depth interviews and observation helped to refine and explain statistical results from the quantitative data with regard to their reality, meaning, dynamics and idiosyncrasies (Hollstein, 2014). Thus, the quantitative – qualitative sequence provided a general understanding of participants' attitudes towards music composition and coding.

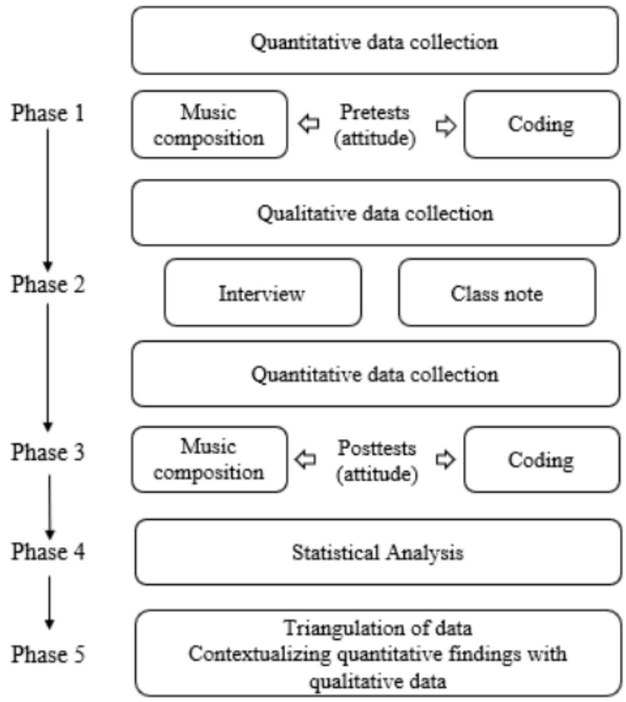

Figure 1: The mixed methods sequential explanatory design.

Table **1** outlines the class-level learning modes; Table **2** presents interviewee demographics. Students were observed during class and their attitudes towards music composition and coding were documented then input and coded in the qualitative analysis statistical program NVivo. Parent codes and child codes were entered into NVivo along with multiple phases of coding to identify themes that emerged from the data analysis.

3.2. School Settings

This study was conducted at a STEM school in Eagle, Idaho, USA. The school has a Level 1 certification through the Marzano High Reliable Schools Network and National STEM School of Excellence certification through AdvancED. The school has 797 students from kindergarten through eighth grade in a suburban community. The students participated in a six-week study within the school day as part of their formal education. Coding and robotics are taught one hour a week in an engineering special.

Robotics is taught from kindergarten through eighth grade in engineering classrooms for both elementary and middle school students. After school robotics clubs are offered to students in fourth through eighth grade. Music courses are taught to students grades kindergarten through eighth grade. The students meet for thirty minutes each week and are instructed by a professional musician. Students in grades 6-8 also participate in band or orchestra as an elective.

3.3. Ethical Considerations

This study was conducted with a strong emphasis on ethical considerations to ensure the privacy and confidentiality of all participants. Every effort was made to adhere to ethical research standards. For example, the researchers ensured that all activities were conducted in a safe and respectful environment and that the data collected was handled with the utmost care to protect the participants' identities and personal information. In addition, researchers were trained in ethical research practices and were vigilant in maintaining these standards throughout the study.

Prior to the commencement of the study, authorization was obtained from the principal of the participating school. The principal reviewed the study's goals, procedures, and potential impact on students, and granted permission for the research to be conducted within the school setting. This approval ensured that the study aligned with institutional expectations and safeguarded the well-being of the students involved. An initial parent information email was sent to the families of the 80 participants, describing the research study and providing contact information for any questions throughout the duration of the research.

Furthermore, informed consent was obtained from the parents or legal guardians of all participating students. Permission was explicitly granted for the use of images involving the students, with the understanding that these images would be used solely for the purposes of this research. To protect the identities of the students, all visible faces in the images have been covered with stickers. Due to their age, the participating students provided verbal assent to take part in the research study. The assent allowed for the students to opt out if they did not want to participate. No students opted out. Additionally, the three fifth grade teachers at the school site gave informed consent for the study.

The classroom instructor, who also served as a co-investigator for this study, worked under the direction of the university professor serving as the principal investigator. The classroom instructor held a dual role as an elementary engineering teacher and a doctoral candidate in the Educational Technology program at Boise State University (BSU). With several years of experience teaching engineering and technology concepts to young learners, she brought both practical classroom expertise and a strong academic foundation to the research. Her doctoral studies at BSU included rigorous training in both qualitative and quantitative research methodologies, equipping her with the skills necessary to design, implement, and analyze educational interventions. This combination of hands-on teaching experience and formal research training uniquely positioned her to investigate the intersection of robotics, music composition, and coding in the elementary classroom.

3.4. Participants

The participating school had three fifth-grade classes, comprising a total of 80 students. For the purposes of this study, all students from these classes were randomly assigned to one of four instructional groups.

