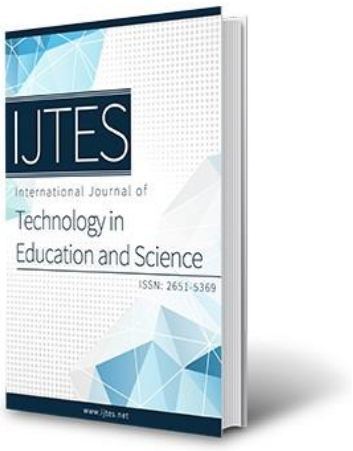

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Kalani Eggington
Utah Valley University, United States of America

Andrew Goodman
Utah Valley University, United States of America

Krista Ruggles
Utah Valley University, United States of America

To cite this article:

Eggington, K., Goodman, A., & Ruggles, K. (2024). Enhancing elementary students' knowledge and attitudes about STEM through a student-led STEM fest. *International Journal of Technology in Education and Science (IJTES)*, *8*(2), 219-232. https://doi.org/10.46328/ijtes.544

IJTES International Journal of Technology in Education and Science
2024, Vol. 8, No. 2, 219-232 https://doi.org/10.46328/ijtes.544

Enhancing Elementary Students' Knowledge and Attitudes about STEM through a Student-Led STEM Fest

Kalani Eggington, Andrew Goodman, Krista Ruggles

Article Info

Article History

Received:
25 January 2024
Accepted:
28 March 2024

Keywords

STEM
STEM fairs
Cross-grade collaboration
Engineering design process

Abstract

Nationwide, low numbers of students are entering STEM-related fields. This is especially true for underrepresented populations and students from rural areas where access to STEM enrichment programs is limited. This qualitative study researched the impact of Micro STEM Fests on 1st to 5th grade students and investigated participating teachers' attitudes toward STEM. The Micro STEM Fest kits used for this study include ten engineering and technology challenges. 5th graders studied and practiced these challenges and then led a Micro Stem Fest for 1st to 4th grade students. Survey and interview data were gathered from participating students and teachers in a rural district. Data was analyzed by grade levels and two themes were identified. Firstly, STEM knowledge was built through handling of materials, engaging in the engineering design process, and enjoying the challenge posed by the concept or activity. Secondly, positive attitudes towards STEM were developed because of their participation, evidenced by students' desire for harder challenges, and expressed enjoyment of autonomous creativity with STEM activities. This paper briefly reviews the literature, describes the methodology, defines and discusses the findings, and makes recommendations for future research.

Introduction

STEM education remains an international topic worthy of focused research and discussion, one that is predominantly driven by concerns about shortages of STEM-prepared workers to maintain a continuously changing, global economy (Kennedy & Odell, 2024). A workforce that is STEM literate refers to an individual's:

- Knowledge, attitudes, and skills to identify questions and problems in life situations, explain the natural and designed world, and draw evidence-based conclusions about STEM-related issues;
- Understanding of the characteristic features of STEM disciplines as forms of human knowledge, inquiry, and design;
- Awareness of how STEM disciplines shape our material, intellectual, and cultural environments; and
- Willingness to engage in STEM-related issues with the ideas of science, technology, engineering, and mathematics as a constructive, concerned, and reflective citizen. (Bybee, 2013)

Increasing students' experiences with STEM areas requires a concerted effort to expose all students to a variety

of STEM-related experiences. Studies have reported the positive impact that exposure to STEM subjects and activities during early childhood can have on language, literacy, and math skills (Mcclure, 2017). This is particularly critical for students from underrepresented and rural populations who often have limited access to STEM enrichment programs (Murphy, 2020). Participation in STEM Fests and similar events shows promise as valuable educational experiences and, as this study demonstrates, positively influences students' knowledge of and attitudes toward STEM subjects.

This paper studies the effect participation in a Micro STEM Fest has on students' knowledge and attitudes toward STEM. First, we briefly explore the literature related to STEM-related activities. Next, we describe the methodology of this study and analyze the findings. Finally, we will discuss the results and offer recommendations for future research.

