



# Science, Technology, Engineering, Arts, and Mathematics (STEAM) Integrated Curriculum in the Elementary School

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## Abstract

An interdisciplinary research team consisting of university professors and elementary school educators examined the impact of Science, Technology, Engineering, Arts, and Mathematics (STEAM) programs at an elementary school in Florida, United States, and the elementary school students' knowledge, identities, and attitudes toward STEAM learning experiences. In this paper, researchers discuss the findings of this explanatory mixed methods study (Fraenkel et al., 2012), by following up the quantitative analysis with qualitative inquiry to gain deeper insight into of participants' responses on a pre-activity questionnaire and a post-activity questionnaire. Open-ended responses on the pre- and post-questionnaire were thematically coded independently by three researchers using a priori codes and discussed collaboratively to connect to quantitative analysis. Research questions include: what are participants' self-reported STEAM knowledge, identity, and attitudes before and after participating in the lessons, and how did the STEAM lessons impact participants' STEAM knowledge, identity, and attitudes? Results indicate an increase in knowledge of figuring out how devices and applications work and solving problems with technology. Concerning identity, students indicated higher recognition in programming robots and utilizing technology while attitudes increased in multiple dimensions, including a desire to consider future STEAM careers. Teaching and learning strategies for reforming elementary school Science, Technology, Engineering, and Mathematics (STEM) and STEAM education in the United States as a dependable human resource for a competitive workforce is a significant part of the study and impacts the field of education.

**Keywords:** Science Technology Engineering Arts and Mathematics (STEAM) education, curriculum integration, student knowledge, student identities, student attitudes

## **1. Introduction**

Recent research has emphasized the value of incorporating the arts into Science, Technology, Engineering, and Mathematics (STEM) education, creating Science, Technology, Engineering, Arts, and Mathematics (STEAM) education, in K-12 settings to nurture creativity, practical learning, design thinking, and prepare students for the workforce (Chistyakov et al., 2023). This integration approach gained political recognition with the establishment of the Congressional STEAM Caucus (2013), aimed at highlighting the importance of arts in education. Advocates argue that STEAM education encourages diverse forms of expression, stimulates critical and innovative thinking, and boosts student engagement (Congressional STEAM Caucus, 2013; President's Committee on the Arts and Humanities, 2011). The acronym STEAM may suggest a simplistic addition of "arts" to Science, Technology, Engineering, and Mathematics (STEM) education (Piro, 2010), but its scope extends beyond merely adding arts projects to the curriculum to a deeper pedagogical approach. Educators, drawing from Gardner's (1999) theory of multiple intelligences, underscore the need to adapt teaching methodologies to accommodate various learning styles, incorporating dynamic activities to enhance student involvement. Moreover, educators stress the importance of integrating curriculum across subjects, facilitating collaborative discussions within small groups and extending learning beyond the classroom. STEAM represents a broader educational paradigm emphasizing creativity, interdisciplinary approaches, real-world applications, and project-based learning (Kim & Park, 2014).

While curriculum integration is not novel, in this paper, the researchers aim to explore optimal educational approaches for the elementary level STEAM curriculum, aimed at improving student outcomes in these disciplines. The research team including: two educational technology associate professors from Florida Atlantic University (FAU), one visual art education professor (FAU), one graduate research assistant (FAU), one director of arts integration and creativity, one arts integration specialist, and one third-grade teacher, was specifically interested in working with robots and coding, science concepts, and visual art concepts. The research team collaboratively planned three lessons (sessions of 1.5 hours each) within a science unit of study, and from that framework, devised the lesson series that would apply the students' prior knowledge and deepen it by exploring the different types of stars and integrating coding, robotics, and visual art. The research contributes to the broader field of education, particularly in STEM and STEAM, by identifying effective strategies for implementing elementary level STEAM education through integrated and thematic activities (Chistyakov et al., 2023; Marshall, 2016).