The four learning groups in the study represented distinct instructional approaches: collaborative, individual, traditional, and Use, Modify, and Create (UMC). In the collaborative group, students worked together in pairs or small teams to complete tasks, promoting peer interaction, shared problem-solving, and co-construction of knowledge. The individual group involved students working independently, allowing for self-paced exploration and personal accountability in the learning process. The traditional group followed a more conventional teacher-directed instructional model, emphasizing step-by-step instruction and limited integration of interdisciplinary content. Finally, the UMC group was based on the Use, Modify, and Create framework, where students first used existing code or tools, then modified them to fit new purposes, and ultimately created original projects. This mode emphasized progressive engagement with computational thinking and creativity, allowing students to build confidence through structured experiences that gradually led to independent innovation.

An overview of the participating students is presented in Table **1**.

Table **2** provides a detailed overview of the students who participated in interviews as part of the study. Each student is represented by an identifying letter to maintain confidentiality, along with key demographic and instructional information. This includes the specific

Table 1: Four Learning Modes

Class	Group	Male	Female	Total
1	Collaborative	15	12	27
2	Individualized	14	11	25
3	Traditional	8	5	13
	Use, Modify, Create (UMC)	9	6	15
	Total	43 (54%)	37 (46%)	80

learning mode they were assigned to, collaborative, individualized, traditional, or UMC, as well as their age and gender. This contextual data helps to frame individual student perspectives within their instructional experiences and personal backgrounds, offering a richer understanding of how different learning environments may influence student attitudes and outcomes.

Table 2: Interview Participant Demographics

Student Letter	Learning Mode	Age	Gender
A	UMC	10	Female
B	UMC	10	Male
C	Individual	11	Male
D	Individual	10	Female
E	Traditional	10	Female
F	Traditional	11	Male
G	Collaborative	10	Male
H	Collaborative	10	Female

3.5. Robotics Music Activities

Throughout the six-week intervention, participants engaged in hands-on learning activities that required them to develop coding skills using the C programming language. These skills were applied to program autonomous robots to perform a variety of music-related tasks, such as producing sounds, playing sequences, and composing original musical pieces. The instructional approach varied across the three classes, which were each assigned one or more of the following four learning modes: Individualized instruction, Collaborative group learning, Traditional instruction, and the Use, Modify, and Create (UMC) model. These modes provided distinct educational experiences, ranging from direct teacher-led instruction to student-driven exploration and code modification. Upon completion of the full six-week robotics and music curriculum, all 80 participating fifth-grade students completed two post-intervention assessments: the Attitude Toward Robotics Survey, which measured students' interest, confidence, and perceptions of working with robotics, and the Music Composition Survey, which assessed their understanding, experience, and attitudes related to composing music through coding. These assessments provided valuable data for evaluating the impact of each instructional model on student learning outcomes and engagement.

3.5.1. Music Composition on the Robots

The six-week intervention in the music and robotics study is systematically aligned with the research data collection phases, as depicted in Figure **2**. Each week introduces a new topic and corresponding activity that incrementally builds students' understanding and skills in both coding and music composition. Week 1 ("Robot Connecting") and Week 2 ("Robot Coding") serve as foundational phases, where students engage in basic programming tasks such as "Coding Hello World" and "Coding Motor Program." These early activities correspond to the "Moving Forward" and "Moving Around" phases of data collection, capturing initial engagement and motor control development. Weeks 3 to 5 gradually deepen the integration of music and coding through activities like "Robot Sound," "Coding a Song," and "Compose a Music," aligning with the "Music Notes," "Music Notes & Codes," and "Music Notes & Program" data collection phases. These weeks provide rich data on students' evolving understanding of musical elements and their ability to translate that understanding into programmable actions. Finally, Week 6 emphasizes finalization and presentation ("Completion and Sharing"), mapping onto the "Iteration and Sharing" phase of data collection, which focuses on students' ability to reflect, refine, and communicate their compositions. This structured progression ensures that each phase of data collection captures meaningful shifts in students' cognitive and creative development.

3.5.2. Four Learning Modes

Class 1, the collaborative learning group, included 27 students and was structured around whole-group instruction followed by peer collaboration. The primary objective was for students to first receive direct instruction as a class and then work together with their