STEM Fairs and Festivals

STEM-related activities in schools can be conducted in a variety of ways. The most typical is an educational fair where students showcase their scientific or engineering projects, experiments, and research. During the fair, students present their project displays. A panel of judges, often consisting of teachers, scientists, or professionals from STEM fields, evaluates the projects based on criteria such as scientific rigor, creativity, and presentation skills. These fairs encourage students to explore their interests in science and technology, develop critical thinking and problem-solving skills, and gain experience in scientific inquiry. These fairs are commonly organized at the school, regional, and national levels, with participants ranging from elementary school to high school students.

While much of the literature focuses on the typical format of a STEM fair as a competitive event focused on scientific inquiry, there has been an increased interest in engineering fairs. Even when these types of fairs vary in format, they tend to follow an engineering design process where students are "formulating a question, generating a theory-based hypothesis, designing the experiment, conducting the experiment and collecting data, preparing and evaluating data, interpretation, and discussion of the results and their conclusions, and communication of findings" (Paul et al., 2016, p. 2368). Participating in the engineering design process can take place prior to the fair through the development of a product like the Ruth Goldberg Machine (2023) contest or through live participation during the fair. Both require students to critically evaluate a problem and develop a solution.

There is a contention that science and STEM fairs induce anxiety among teachers, parents, and students (Carrier, 2006). Critics also argue that the reliance on formulaic approaches fails to foster genuine engagement with authentic scientific inquiry among students (Magee & Flessner, 2012). These factors should be taken into consideration when planning and facilitating school-wide fairs, in addition to issues of equity and access.

Another STEM-related activity, and one that is considered more equitable in terms of accessibility to all students, is a STEM festival (fest) where students explore activities provided by industry partners, non-profit organizations, and government entities. The purpose of such fests is to expose students to STEM careers and resources in their community. They also serve as a bridge between the classroom and the real world, helping students see the

relevance and importance of STEM in their lives and society. Seeing the exciting projects and achievements of community members can motivate students to pursue STEM studies and careers (Koomen et al., 2021; Sahen et al., 2014).

Knowledge Acquisition

Participation in STEM fairs and fests has been linked to an increase in STEM knowledge among students. Numerous studies have reported that students who engage in hands-on STEM activities, presentations, and demonstrations at such events tend to acquire new scientific knowledge, the capacity to engage in authentic inquiry, and a deeper understanding of STEM concepts (Koomen et al., 2021; Miller et al., 2018). STEM fairs and fests often require participants to design, build, and test their projects. This hands-on approach to learning allows individuals to gain practical knowledge and skills. Acara et al. (2018) found this to be true when they conducted a qualitative study on a group of 4th-grade students who participated in six STEM activities that were integrated into their curriculum. The group of students who participated in the STEM activities demonstrated a significant positive difference in science achievement based on pre-and post-test scores compared to a control group of students who did not participate in the STEM activities. The students who were part of this experimental group also stated that they enjoyed learning more about science and mathematics as a result of the STEM activities and wanted to see more STEM activities in their future courses (Acara et al., 2018).

Similar findings are evident in a study conducted by Sahin et al. (2014) who explored the student outcomes of an after-school STEM program. The researchers concluded that "such after-school program activities may be considered a means to cultivate STEM literacy because students were engaged not only in open-ended and real-world problems but were also provided with the opportunity to acquire both problem-solving skills and experience similar to that which they might encounter in their daily lives" (p. 319). The results of a meta-analysis that focused on the effects of STEM education in schools show that students who receive STEM education demonstrate better academic success and experience a significant positive effect on the development of scientific process skills, including stronger problem-solving and creative thinking skills (Yildirim, 2016). Findings such as these support the notion that STEM-related activities in schools can result in an increase in STEM knowledge among participating students.