## **2. Literature Review**

To fully leverage STEAM education, an inclusive perspective that embraces interdisciplinarity, including design thinking and robotics is needed (Henriksen, 2017). Such an integrated approach requires support structures to enable teachers to navigate the complexities of integrating diverse subjects creatively and scaffold student learning. The addition of design thinking to the framework of STEAM education offers a structured approach for educators to develop interdisciplinary practices, guiding both their own thinking and their students' STEAM learning experiences (Henriksen, 2017). Design thinking refers to the cognitive skills and problem-solving practices employed by designers in a variety of fields (Cross, 2001, 2011). Scholars and practitioners increasingly recognize its potential in education, emphasizing design thinking applications to foster innovative learning experiences (Norton & Hathaway, 2015; Kirschner, 2015). The design thinking process can be described through five stages: Empathize, Define, Ideate, Prototype, and Test (Hasso-Plattner Institute of Design at Stanford d.school, n.d.). Using this cycle to promote innovative design thinking skills

and processes, educators can encourage students to explore the user's needs (empathize), describe a problem (define), creatively brainstorm ideas (ideate), create representations of potential solutions (prototype), and try out the solutions and further adapt as necessary (test). Students have opportunities to apply critical and creative thinking skills in a structured environment guided by the educator to learn through the design thinking process. This type of inquiry promotes empathetic observers who listen, carefully observe, and deeply comprehend problems. Students can collaborate to solve problems and hone personal strengths or interests to creatively design innovative solutions (Hasso-Plattner Institute of Design at Stanford d. school, n.d.)

The research study included the integration of robotics, coding, visual art, and science concepts through a STEAM unit of study. Robotics are often used as a tool for the development of computational thinking in the K-12 classroom. Zhang, et al. (2021) describe educational robots as a popular and important tool widely used in STEM, sociology, dance, music, art, and other disciplines. They attribute the popularity of open-source programming, combined with the robot's openness and friendly interaction have made robotics an important tool for cultivating students' innovative practice, analysis, and problem-solving skills (Zhang, et al., 2021). Robotics education and its educational values has not only been extolled for its role in learning but has also been identified as a pathway to broaden participation in STEM and STEM-related careers by encouraging students' abilities to code (Sheridan et al., 2013). Of particular interest to this research which focuses on elementary students' STEAM identities, attitudes, and knowledge many scholars and researchers strongly believe that students' STEM attitudes are particularly important and are closely related to their future investment in the STEM field. Positive perceptions and active engagement in STEM activities may increase students' STEM attitudes (Bonvillian, 2002).

### 3. Methods

This mixed-methods research study examined how the implementation of science, technology, engineering, art, and mathematics (STEAM) lessons into a third-grade class at a South Florida independent school influenced participants' STEAM knowledge, identity, and attitudes toward STEAM and asked the following research questions (RQ):

1. What are participants' self-reported STEAM knowledge, identity, and attitudes before and after participating in the lessons?
2. How did the STEAM lessons impact participants' STEAM knowledge, identity, and attitudes?

An explanatory mixed methods design was utilized, as described by Fraenkel et al. (2012). By following up the quantitative analysis with qualitative inquiry, the researchers gained a deeper insight into the qualitative findings. In doing so, first, the researchers evaluated the quantitative research question (RQ1) and then followed up with qualitative analysis (RQ2) to refine the quantitative findings. The research procedures are described in the subsections that follow.

### 4. Data Collection

Data for this study was collected using a pre-and post-test survey created with *Qualtrics* software. The surveys were administered electronically through a collection link given to their teacher by the researchers. The participants completed the surveys at school under the supervision of their teacher using individual tablets. Participants completed the pre-test survey before the STEAM lessons took place and a follow-up post-test survey shortly after the

instruction. Although all students were presented with the surveys, participation in the research was voluntary, and thus, only those students who agreed to participate were included in this study.

The two surveys included the same questions regarding knowledge, identity, and attitudes toward STEAM but differed slightly in that the researchers did not repeat asking the demographic questions on the post-test survey; and included different open-ended questions on each. The first item on each survey was the optional consent of the student to be included in the study. The next group of items was designed to collect demographic and background information about the participants' gender, age, and race. To measure participants' STEAM knowledge and identity, the researchers adapted items from the survey used by Rodriguez et al., 2019. Items measuring knowledge utilized a 5-point Likert scale ranging from "no understanding" to "full understanding." The dimensions of identity explored in the survey, including performance, self-recognition, and external recognition, were also measured on a five-point scale but used endpoints ("strongly disagree" to "strongly agree"). Items from the instrument used by Yadav et al. (2017) were adapted to assess participants' attitudes toward STEAM in three categories: Comfort, Interest, and Future STEAM. In addition, several open-ended survey items were included to gather qualitative data for this study.