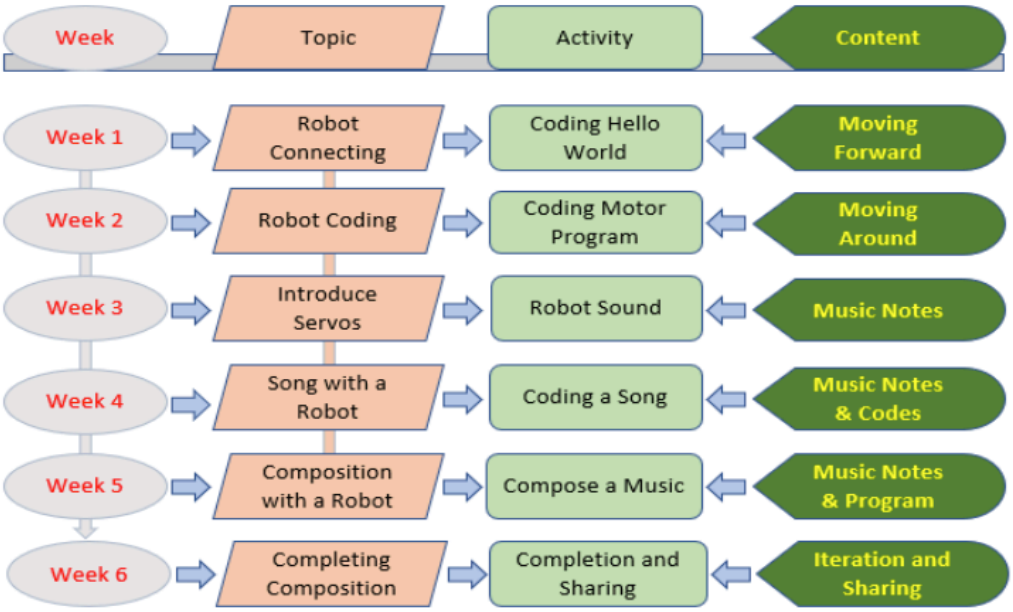

Figure 2: Participants' robotics music composition process.

classmates to complete the music composition challenge. During this process, the teacher facilitated learning by providing support and addressing questions across the entire group.

Class 2, the individualized learning group, consisted of 25 students who engaged in coding activities in a personalized, one-on-one setting. The teacher provided individual instruction to each student before they began working on their coding challenges independently. After the initial guidance, the teacher circulated the room to address questions and offer support as needed on an individual basis.

Class 3 was divided into two instructional groups. The first group, consisting of 13 students, received traditional instruction that began with whole-class teaching, followed by a small group collaboration to complete the music composition challenge. The second group, made up of 15 students, followed the Use, Modify, Create (UMC) instructional model. While both groups received the same initial whole-group instruction, students in the UMC group were given sample C code to modify individually, progressing toward developing their own original code by the end of the activity.

Figure **3** illustrates robotics music activities, showing students coding music notes (left) and sharing their compositions (right). These hands-on tasks aimed to deepen engagement and reinforce both coding and music composition concepts through real-world application.

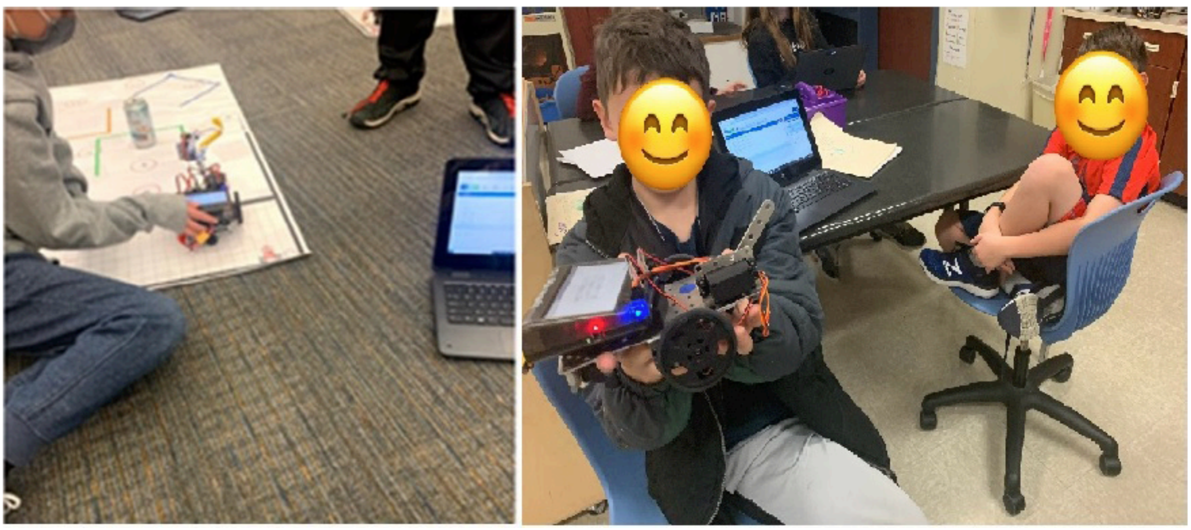

Figure 3: Robotics music activities: Coding music notes (left) and Sharing (right).

3.6. Tools and Data Collection Instruments

Data on students' attitudes toward music composition was collected through a quantitative survey consisting of 10 questions. The survey was designed to assess students' knowledge of music composition, their experience with coding music on a computer device, and their attitudes toward sharing their compositions with classmates.

The Attitude Attitude Toward Computational Thinking (pre/post) Likert scaled surveys included 15 questions designed to assess each student's knowledge and attitude towards robotics. Students completed the surveys individually, without time constraints, during the same week across all three classes.

Qualitative interviews with 8 randomly selected participating fifth-grade students representing all three study groups were conducted by the researcher. The interviews were 1:1 and lasted approximately 30 minutes each. The interview questions were composed from valid, peer reviewed sources. The interview questions identified student attitudes towards music composition and coding through computational thinking skills.