Increased Interest and Engagement in STEM

In addition to STEM knowledge and skills being enhanced through participating in STEM-related activities, studies have shown that students also experience an increase in interest and engagement in STEM. Miller et al.'s (2018) research examined the influence of STEM competitions, including robotics, engineering projects, science fairs, and technology events, on students' inclinations toward STEM careers. Their findings indicated that students who engaged in STEM competitions demonstrated a higher propensity to develop an interest in STEM-related careers by the conclusion of their high school education, compared to their counterparts who did not participate in such competitions. Jiang et al.'s (2022) study found that the qualitative and quantitative results from their study of high school alumni in China suggested that STEM competitions can boost students' interest in STEM careers

and promote their persistence in STEM. Koomen et al. (2021) noted that building on students' interests creates a bridge between the process and academic learning. It also provides students with an opportunity to blend their personal and cultural assets with academics, ultimately increasing engagement.

Feille and Wildes (2021) researched a group of elementary students who utilized their personal and cultural assets while participating in an engineering fair. The students chose a real-world engineering problem that needed to be solved, researched, and designed solutions, drew their best solution in prototypes, and presented the process at an engineering fair. It was found that the students experienced an increase in interest in STEM after this experience. At the beginning of the study, the students were demonstrating a passive learning approach related to science and engineering content. By the end of their experience, these same students saw science and engineering in everything. The students also indicated that they felt science and engineering were a lot more fun than they had originally believed (Feille & Wildes, 2021).

Very similar results were found by Salvado et al. (2021) who researched the effects that afterschool STEM workshops had on participating at-risk elementary students. This learning opportunity left students feeling that science was more accessible than originally thought. One student stated, "I thought science was much more difficult, that it was very boring, but it depends on how you do it and if you are focused, it is fun. I have learned that science is not always about numbers and reading and books" (Salvado et al., 2021, p. 6). As demonstrated through these findings, students' participation in STEM-related activities can enhance their interest and engagement in STEM.

Method

This study sought to gain an in-depth understanding of elementary students' experiences participating in a Micro STEM Fest. More specifically, we sought to answer the following research question: "What effect does participation in a Micro STEM Fest have on participating students' knowledge of and attitudes toward STEM?" This Micro STEM Fest consisted of 10 stations. The materials for these stations were loaned to the school by a state university's School of Education in the form of a Micro STEM Fest kit. The kit included the required materials, a description of each station's STEM challenge, and definitions for specific vocabulary words relevant to each station. The following is a list of the ten stations included in the Micro STEM Fest kit:

1. Code & Go Mouse
2. Tetris Puzzle
3. Magnets
4. littleBits Code Kit
5. Hot Wheels
6. Keva Contraptions
7. Cat & Dog Robots
8. K'Nex
9. Snap Circuits
10. Marble Run

Fifth grade students were the first in the school to interact with the Micro STEM Fest kit. Before doing so, however, the 5th grade teachers received asynchronous online training on how to run the Micro STEM Fest at their school. These teachers then used class time to allow their 5th graders to learn how to facilitate each station. Time was allocated during the school day for the Micro STEM Fest to take place. The 5th graders prepared the school's gym for the event by placing the materials for each station on tables. Students from 1st to 4th grade were invited to attend the Micro STEM Fest that was scheduled to last for 1 hour during the school day. The younger students worked together in small groups for 18 minutes at each station trying to complete each station's STEM challenge. The 5th graders ran their assigned stations and were responsible for describing the challenge to the younger students, reviewing the vocabulary associated with the challenge, and answering any of the younger students' questions. The younger students spent 18 minutes at each station before rotating to the next one. Time allowed for them to complete three stations.