#### **4.1. Research Site and Participants**

The Foundations School (TFS), housed within the Center for Creative Education (CCE), is an independent elementary school established in 2021 and located in West Palm Beach, Florida USA. Its mission is to "transform teaching and learning through creativity and the arts" (Center for Creative Education, 2024). The majority of students at TFS come from economically and socially challenging backgrounds and are considered "at risk" of academic underachievement. By employing arts integration as its instructional approach, The Foundations School aims to engage students through various means, inspiring their creativity and providing multiple avenues for demonstrating knowledge and achieving academic success.

In the third-grade class, 11 students participated in the survey. Of these, ten participated in both the pre-survey and post-survey, and only one student participated in the post-survey. The participants were five boys and five girls, and since one student did not participate in the pre-survey, the gender remains unclassified. The average age of participants was 8.5 years old. The Center's Director of Arts Integration and Creativity facilitated the school's participation by preparing the students for their role in the study, administering the consent forms, the pre-post surveys, and digitally documenting the process. The students had little prior experience with robotics, so they were excited at the prospect of learning about coding and at the opportunity to participate in a research project.

#### **4.2. Data Analysis**

Both quantitative and qualitative analysis methods were utilized in this study to answer the research questions. More details are included in the following sections.

##### **4.2.1. Quantitative Analysis**

The quantitative data were entered into SPSS® 27 software for analysis. Descriptive statistics were calculated for self-reported demographic and background variables to paint a picture of the study's participants. Then, to answer RQ1, the researchers summarized the items from both surveys regarding knowledge, identity, and attitudes toward STEAM by calculating descriptive statistics.

#### **4.2.2. Qualitative Analysis**

Using deductive or a priori coding (Bingham & Witkowsky, 2022) for each category of attitudes, knowledge, and identity, three researchers on the team independently coded the twelve participants' responses on the qualitative questions in the pre/post surveys. The pre-defined codes were applied through a color-coding system to the responses and were derived from existing literature and theoretical frameworks that guided the study (Bingham, 2023; Rodriguez et al., 2019). The a priori codes for attitudes included: art interest, science interest, technology interest, and technology comfort. The a priori codes for knowledge included: art knowledge, science knowledge, and technology knowledge. The a priori codes for identity included: self-recognition, external recognition, and future with STEAM. As codes often emerge from the data, the inductive analysis process allowed for codes, categories, patterns, and themes to arise (Miles, et al., 2020). Researchers discerned and labelled emergent elements during the data examination. For the pre-test survey data, one code emerged for design thinking. The same three researchers met to discuss their independent coding analysis and discussed interpretations of data for qualitative analysis.

#### **4.3. Purpose of the Study**

The purpose of the study is to gain a deeper understanding of elementary students' STEAM identities, attitudes, and knowledge before and after participating in a STEAM class. The goal of this research is to provide information to inform the field of education on effective STEAM teaching and learning strategies that can be adapted or implemented in other educational settings. The results are of STEAM classes at a specific South Florida elementary school and although the results are not generalizable, the research gathered is valuable to educators interested in developing similar STEAM programs.

### **5. Curriculum Description and Data**

The third-grade students were engaged in a unit of study focused on a science concept, "Earth in Space and Time." The researchers collaborated to design a unit of three lessons entitled, "Stellar Explorers: Discovering the Stars of the Universe." During the first visit, two FAU researchers introduced the project to the students, including vocabulary and example stars and tasked them with researching the star of their choice, with the understanding that they would be using this research during the second visit to create a watercolor wax resist representation of their star, highlighting its key features. The students wrote down what they discovered and drew a color sketch of their subject using a template format given by the researchers. After the students completed their sketches, the research team demonstrated the robots and explained the concept of coding (see Figure 1). The robotics demonstration was an excellent way to heighten the anticipation for the upcoming visits; several of the students noted that this felt more like "play" than "school," and they each wanted an opportunity to try using the iPad to command the robot. The education staff at the school noted that one of the students who is identified as neurodivergent was extremely engaged in this activity, which would prove to hold for the subsequent two visits.