3.6.1. Attitude toward Music Composition

This instrument, adapted from Kafol *et al*. (2015), consists of 10 items rated on a 5-point Likert scale (1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree) across three domains: Participation in Music Composition, Coding Music Notes on a Robot, and Sharing Robotics Music with Others. Domain scores were calculated by summing relevant items, and the total score is the sum of all items, with higher scores indicating more positive attitudes. The maximum possible total score is 50. In the present study, this instrument demonstrated high internal consistency (Cronbach's α = .88).

Table **3** presents the survey items and categorizes them into the three domains. Items 1–3 address students' enjoyment and foundational knowledge of music, such as their desire to play their own compositions, enjoyment of composing, and ability to read music notes. Items 4–7 assess students' confidence and prior experience with coding music, including composing and programming musical notes using a computer or device. Items 8–10 explore attitudes toward collaboration and sharing, such as enjoyment of coding music with others, confidence in collaborating on coding tasks, and willingness to share projects with classmates. Together, these items provide a comprehensive overview of students' musical background, technical skills, and social engagement in the context of music and robotics integration.

3.6.2. Attitude toward Coding

The Attitude Toward Coding Survey consists of 15 items rated on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree), yielding a maximum possible total score of 75. Higher scores indicate more positive attitudes toward coding. Developed by the researchers with reference to the *Elementary Student Coding Attitudes Survey* by Mason and Rich (2020), the instrument was designed to capture students' perceptions and experiences related to coding and demonstrated good internal consistency in the present study (Cronbach's α = .91). The items are organized into three key domains: confidence in coding, which assesses how self-assured students feel about their ability to code; intrinsic motivation to develop coding skills, which examines students' personal interest and enthusiasm for learning to code; and experience with

Table 3: Quantitative Survey Data

Question Number	Question	Domain
1.	I want to play the music I compose	Participation in music composition
2.	Composing Music is fun	Participation in music composition
3.	I know how to read music notes	Participation in music composition
4.	I feel confident that I can code a song onto a device	Coding music notes on a robot
5.	I know how to code musical notes on a computer	Coding music notes on a robot
6.	I have composed music on a device before	Coding music notes on a robot
7.	I have used a computer to compose music before	Coding music notes on a robot
8.	I like to code musical notes with others	Sharing robotics music with others
9.	I feel confident that I can work with others to code music notes on a device	Sharing robotics music with others
10.	I like to share my coding projects with my class	Sharing robotics music with others

Table 4: Attitude Toward Coding

Survey Question Number	Survey Question	Domain
1.	To me coding is not difficult	Confidence in coding
2.	I can use the robot to code independently	Confidence in coding
3.	I am confident coding in C	Confidence in coding
4.	I have confidence in my coding ability	Confidence in coding
5.	I like coding music projects	Confidence in coding
6.	I want to express my ideas by coding	Intrinsic motivation to develop coding skills
7.	I know it is important to learn from failures	Intrinsic Motivation to develop coding skills
8.	I want to learn coding because it is important for my future	Intrinsic Motivation to develop coding skills
9.	I want to solve more problems by using coding	Intrinsic Motivation to develop coding skills
10.	I can use computational thinking to understand problems in the real world	Intrinsic Motivation to develop coding skills
11.	I understand in coding small changes affect the whole program	Expertise with coding with robots
12.	I know C coding includes planning and the steps and instructions for solving problems	Expertise with coding with robots
13.	I know it is easier to chunk my code into small pieces to successfully complete the project	Expertise with coding with robots
14.	I know I can successfully complete coding challenges multiple ways	Expertise with coding with robots
15.	I know it is important to solve the main challenge with the robot	Expertise with coding with robots

coding robots, which explores students' prior exposure to programming physical devices. Each item prompts students to indicate their level of agreement, providing insight into both their cognitive and emotional engagement with coding. This structure enables researchers to identify patterns in students' attitudes and potential differences across instructional groups. The full set of survey questions is presented in Table **4**.

3.6.3. Interview

Eight fifth-grade students, one male and one female from each of the four instructional groups, participated in individual interviews. These interviews were conducted during the students' regularly scheduled engineering class time to minimize disruption to their academic schedule. The interview questions were qualitative in nature and did not use a numeric rating scale. All questions were adapted from peer-reviewed sources to ensure validity and relevance to the study's focus. Responses were collected in an open-ended format and analyzed using NVivo version 14, employing a deductive coding approach to identify recurring themes and patterns related to students' experiences with music composition and coding. The complete list of qualitative interview questions used in this study is presented in Table **5**.

Table 5: Qualitative Interview Questions

Question Number	Interview Question
1.	Have you ever written code on a device?
2.	Can you explain text-based coding?
3.	Do you like coding?
4.	Have you ever composed a song?
5.	Have you composed a song on a computer device?
6.	Do you like composing songs?
7.	Would you like to share a song you composed on a device with your classmates?