To learn more about the students' experiences, a qualitative phenomenological research design (Rossman & Rallis, 2016) was applied to this study. Participants were students and teachers from Evergreen Elementary School and Fountain Valley Elementary School. Pseudonyms have been used to maintain the anonymity of the schools. Both schools are part of the same school district where 54% of students recently scored at or above proficiency for math and 47% scored at or above proficiency for reading (Utah State Board of Education, 2023). Evergreen Elementary School is in a remote rural setting. According to recent demographic data, the population of the community is 750 (American Community Survey, 2021a). The school provides instruction for approximately 120 Pre-Kindergarten to 6th grade students with 53% being minority and 74% percent of the student body being classified as economically disadvantaged.

The 5th graders at this school were provided class time to learn how to facilitate each of the ten Micro STEM Fest stations. Their teacher assisted them during this training period. The 5th graders were then given the responsibility to facilitate these ten stations at a Micro STEM Fest. To learn what this experience was like for the older students who facilitated the stations, we conducted small group interviews with 12 5th graders. Holding the Micro Stem Fest during the school day allowed for students in Grades 1 through 4 to participate. We conducted small group interviews with two 2nd graders, three 3rd graders, and six 4th graders to learn about the impact participating in the Micro STEM Fest may have had on their knowledge of and attitudes towards STEM. We also interviewed the 2nd grade teacher and the 5th grade teacher to learn their thoughts about how this experience may have impacted their students.

Fountain Valley Elementary School also participated in this study. This school is in a remote town setting with a population of 50,300 (American Community Survey, 2021b). The school services 540 Kindergarten to 5th grade students with 20% of them being minority and 49% classified as economically disadvantaged. As was done at Evergreen Elementary School, the 5th graders from Fountain Valley Elementary School learned how to facilitate each of the Micro STEM Fest stations during class time with assistance from their teacher. These 5th graders then facilitated a Micro STEM Fest for students in Grades 1 through 4 held during school hours. We conducted small group interviews with eight 5th grade students to learn about their experiences. We also conducted small group interviews with students from the younger grades who attended the Micro STEM Fest to better understand their

perspectives. More specifically, we conducted small group interviews with eight 2nd graders, and 18 4th graders. The participating teachers' views were also gathered by interviewing two 4th grade teachers and two 5th grade teachers.

In sum, 57 students and six teachers were interviewed. Each interview was audio recorded and transcribed. The constant-comparative method was then used to analyze the data (Boeije, 2002). All data were independently analyzed by three researchers to eliminate individual biases. Initial codes were identified in the interview transcripts. These codes were modified and eventually categorized. The categories were used to identify and create overarching themes that best describe the findings (Boeije, 2002; Rossman & Rallis, 2016).

Results

The purpose of this study was to investigate the effect that participation in a Micro STEM Fest had on participating students' knowledge of and attitudes toward STEM. Two main themes emerged from the interview data. The first theme confirmed that students' knowledge of STEM was enhanced in various ways due to the handling of STEM materials. The second theme showed an increase in students' positive attitudes towards STEM. These themes will now be explored in more detail.

Enhanced Knowledge of STEM

Students' enhanced knowledge of STEM owing to the handling of the Micro STEM Fest kit materials became evident through three sub-themes that emerged from the interview data. More specifically, students referred to specific STEM-related knowledge and vocabulary they gained during their participation in the Micro STEM Fest. They also commented on critical thinking skills used when involved in the engineering design process. Students' enhanced STEM knowledge also became apparent as they extended their new knowledge to verbally design more complicated learning tasks.

New Specific Knowledge and Vocabulary

During the interviews, students referred to new specific knowledge gained from the handling of the Micro STEM Fest kit materials. For example, when asked if they had learned anything from their experience, a 4th grade student from Fountain View Elementary focused on what they had learned about circuits. The student said, "I learned about these (student points at a picture of littleBits). Like you had to connect them and if you didn't have a resource that produced energy, you couldn't get it to move." Another 4th grader from Fountain View Elementary effectively integrated newly acquired vocabulary when asked what they had learned during the Micro STEM Fest. The student focused on electricity and circuits as they explained, "These have to be connected to work…They have to be connected to work so electricity can go through it, so it can power the whole thing…So you put the battery circuit here and if you didn't snap it into here, it wouldn't connect." A 4th grade student from Evergreen Elementary was also asked if they had learned anything from the Micro STEM Fest. They said they liked "learning how to connect things to energy." A 2nd grader from Fountain View Elementary excitedly answered this question