*Figure 1. Initial Robotic Coding Experience*



*Note.* Photograph taken by researcher, Dr. Susan Gay Wemette

At the second visit, the students visited the art lab with their research and sketches in hand to use as a guide for their watercolor paintings (see Figure 2).

*Figure 2. Student watercolor painting of star*



*Note.* Photograph taken by researcher, Dr. Susan Gay Wemette

While the students were familiar with the idea of using crayon wax to resist the water in the paint, they were fascinated to see what happened when the salt was sprinkled onto their work. This discovery led to a discussion about chemical reactions and absorption, as well as some predictions about what the results would be when the paintings were completely dry. Students happily shared their paintings with class and explained the artistic and scientific processes used in its creation (see Figure 3).

*Figure 3. Student painting a star*



*Note.* Photograph taken by researcher, Dr. Susannah Brown

On the third and final visit, the FAU team combined the students' new knowledge about stars, their artwork, and their excitement for learning the process of coding into the creation of three "star maps," which served as the culmination of the project. The students' paintings served as the various designation points on the three maps and were taped to the floor for stability (see Figure 4).

*Figure 4. Student with researcher coding robot to travel the star map*



*Note.* Photograph taken by researcher, Dr. Susan Gay Wemette

The class was grouped into teams of four and each given an iPad loaded with Blockly, a Google-driven educational coding program. The students in each group created pieces of code that would drive (or spin, dance, jump, sing, etc.) the robot through the group's star map. Two of the teams achieved their goal of navigating their star maps and using the robots' voice features to announce their success (see Figure 5).

*Figure 5. Students observing a team's robotic star map*



*Note.* Photograph taken by researcher, Dr. Susan Gay Wemette

One student in the third team accidentally erased the group's coding; while they were not able to complete the assignment as planned, they did understand the coding process and were able to explain their intended outcome. During this lesson, the researchers noted that one adult needed to be assigned to each collaborative group to assist throughout the lesson for ease of time and task management.

## 6. Results

What were the self-reported levels of STEAM knowledge, identity, and attitudes before and after participating in the lessons? To answer this question (RQ 1), descriptive statistics for participants' self-reported ratings of pre-and post-test survey items that measured these concepts are presented and discussed.

### 6.1. STEAM Knowledge

Descriptive statistics for the three survey items that measured STEAM knowledge are shown in Table 1. The pre-test mean score for the item "I am good at explaining science concepts to other people" indicates that students rated themselves moderately in their ability to explain scientific topics to others. The post-test mean score fell slightly to 2.75, showing a slight loss in students' perceived ability to convey science topics to others following the intervention. Regarding the next survey item, the pre-test mean score indicates that students ranked themselves fairly high regarding their ability to figure out how devices and apps work. The post-test mean score rose slightly for this item to 3.71, showing a minor improvement in students' self-perceived competence in this area following the intervention. The final statement, "I am good at solving problems with technology," within STEAM knowledge showed the greatest increase in the mean between pre- and post-intervention with an increase of 0.37. This suggests that after working with the iPads and robots, students perceived themselves to be better at problem-solving with technology than before.

*Table 1. Descriptive Statistics of Participants' STEAM Knowledge*

|                                                           | Pre-Test |                | Post-Test |                |
|-----------------------------------------------------------|----------|----------------|-----------|----------------|
|                                                           | Mean     | Std. Deviation | Mean      | Std. Deviation |
| I am good at explaining science concepts to other people. | 3.00     | 1.512          | 2.75      | 1.389          |
| I am good at figuring out how devices and apps work.      | 3.57     | 1.195          | 3.71      | 1.282          |
| I am good at solving problems with technology.            | 2.88     | 1.126          | 3.25      | 0.707          |