3.6.4. Class Notes

The researcher listened to student conversations as she monitored the classroom to document attitudes towards music composition and coding. Examples of observations recorded include one student in the traditional learning group stated, *"This is a challenge but so much fun to learn to code the robot."* (Student M). Another observation made was a student in the UMC learning group said, *"This is my favorite coding and robotics challenge. I love coding music."* (Student P). Table **6** illustrates examples of class notes documenting student interactions.

Table 6: Examples of Class Observation Notes

Student Letter	Learning Mode	Age	Gender
M	Traditional	10	Female
P	UMC	11	Male

3.7. Data Analysis

Survey data was analyzed with the ANCOVA procedure in SPSS 27 while the qualitative data obtained through interviews and class notes were coded and analyzed using a deductive coding approach. The interview data was entered into NVivo to calculate the score, change in the attitude toward music composition and coding with robots, the scores of the pretest scores were subtracted from the posttest scores. Qualitative data processing began with transcription, proceeded to developing coding knowledge followed by music computation. Pre and Post study interview responses were coded into NVivo to develop relationships among themes. In accordance with Adu (2019), the following steps were implemented to construct qualitative analysis coding data and thematic analysis.

1. Interview question data was prepared to code.
2. Perspectives and preconceptions were reflected on and acknowledged.
3. Student interviews were documented.
4. Codes were manually assigned to the data in NVivo
5. Categories and Themes developed from the qualitative analysis data codes.
6. Themes were connected and tables were developed.
7. Qualitative findings were presented in this article.

The qualitative data coding using NVivo was used to determine themes for both attitude toward music composition and attitude toward coding. The themes are represented by tables and presented in this article.

4. FINDINGS

4.1. Findings from Quantitative Analysis

4.1.1. Attitude Toward Music Composition

Both collaborative and individual group participants' attitudes toward music composition positively improved after the robotics music programming activity. Calculating the mean for the music attitude tests for all participants in the collaborative and individualized groups, produced 14.38 for the pre-test and 19.94 for the post test (scale range: 10 items × 5 points = 10–50). See Figure **4**.

According to Figure **4**, the individualized learning group had the greatest increase in attitude from 13.64 to 21.00. To test the significance of these changes, the means of the two groups' attitude scores were calculated and an ANCOVA (Analysis of Covariance) procedure with the pretest score as a covariate from SPSS was applied. The means of the scores on the posttest for the attitude toward music composition were 18.96 (SD=2.39) for the collaborative and 21.00 (SD=2.46) for individualized learning groups. Table **7** has the result of the ANCOVA analysis for the two groups. The difference of the means for the two groups was significant ($F(1,49) = 45.322$, $p < .001$). Therefore, the individualized learning group showed a more positive attitude toward their music composition after their robotics activities.

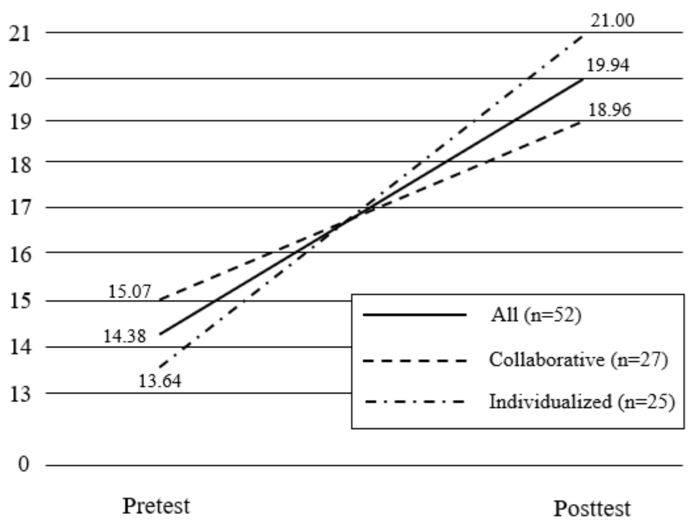

Figure 4: Changes in attitudes toward music composition for the collaborative and individualized learning groups (maximum possible score=50).

Table 7: ANCOVA for Sum of the Attitude Toward Music Composition

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	187.747[a]	2	93.873	37.990	
Intercept	104.285	1	104.285	42.203	
Pretest Sum	133.883	1	133.883	54.181	
Learning Modes	111.991	1	111.991	45.322	< .001
Error	121.080	49	2.471		
Total	20989.000	52			
Corrected Total	308.827	51			
R Squared = .608 (Adjusted R Squared = .592)					

Because the overall attitude showed a significant difference between the two learning groups, it would be good to see which domain of the music attitude produces the difference. The attitude toward music composition consisted of three domains: participation in music composition, coding music notes on a robot, and sharing robotics music. Means and ANCOVA tests with each domains' pretest scores as covariates were presented in order.

The domain of 'participation in music composition' has the means of 6.70 (SD=1.06) and 7.48 (SD=1.22) for collaborative and individualized learning, respectively. Table **8** has the result of ANCOVA analysis for the two groups.

According to Table **8**, the difference of the means for the two groups was significant ($F(1, 49)=16.584$, $p < .001$). Therefore, the individualized learning group showed a more positive attitude toward participation in music composition after the robotics activities.