by stating, “It’s very weird that magnetism can actually be electricity because when these things were connected, the lever turned and controlled how fast the arm moved, which was crazy.” One 4th grade teacher from Fountain View Elementary School was surprised by how much her students had learned during the Micro STEM Fest. She overheard two of her students responding to the interview questions being asked for this study and said during her interview, “Well, one thing I noticed is when they were doing their little interviews, some of my higher kids actually had really good answers. They were explaining really what they learned in that teeny, short period of time.” The 5th grade teacher from Evergreen Elementary described her students’ experiences learning new vocabulary. She explained, “So learning the new vocabulary was fun for them about conductors and insulators. And some of them really perk up and want to know those words.” These comments verify that students acquired new STEM knowledge and new vocabulary from participating in the Micro STEM Fest.

Critical Thinking Used When Involved in the Engineering Design Process

Students also referred to aspects associated with being involved in the engineering design process during their interviews. Each of the Micro STEM Fest stations requires students to complete particular tasks using provided materials. A 4th grade student from Evergreen Elementary summarized the cyclical design process they used to complete the tasks in the following way, “So you can build stuff and we have to test, make trials, and see what was wrong.” A 5th grade student who helped to facilitate the stations during Evergreen Elementary’s STEM Fest observed that the younger students were engaged in the cyclical engineering design process during the STEM Fest. This 5th grader stated, “They would experiment and then they would say, ‘Oh!’ They use this and this, like, ‘Oh, this is how you make it go fast and this is how you make it go slow.” A 2nd grader from Fountain View Elementary encapsulated the growth mindset that is inherently associated with the cyclical engineering design process by saying, “You can keep on trying your best.” One of the 5th grade teachers at Fountain View Elementary had several discussions with her 5th graders after the completion of the Micro STEM Fest. She reflected on one of these discussions during her interview by stating, “And one of them, it was interesting, one of them was like, ‘Why did the younger kids do better?’ I’m because they're just not afraid to make mistakes.”

Students also referred to critical thinking skills needed to problem solve during the engineering design process. For example, an Evergreen Elementary 5th grader who helped facilitate the stations stated, “They would have to figure out how many things it would take to get the dog to the ball. And if some didn’t make it, they’d have to do it again and they’d have to learn how to use their brain.” Other students made reference to utilizing critical thinking skills by saying things similar to a 4th grader from Evergreen Elementary who expressed, “I liked how you had to try and use brain power.” A different 4th grader from Fountain View Elementary explained, “You have to take your time on the thing you’re doing.” This increased awareness of the necessity to think critically while trying and retrying new ideas when engaged in STEM-related tasks contributes to students’ overall enhanced knowledge of STEM.

Extension of New Knowledge

Further evidence that supports students’ enhanced knowledge of STEM from participating in the Micro STEM

Fest was their ability to apply their newly acquired knowledge to design more complicated STEM activities they felt could be included in future Micro STEM Fests. For example, a 2nd grade student from Evergreen Elementary referenced the littleBits challenge during her interview. She stated, "It would be fun if you could do more than just a hand. Let's say, but you still have the ball, you have to move around the ball, with a triangle or a circle. That would be very hard." A 4th grade student from Fountain View Elementary also had an idea on how to make the K'Nex station more challenging. They explained, "Like the K'nex. You can try to make a build that can hold a book, like a heavy book, and it won't fall." Another 4th grader from Fountain View Elementary had the following suggestion for the Hot Wheels station. "So with the Hot Wheels, I don't really know how to explain it, but if you were holding the end, you could make this (student gestures making a curve with a track). That would be a challenge to make the car keep going. Something that would let the car keep going up." This extension of the students' new knowledge to design more complex learning situations demonstrates an enhanced understanding of the STEM content integrated into the various Micro STEM Fest stations.