*Note.* Table created by Dr. Jillian Powers and Robert Bogle, research team

### 6.2. STEAM Identity

The descriptive statistics for survey items that measured various dimensions of STEM identity are presented in Table 2. The first statement focused on the STEAM identity dimension of competence, "I can program robots to do what I want them to do," and showed the largest increase in mean self-reported scores, an increase of 1.5. This provides evidence that the students felt more competent at controlling the robot post-intervention. Moderate increases in mean self-reported scores for both of the STEAM identity items in the dimension of external recognition, which focused on whether participants believed their teachers viewed them as someone "who is smart" when it comes to science and technology, also showed moderate increases in pre- and post-test mean self-reported scores. Lastly, the STEAM identity item in the self-recognition area, "I am good at solving problems with technology," also showed a moderate increase in third-graders self-reported scores from pre- to post-test, with the mean increasing from 2.88 to 3.25.

Table 2. Descriptive Statistics of Participants' STEAM Identity

|                                                                                         | Pre-Test |                | Post-Test |                |
|-----------------------------------------------------------------------------------------|----------|----------------|-----------|----------------|
|                                                                                         | Mean     | Std. Deviation | Mean      | Std. Deviation |
| I can program robots to do what I want them to do. (competence)                         | 2.38     | 1.506          | 3.88      | 1.458          |
| My science teachers see me as someone who is smart in science. (external recognition)   | 3.00     | 1.000          | 3.86      | 1.069          |
| My technology teachers see me as someone smart using technology. (external recognition) | 2.75     | 1.035          | 3.50      | 1.309          |
| I am good at solving problems with technology (self-recognition)                        | 2.88     | 1.126          | 3.25      | .707           |

Note. Table created by Dr. Jillian Powers and Robert Bogle, research team

### 6.3. Attitudes Toward STEAM

In Table 3, the descriptive statistics for survey items that measured attitudes toward STEAM are presented. The pre-test average mean scores indicate that students' attitudes toward STEAM increased in each of the dimensions examined. The self-reported mean for the survey item that focused on comfort, "I am good at STEAM," increased from 2.75 to 3.88, indicating the intervention has a positive impact on students' comfort with the STEAM model of learning. Next, the mean self-reported scores for the statement that focused on interest, "I like to imagine creating new things," increased from 4.00 to 4.38, which was slight, but it is also interesting to note that it was the only survey item on which these third graders reported a mean of 4.0 or above. The final statement, "I would consider a career that involves STEAM," yielded a self-reported mean that increased by 1.0, indicating the intervention that the students engaged in had a positive impact on their future STEAM career ambitions.

Table 3. Descriptive Statistics of Participants' Attitudes Toward STEAM

|                                                               | Pre-Test |                | Post-Test |                |
|---------------------------------------------------------------|----------|----------------|-----------|----------------|
|                                                               | Mean     | Std. Deviation | Mean      | Std. Deviation |
| I am good at STEAM. (comfort)                                 | 2.75     | 1.165          | 3.88      | 1.126          |
| I like to imagine creating new things. (interest)             | 4.00     | 1.604          | 4.38      | .744           |
| I would consider a career that involves STEAM. (future STEAM) | 2.25     | 1.282          | 3.25      | 1.581          |

Note. Table created by Dr. Jillian Powers and Robert Bogle, research team

Overall, the statistical findings indicate that the intervention positively affected students' self-perceptions in different STEAM knowledge, identity, and attitudes. While there was a small drop in the average mean of one of the STEAM knowledge items ("I am good at explaining science concepts to other people"), the third-grader's self-reported means for all other survey items was greater on the post-test than on the pre-test.

### 6.4. Qualitative Findings

How did the STEAM lessons impact participants' STEAM knowledge, identity, and attitudes? The pre/post-test survey data indicated that participants' knowledge levels of

STEAM concepts (RQ2) were impacted in a variety of ways, as evidenced by their responses. Ten participants indicated that art integrated with science concepts impacted their knowledge of STEAM, with two participants replying that they did not know how their knowledge was impacted. Several students explained the science concepts in the art project about the use of salt with watercolors and using wax crayons to resist the watercolor. When asked about knowledge of robots and technology and to think about a robot that could help people, participants responded creatively. One participant replied about the robot: "It would create whatever I wanted to create. And it would make the creations by me texting the ideas to the brain." Another participant responded that their knowledge and confidence in working with robots increased because of learning to code.