The domain of 'coding music notes on a robot' has the means of 6.48 (SD=1.06) and 6.96 (SD=1.22) for collaborative and individualized learning, respectively. See Table **9**.

Table 8: ANCOVA for Participation in Music Composition

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	30.894[a]	2	15.447	17.686	
Intercept	68.914	1	68.914	78.901	
Pretest Sum	23.072	1	23.072	26.415	
Learning Modes	14.485	1	14.485	16.584	< .001
Error	42.798	49	.873		
Total	2678.000	52			
Corrected Total	73.692	51			
R Squared = .419 (Adjusted R Squared = .396)					

Table 9: ANCOVA for Coding Music Notes on Robots

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	32.318[a]	2	16.159	15.724	
Intercept	37.350	1	37.350	36.345	
Pretest Sum	29.346	1	29.346	28.556	
Learning Modes	6.476	1	6.476	6.302	< .05
Error	50.355	49	1.028		
Total	2425.000	52			
Corrected Total	82.673	51			
R Squared = .391 (Adjusted R Squared = .366)					

Table 10: ANCOVA for Sharing Robotics Music

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	13.573[a]	2	6.786	19.337	
Intercept	30.063	1	30.063	85.660	
Pretest Sum	5.630	1	5.630	16.042	
Learning Modes	11.422	1	11.422	32.546	< . 001
Error	17.197	49	.351		
Total	2000.000	52			
Corrected Total	30.769	51			
R Squared = .441 (Adjusted R Squared = .418)					

The difference of the means for the two groups was significant ($F(1,49)=6.302$, $p < .05$) as shown in Table **9**. The individualized learning group showed a more positive attitude toward coding music notes on a robot after their robotics activities.

Lastly, the domain of ‘sharing robotics music’ has the means of 5.78 (SD=.69) and 6.56 (SD=.65) for collaborative and individualized learning, respectively. See Table **10**.

According to Table **10**, the difference of the means for the two groups was significant ($F(1,49)=11.422$, $p < .001$). The individualized learning group showed a more positive attitude toward participation in music composition after the robotics activities.

In summary, after robotics music programming activities attitudes toward music composition are positively changed. The individualized learning group had the greatest attitude increase. In addition, the individualized learning group showed a more positive attitude toward coding music notes on a robot after their robotics activities. Lastly, the individualized learning group showed a more positive attitude toward participation in music composition after their robotics activities.

4.1.2. Attitude toward coding

Participants’ attitudes toward coding are positively changed after the robotics music programming activities. Calculating the means of the coding attitude tests in two learning groups, traditional and UMC, produced 17.67 for the pre-test and 21.64 for the post test (scale range: 10 items × 5 points = 10–50). Figure **5** shows the attitude changes with the general tendency of a positive increase.

According to Figure **5**, participants in two groups displayed attitude increases. To test the significance of these changes, the means of the two groups’ attitude scores were calculated and an ANCOVA (Analysis of Covariance) procedure with the pretest score as a covariate from SPSS was applied. The means of the scores on the posttest for the attitude toward coding were 21.84 (SD=2.04) for the traditional group and 21.46 (SD=4.44) for the UMC group. See Table **11**. The difference of the means for the two groups was

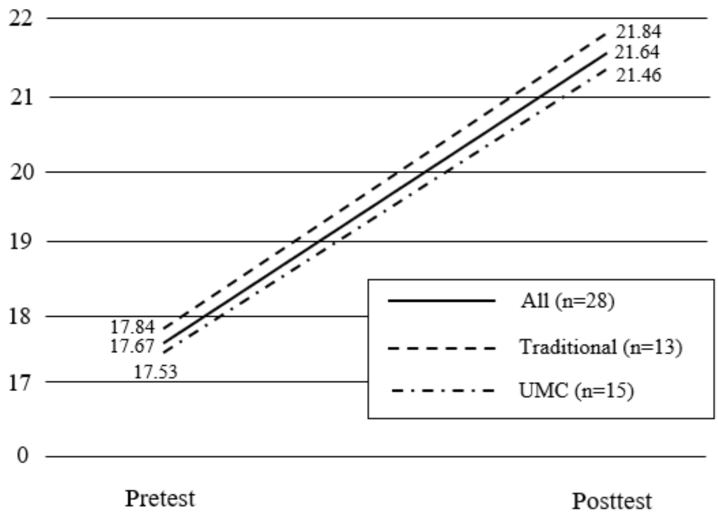

Figure 5: Changes in students attitudes toward coding for the traditional and UMC groups (maximum possible score=75).

Table 11: ANCOVA for Sum of the Attitude Toward Coding

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	113.647[a]	2	56.823	5.096	
Intercept	188.219	1	188.219	16.879	
Pretest Sum	48.152	1	48.152	4.318	
Learning Modes	88.049	1	88.049	7.896	< .01
Error	278.782	25	11.151		
Total	14748.000	28			
Corrected Total	392.429	27			
R Squared = .290 (Adjusted R Squared = .233)					

significant (F(1,25)=88.049, p < .001). The UMC group showed a more positive attitude toward coding after their robotics activities than the traditional group.