Increase in Students' Positive Attitudes towards STEM

The second main theme regarding this study's research question addressing ways in which students' knowledge of and attitudes towards STEM were impacted by participating in a Micro STEM Fest showed an increase in students' positive attitudes towards STEM. Two sub-themes supported this finding. Firstly, students expressed enjoyment, enthusiasm, and excitement related to STEM after the STEM Fest. Secondly, students enjoyed the element of autonomous creativity they experienced while completing the various STEM challenges. These sub-themes will be presented in more detail below.

Enjoyment, Enthusiasm, and Excitement related to STEM

During the interview process, students were asked how the STEM Fest could be improved. A 2nd grade student from Fountain View Elementary stated the following, "Playing with it a lot and playing with it after homework and playing with it after the shower and kind of playing with it in the middle of the night…I would play in the middle of the night." This response demonstrates the enjoyment the students experienced while handling the STEM materials. Another 2nd grader from Fountain View Elementary was asked, "Do you know what STEM means?" Their response was, "I think STEM means fun." A 5th grade teacher from Evergreen Elementary reflected on one of her students' discovery experiences by sharing, "One boy, I was quite surprised, he found out he loved the Tetris. And I was surprised too. I thought he'd be all about the Hot Wheels cars but he loved the Tetris. That just became his thing and I think that was surprising to him and me...I think it gave him the confidence to try other things." A 4th grade teacher from Fountain View Elementary summarized the students' experience by stating, "It was just fun to see them have a good time. Well, I just think they had a ton of fun going through each one." The 5th grade teacher from Fountain View Elementary who helped her students learn how to facilitate each station explained how much her students enjoyed handling the STEM materials by sharing, "They begged all the time, every day, and we usually had other stuff we had to do. So I used that as a reward at the end of the day. If we get everything done, then we can get the STEM stuff out. So they just played with it themselves all the time." This same teacher was asked what she felt the most valuable outcome of the experience was for her 5th grade

students. She answered by stating, "I think the biggest takeaway was that our kids get to be leaders and communicators and teachers. I was just like, get them motivated, get them engaged. They're like, 'Ooh, STEM's fun.'"

Enjoyment of Autonomous Creativity

Throughout the interviews, students referred to their enjoyment of being given time to autonomously create their own solutions to the STEM challenges. One of the 4th graders from Fountain View Elementary was asked at the end of the interview if there was anything else they wanted to mention about the STEM Fest. They responded by expressing, "I liked it a lot because there was endless creativity, and it just had a lot of options." This enjoyment of autonomous creativity was voiced quite often in relation to the low-tech Tetris activity. For example, a 4th grader from Evergreen Elementary explained that their favorite activity was the Tetris station where students use different colored shapes to create various patterns. When questioned why this was, they stated, "You can do different things instead of having to do the exact same thing. I got to make shapes. All the shapes that I wanted and there was a bunch of different color choices that I could choose from." A 2nd grade student from Fountain View Elementary also enjoyed the low-tech Tetris station the most "because you can fill the whole thing up and you can take it back apart and you can make flowers, a fish, a robot...Yeah, and it's really creative." A 4th grader from Fountain View Elementary was asked what they had learned during the STEM Fest and they explained with excitement in their voice, "We could do whatever we want. And the K'Nex. I'm pretty sure over there, I built this thing and I could stack up half the cups before I fell over the first try." Similar statements were made by other participating students which highlighted the students' enjoyment of having the opportunity to autonomously create.