Concerning the STEAM identities of the participants, prior to this study, students had not experienced coding robots, and their responses on the pre/post-test surveys clearly indicated that their identities about art, science, coding, and robotics resulted in self-recognition of STEAM abilities and possible future in STEAM. One participant responded: "Because I love to make things and look at them and be proud of myself." This response indicated self-recognition. STEAM attitudes were impacted as evidenced in the pre/post-test survey data as patterns of specific themes were indicated in the attitudes (RQ2) of participants with interest in art being noted more often than interest in technology and science. Another participant responded: "I am really excited for art!!!!!" One participant responded that learning how to code robots: "It changed all that fear and made it into happiness." Another participant responded about coding robots: "It's fun about the robots, and we learned a lot." One participant responded: "I wonder if markers can work too?"

## **7. Discussion**

Participation in this study demonstrated an untapped well of learning opportunities for both the students and the teachers. No one currently on staff has much, if any, experience with coding or robotics, so seeing the students' excitement and the various ways these ideas could be implemented in units of study highlighted the need for professional development in this area.

The discussion is framed regarding the research questions: (RQ1) What are participants' self-reported STEAM knowledge, identity, and attitudes before and after participating in the lessons? And (RQ2) How did the STEAM lessons impact participants' STEAM knowledge, identity, and attitudes? The study findings indicated that the STEAM lessons impacted participating third graders' art, science, and technology knowledge, identity, and attitudes in a variety of ways.

Regarding knowledge, though there was a decrease in mean scores for one science question, both self-reported means for survey items measuring technology knowledge increased from pre-test to post-test. Since participants had very little experience coding robots prior to the study, the increase in coding knowledge is clear. Concerning increasing art knowledge, one participant responded in the open-ended survey responses: "I wonder if markers can work too?" This indicates that participants are thinking beyond the demonstrated project and are willing to experiment to increase their knowledge of the topic.

Regarding identity, this research also suggests that STEAM (art, science, and technology) identities were positively impacted through informal STEAM learning experiences. In the open-ended survey items, participants cited two dimensions of STEAM identity, self-recognition, and external recognition, multiple times. One participant's comment about designing robots to help people was, "Yes, I can imagine anything." This type of response indicates a high level of self-recognition and confidence.

Regarding attitudes, technology comfort levels were shown to be positively impacted by participants' comments on the open-ended questions as well as in the quantitative findings, as shown by the increase in the self-reported scores for the survey item "I am good at STEAM." Since the school's program focuses on arts integration throughout the curriculum, the interest in art as an indicator of their attitudes towards STEAM can be attributed to the many experiences that the students have daily that pertain to art. Also, the students often utilize technology with individual tablets for research on many different topics, including the topic of stars, which was the theme of the STEAM lesson. The interest in science may also be attributed to the curriculum and theme of stars for this study. Participants noted that attitudes towards technology and comfort with technology were increased.

Upon analyzing the results of the study, it may indeed provide a compelling case for the school to pursue funding for equipment and training to implement a coding and robotics program. While the school provides students with 1:1 iPads for research and study, the full implications of the study may suggest that investing in additional resources for coding and robotics could greatly enhance the educational experience and opportunities for students.

## 8. Conclusion

Art integration nurtures creativity and expression, enabling students to explore concepts innovatively (Marshall, 2016). Art integration to create a STEAM pedagogical approach serves as a means for self-discovery and confidence-building and facilitates collaboration and communication, which are crucial skills for success in academic and real-world scenarios (Chistyakov et al., 2023). For at-risk students who may have limited exposure to technology outside of school, the opportunity to engage with coding, robotics, and other technology tools enhances their digital literacy (Zhang, et al., 2021). It fosters problem-solving and higher order thinking skills, ultimately levelling the playing field and equipping them for future academic and career endeavours. By integrating science, technology, and the arts into the curriculum, educators can offer diverse avenues for engagement and learning, supporting various learning styles and interests.

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