Because the overall attitude toward coding showed a significant difference between the two learning modes: traditional and UMC, it would be good to see which domain of the coding attitude produces the difference. The attitude toward coding consisted of three domains: confidence in coding, internal motivation toward coding, and coding with robots. Means and ANCOVA tests with each domains' pretest scores as covariates were presented in order.

The domain of 'confidence in coding' has the meaning of 6.69 (SD=1.88) and 8.13 (SD=3.02) for the traditional and UMC groups, respectively. See Table **12**.

According to Table **12**, the difference of the means for the two groups was significant (F(1,25)=17.948, p < .01). The UMC group showed a more positive attitude toward confidence in coding after their robotics activities.

The domain of internal motivation toward coding has the means of 5.31 (SD=3.41) and 7.27 (SD=3.67) for the traditional and UMC groups, respectively. See Table **13**.

The difference of the means for the two groups was significant (F(1,25)=37.366, p < .05). The UMC group, however, showed a more positive attitude toward coding after their robotics activities.

Lastly, the domain of 'coding with robots' has the means of 9.00 (SD=2.12) and 8.67 (SD=2.71) for the traditional and UMC groups, respectively. However, the result of ANCOVA analysis for the two groups revealed that this difference was not significant.

In summary, after the robotics music programming activities participants' attitudes toward coding positively changed. Participants in two learning modes have attitude increases. The UMC group showed a more positive attitude toward coding than the traditional group. The UMC group showed a more positive attitude toward confidence in coding after their robotics activities.

4.2. Findings from Thematic Analyses

4.2.1. Attitude toward Music Composition

Interviews with eight students were analyzed using a thematic analysis method suggested by Clarke and

Table 12: ANCOVA for Sum of the Attitude Toward Confidence in Coding

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	127.733[a]	2	63.867	27.899	
Intercept	15.876	1	15.876	6.935	
Pretest coding	113.272	1	113.272	49.480	
Learning Modes	17.948	1	17.948	7.840	< .01
Error	57.231	25	2.289		
Total	1745.000	28			
Corrected Total	184.964	27			
R Squared = .691 (Adjusted R Squared = .666)					

Table 13: ANCOVA for Sum of the Attitude Toward Internal Motivation

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	181.173[a]	2	90.586	13.071	
Intercept	103.934	1	103.934	14.997	
Pretest motivation	154.447	1	154.447	22.286	
Learning Modes	37.366	1	37.366	5.392	< .05
Error	173.256	25	6.930		
Total	1486.000	28			
Corrected Total	354.429	27			
R Squared = .511 (Adjusted R Squared = .472)					

Braun (2016). A semantic approach was taken when analyzing the interview data, meaning that the analysis focused on the explicit content of the students' responses rather than interpreting underlying assumptions or latent meanings. This approach aimed to capture the surface-level meaning of the language used by participants, staying close to their actual words and intended messages. Following this, inductive codes were developed in NVivo based on the students' responses, allowing repeated ideas, phrases, and patterns to emerge organically from the data rather than being predetermined by existing theories or frameworks.The research themes were refined through coding analysis. Three themes resulted from the analysis of the attitude toward music composition: *Willingness to participate in Music Composition, Attractiveness of Coding Music Notes on a Robot, and Sharing Robotics Music* (See Table **14**). Students expressed that participation in music composition through robotics activities was a good feeling and they desired to continue their robotics activities. One student reported, "*I'm very proud of myself for working hard*." (Student A). Another student stated, "*I feel really good, like I learned to do something difficult.*" (Student B). The second theme was "*Attractiveness of Coding Music Notes on a Robot.*" in which they expressed their excitement to code a song onto a robot. A student stated in the post interview, "*I feel so happy when I master it because it probably took a long time.*" (Student C). '*Sharing Robotics Music*' was the third advantage that they could enjoy during their robotics activities. The students were able to share their music composition with their classmates. One student said about this, "*It's just so much fun to play music for other people and people who love the song.*" (Student A).

Similarities and differences were observed in class and in the pre and post interviews. One similar attitude towards music composition between the learning modes was a feeling of excitement for accomplishing coding a song onto a robot. One student in the UMC group stated, "*it makes me really excited to code a song correctly onto the robot.*" Another student in the Individualized group said, "*I feel really excited when I code correctly on the robot.*"

Differences in attitudes towards music composition are characterized by different emotional responses. For example, one student in the UMC group stated, "*it just makes me happy to think someday that I will be able to play like that*" whereas a student in the collaborative group said, "*I sort of feel envious that the person playing the song can play that good.*"

Table 14: Attitude Toward Music Composition Themes

Theme	Definition	Quote	Learning Mode
Willingness to participate in Music Composition	Participation in music composition through robotics activities produces a desire to continue robotics activities.	"*I want to keep doing robotics projects like this because it's so much fun.*" "*After composing my song, I'm excited to try another robotics music challenge.*"	UMC UMC
Attractiveness of Coding Music Notes on a Robot	Expressing excitement to code music onto a robot.	"*I feel so happy when I master it because it probably took a long time.*"	Individual
Sharing Robotics Music	Sharing music composition with classmates	"*It's just so much fun to play music for other people and people who love the song.*"	UMC