Discussion

As presented, the elementary students who participated in the Micro STEM Fest gained an increase in STEM-related knowledge. This was demonstrated through their use of newly acquired vocabulary, their description of critical thinking skills utilized when undergoing the engineering design process, and their verbal descriptions of, and their desire for, more complicated STEM activities they felt could be included in future Micro STEM Fest experiences. This main finding supports previously conducted research focused on an increase in STEM-related knowledge because of students participating in STEM-related activities in school. See Acara et al. (2018), Koomen et al. (2021), Miller et al. (2017), Sahin et al. (2014), and Yildirim (2016) for more details about their specific studies and findings that are like the findings of this study. These studies, and the present study, highlight the importance of offering students STEM-related experiences during school. These hands-on experiences enhance students' STEM literacy by providing opportunities for them to gain practical knowledge and skills, to better understand the connections between science, technology, engineering, and mathematics, and to utilize their problem-solving and creative thinking skills.

Participating students of the present study also demonstrated an increase in positive attitudes towards STEM. This became apparent by their expressed enjoyment, enthusiasm, and excitement related to the STEM challenges

completed during the Micro STEM Fest, as well as their expressed enjoyment of being able to autonomously create during the Micro STEM Fest. Studies conducted by Feille and Wildes (2021), Koomen et al. (2021) and Miller et al. (2018) support these findings related to students' attitudes towards STEM being positively affected by participating in STEM-related experiences. These studies provide additional instances of students becoming more actively engaged and excited about STEM after such experiences. This increased engagement level can lead to a boost in students' interest in STEM-related careers (Feille & Wildes, 2021; Jiang et al., 2022; Miller et al., 2018).

With these valuable outcomes in mind, it's imperative that all students have access to high-quality STEM learning experiences. Unfortunately, marginalized K-12 students are not always provided access to meaningful, integrated STEM experiences while at school (Jackson et al., 2021; Jong et al., 2020). As a result, marginalized individuals continue to be underrepresented in the STEM workforce due to a lack of exposure to meaningful STEM learning experiences. This lack of exposure to STEM education in schools does little to enhance students' STEM literacy. STEM literacy "promotes and fosters in students innovative thinking, collaboration, creativity, problem solving and critical thinking, and communication skills" (Jackson et al., 2021, p. 2). If equal access and opportunity are not prioritized by those initiating, developing, and implementing STEM learning experiences, the STEM literacy development of marginalized students continues to be hindered (Jackson et al., 2021).

Impactful STEM learning experiences should involve students applying STEM content and practices to solve authentic, rigorous problems (Bush & Cook, 2019). Formal advanced STEM classes in high school usually implement this approach. Such formal classes play a prominent role in a student's decision to pursue a STEM-related career. However, these types of formal STEM classes are most often offered at high schools attended by white, affluent students. Marginalized students, who do not have access to such classes, fall behind in their STEM knowledge (Jong et al., 2020).

In comparison, marginalized students are more likely to have access to informal STEM learning experiences. These include "camps, museums, after-school programs, and other environments where students have the option to attend" (Jackson et al., 2021). Although such opportunities are short-term, participation has been shown to have a positive impact on the development of students' STEM literacy (Jackson et al., 2021). However, these optional programs are often not held during the school day which can make it difficult for marginalized students to attend.

The utilization of the Micro STEM Fest kits presented in this study provides an example of an informal STEM learning experience deliberately designed to take place during the school day so all students can have access to the benefits associated with participating. Holding the STEM Fest during the day allows students to participate without them needing to rely on someone to transport them to school at another time. As the findings indicate, student participants of this study enjoyed collaborating with their peers to creatively solve STEM-related problems during the school day. These types of positive social interactions contribute to an increase in a student's confidence related to their STEM abilities which then helps them to persist through challenges they may face while pursuing a STEM-related career (Jackson et al., 2021).

Conclusion

Micro STEM fests, like the one featured in this study, serve as invaluable tools for promoting interest and engagement in science, technology, engineering, and mathematics. These events provide a platform for innovation, hands-on learning, and collaboration, ultimately shaping the future of STEM education. While this research has shed light on how such fests broadly improve knowledge of STEM and increase positive attitudes toward STEM, it is not without its constraints.

The scope of this study focused on specific regions and demographics, and there is a need for broader, more diverse research to gain a comprehensive understanding of the impact of STEM fests across a broader cross-section of rural, suburban, and urban schools. A second limitation of this study is the financial resources necessary to provide comprehensive STEM experiences and education beyond this study. Here, the Micro STEM Fest kits were grant-funded and then loaned to schools, whereas limited funding would likely limit continued work in these areas within schools beyond the completion of this study.

Recommendations

While the research presented here supports findings that STEM fests improve knowledge of STEM and increase positive attitudes towards STEM, the following actionable recommendations are offered as the study of STEM continues.

Sustained, Interdisciplinary Approach to STEM Instruction

Continued STEM instruction after students participate in a STEM fest is of utmost importance for their educational and personal development. STEM fest-type experiences provide students with hands-on, real-life applications of science, technology, engineering, and mathematics concepts. It ignites their curiosity, fosters critical thinking, and encourages problem-solving skills. However, it cannot be a one and done experience; students' experiences at a single STEM fest do not adequately provide the amount or level of STEM instruction and experiences that a 21st-century worker will need to call upon.

Even while updated standards and curricular programs and materials promote the integration of all STEM areas (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010; Porter et al., 2011), STEM teacher development has not been adequately defined or analyzed. Teachers need access to materials, coaching, peer modeling, and reflective practice opportunities to develop their STEM integration repertoire. Until those supports are firmly established, teachers may not know how to continue sustained STEM instruction beyond the fest. Additionally, "time" is often mentioned as the missing ingredient in the development and implementation of STEM lessons (Ryu et al., 2019). Quality, consistent STEM instruction nurtures students' interest and passion for these subjects, encouraging lifelong learning and fueling a pipeline of well-rounded, innovative thinkers. Prioritizing STEM instruction following a STEM fest is essential for nurturing the curiosity and potential of students in these critical fields.

Rethinking Pre-Service Teacher Preparation

Enhancing STEM instruction in pre-service teacher programs is crucial for preparing educators to meet the demands of the 21st-century classroom. With technology and scientific advancements continually shaping our world, teachers must be equipped with the knowledge and skills to foster students' STEM competencies. To achieve this, pre-service teacher programs should prioritize more immersive and experiential learning opportunities, which include real-world problem-solving and hands-on experiments. Though little attention has been paid to how STEM is taught within teacher preparation programs, research by Rinke et al. (2016) shows that innovative, integrated STEM blocks have promise. This shift in program offerings integrated "the STEM literacies of technology, engineering, 21st century skills, and the arts" (Rinke et al., 2016, p. 303) rather than traditional classes, taught in isolation. Their work implementing and researching an integrated STEM block option showed an increase in pre-service teachers' self-efficacy in teaching STEM and resulted in more meaningful content integration compared to traditional course offerings. This and a deeper emphasis on interdisciplinary teaching methods and integration of STEM principles can empower pre-service teachers to make STEM subjects more engaging and accessible for their students. Ultimately, a comprehensive and dynamic adjustment to STEM instruction within pre-service teacher programs is essential for nurturing the next generation of innovative, proficient, and inspiring educators.

Acknowledgements

We would like to express our sincere appreciation to Claire Webber and Adelia Roberts, the student researchers who contributed significantly to this research project. Claire and Adelia played a critical role in conducting the literature review, data collection, and analysis. Their critical thinking and synthesis of research materials greatly enriched our work, and their attention to detail and meticulous approach ensured the accuracy and reliability of our findings.

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Author Information

Dr. Kalani Eggington

https://orcid.org/0009-0001-5155-2599

Utah Valley University

800 W University Parkway

Orem, UT 84058

United States of America

Contact e-mail: *keggington@uvu.edu*

Dr. Andrew Goodman

https://orcid.org/0009-0000-5031-3513

Utah Valley University

800 W University Parkway

Orem, UT 84058

United States of America

Dr. Krista Ruggles

https://orcid.org/0000-0003-3926-5789

Utah Valley University

800 W University Parkway

Orem, UT 84058

United States of America