Table 15: Attitude Toward Coding Themes

Theme	Definition	Quote	Learning Mode
Increased Confidence in Coding	Developing confidence in coding through robotics activities by successfully completing coding challenges on autonomous robots.	"*I prefer using C because that makes it so I can tell exactly what I want the robot to do*." '*I really enjoyed writing code on C coding language.*'	Individual Traditional
Enhanced Internal Motivation Towards Coding	Being driven by an internal desire to successfully write a coding program on a robot.	"*I was really excited when I got that program coded successfully. I showed two of my friends that were in my class.*'	Traditional
Fun Coding with Robots	Enjoyment of the successful coding project.	It's *something that I love to do because it's just so much fun to play music for other people and people who love the song.*"	UMC

4.2.2. Attitude toward Coding

Three themes to emerge from the analysis of the attitude toward coding include: *Increased Confidence in Coding, Enhanced Internal Motivation Towards Coding, and Fun Coding with Robots* (See Table **15**). Students expressed confidence in the coding activities on autonomous robots. One student stated, "*I prefer using C because that makes it so I can tell exactly what I want the robot to do*." (Student D). Another student added, '*I really enjoyed writing code in C coding language.*' (Student F). The second theme was 'Enhanced Internal Motivation Towards Coding*'* in which students expressed their feelings of accomplishment. One example is, "*I was really excited about when I got that program coded successfully. I showed two of my friends that were in my class.*' (Student E). 'Fun Coding with Robots*'* was the third advantage students reported. One student said, `...it's *something that I love to do because it's just so much fun to play music for other people and people who love the song.*" (Student A).

The similarities and differences of students' attitudes within the four learning modes were noted during classroom observations and pre and post interviews. The similarities between the learning modes are exemplified by a student in the collaborative group stating, *"C coding is writing code. It's harder than block coding".* Similarly, a student in the traditional group said, *"C, I think it's a lot more difficult ".*

Differences in learning modes included one student in the collaborative group stating, *"I prefer block coding".* (Student G). Whereas a student in the individualized group said, *"I prefer C because I get to type it".*

5. DISCUSSION, CONCLUSION, AND SUGGESTIONS

Positive attitudes toward music education can be encouraged, as demonstrated by the participating 5th grade students, by integrating educational robotics into the curriculum. This study suggests that students become actively engaged in music education when they have the opportunity to integrate robots. Robotics in music education enable students to create rhythms, play melodies, and compose simple songs, making music more interactive. Abstract music ideas become something students can see and manipulate with robotics. Hands on music education makes music composition more fun but also builds coding skills, increases confidence, collaboration, and problem-solving abilities. Music education can benefit from integrating coding and robotics by allowing students to see music as a creative, technology-enhanced field, leading to positive attitudes towards music composition. However, this study's findings are based on a relatively small sample of 80 fifth-grade students from a single school, which may limit the generalizability of the results to other grade levels, regions, and socioeconomic contexts. The six-week intervention period is also relatively short, and changes in student attitudes may require longer-term observation to fully capture sustained effects.

Attitudes toward music composition improved positively following the robotics coding activity, with the individualized learning group exhibiting the most significant attitude increase. These findings compare with another study by Sullivan *et al*. (2017), who discovered that the emerging field of robotics can provide playful strategies to engage young children with STEAM technology and engineering components.

Moreover, participants' attitudes toward coding also improved positively after the robotics activity. The UMC group demonstrated a more favorable attitude toward coding compared to the traditional group, and they also showed increased confidence in coding. These results support the findings of Gorson *et al*. (2017), which concluded that integrating computational thinking into artistic fields enhances participation in computer science. Furthermore, this study also compares with research by Khine (2018), who stated that educational robotics offers rich opportunities to integrate not only STEM but also various other disciplines, including literacy, social studies, dance, music, and art. This integration enables students to collaborate, express themselves using technological tools, solve problems, and think critically and innovatively.

Collaborative, Individualized, Traditional, and UMC learning modes were implemented in this study. Similarities and differences among learning modes were observed in class and in the pre and post interviews in terms of attitudes toward music composition and attitude toward coding. The students in the study had various levels of experience in music composition, music knowledge, and coding a song onto a robot. This study demonstrates that music education activities using robotics positively affects attitudes toward music composition and coding.

Based on the findings, it is recommended that educators consider integrating robotics into music education to enhance learning outcomes. Bell and Bell (2018) highlighted clear connections between music and computation but emphasized that combining authentic computational thinking with meaningful music-making experiences opens new avenues for student engagement and interdisciplinary learning. Incorporating robotics into music instruction can foster a rich educational environment that supports both STEAM integration and the development of computational thinking skills.

CONFLICTS OF INTEREST

The author declared no conflicts of interest.

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