

Article

Middle School Students' Interest and Self-Efficacy in a One-Day Informal STEM Learning Experience

Shaoan Zhang ^{1,*}, Emma E. Regentova ², Hongming Xu ³, Venkatesan Muthukumar ² and Si Jung Kim ⁴¹ Department of Teaching and Learning, University of Nevada, Las Vegas, NV 89154, USA² Department of Electrical and Computer Engineering, University of Nevada, Las Vegas, NV 89154, USA; emma.regentova@unlv.edu (E.E.R.); venki.muthu@unlv.edu (V.M.)³ Cheyenne High School, Clark County School District, North Las Vegas, NV 89032, USA; xuh6@unlv.nevada.edu⁴ Department of Entertainment Engineering and Design, University of Nevada, Las Vegas, NV 89154, USA; sj.kim@unlv.edu

* Correspondence: shaoan.zhang@unlv.edu

Abstract

Informal STEM learning experiences are widely used to promote students' interest and engagement in science, technology, engineering, and mathematics (STEM), yet limited evidence exists regarding the educational value of one-day STEM outreach events. This study examined middle school students' perceptions of STEM interest and self-efficacy following participation in NSF STEM Day, a one-day informal STEM learning experience that combined project demonstrations designed by college student mentors with a field-based learning experience at the Museum of Illusions to learn about hands-on robotics, coding, Internet of Things (IoT), and engineering and mathematical concepts. This study explored students' learning experiences, STEM interests and STEM self-efficacy perceptions, and college student mentors' reflections. First, participants reported positive learning experiences, and engineering was reported more frequently as an area of STEM interest in the post-survey (38.0%) than the pre-survey (25.6%). Second, they reported positive STEM self-efficacy perceptions in the post-survey. A significant grade-level difference was observed for one STEM self-efficacy item assessing students' confidence in applying scientific principles, with eighth-grade students reporting higher confidence than sixth-grade students ($F(3,26) = 3.76, p = 0.023$). Third, qualitative findings showed that college student mentors' reflections reported positive experiences and valued the opportunity to engage middle school students in hands-on STEM learning activities. The findings contribute evidence regarding the educational value of short-duration STEM outreach experiences for broadening students' exposure to STEM learning.

Keywords: middle school students; STEM interest; STEM self-efficacy; college student mentors; informal learning



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1. Introduction

Developing students' interest and confidence in science, technology, engineering, and mathematics (STEM) remains a priority in K-12 education because STEM knowledge and skills are increasingly important for workforce development, innovation, and economic competitiveness. Researchers have consistently identified middle schools as a critical period for STEM development because students begin to form stronger academic identities during these years (L. Archer et al., 2012; Tai et al., 2006). Consequently, educators and researchers

have sought strategies that can engage students in meaningful STEM learning experiences and encourage continued participation in STEM-related educational pathways.

Informal STEM learning experiences have emerged as one promising approach for supporting students' STEM development. These experiences include STEM camps, after-school programs, outreach events, museum visits, engineering competitions, and university–community partnerships that provide opportunities for students to engage with STEM beyond traditional classroom settings. Previous studies have demonstrated that informal STEM learning experiences can positively influence students' STEM interests, STEM identity, and self-efficacy (Beier et al., 2019; Habig et al., 2020; Roberts et al., 2018). Such experiences often provide hands-on learning opportunities, exposure to STEM professionals, and authentic problem-solving activities that help students connect STEM concepts to real-world applications.

Although substantial evidence supports the effectiveness of informal STEM learning experiences, much of the literature focuses on multi-day summer camps, recurring after-school programs, semester-long interventions, and other sustained learning experiences. For example, previous studies have reported positive outcomes associated with STEM camps lasting several days or weeks, including improvements in STEM interest and self-efficacy (Beier et al., 2019; Chiang et al., 2022; Habig et al., 2020). Similarly, recent NSF-funded studies have documented positive relationships among STEM learning experiences, STEM interest and STEM self-efficacy among secondary students participating in extended STEM programs (Xu et al., 2024, 2025).

In contrast, comparatively little evidence exists regarding the educational value of short-duration, one-day STEM outreach experiences despite their widespread implementation. Universities, school districts, community organizations, and industry partners frequently organize STEM Days, STEM festivals, and outreach events because they are relatively low-cost, scalable, and capable of reaching large numbers of students. However, evaluations of these events often focus on participation rates, satisfaction, or general perceptions rather than examining STEM interest and self-efficacy outcomes (M. Archer et al., 2020; Kaggwa et al., 2023). M. Archer et al. (2020) highlighted the need for stronger evidence regarding their educational impact, particularly with college student mentors' participations in the project design and demonstration. Consequently, important questions remain regarding the educational potential of one-day STEM outreach experiences, particularly among middle school students.

This study examines middle school students' perceptions following participation in NSF STEM Day, with particular attention to their STEM interests and self-efficacy perceptions. The study explores whether students' self-efficacy perceptions differ across grade level, gender, and ethnicity. This study also reports college student mentors' reflections on engaging middle school students in STEM learning activities.

2. Literature Review

2.1. STEM Interest Among Middle School Students

STEM interest refers to students' curiosity, enjoyment, and willingness to engage in STEM learning activities and pursue STEM-related opportunities. According to Hidi and Renninger (2006), interest develops through experiences that capture learners' attention and encourage continued engagement with a topic. Interest is considered an important motivational construct because students who are interested in a subject are more likely to participate actively, persist through challenges, and pursue future learning opportunities.

Middle school represents a particularly important period for STEM interest development. During adolescence, students begin to form stronger academic preferences and

consider future educational and career possibilities (L. Archer et al., 2012; Tai et al., 2006). However, research has also documented declines in STEM interest during these years, particularly among students from groups historically underrepresented in STEM fields (Potvin & Hasni, 2014; Wang & Degol, 2017). Because interests developed during middle school often influence later educational and occupational choices, researchers have emphasized the importance of providing engaging STEM experiences during this developmental period.

Prior studies suggest that authentic STEM learning experiences can support the development of STEM interest. Hands-on engineering projects, robotics activities, problem-based learning, and STEM outreach initiatives have been associated with increased engagement and stronger interest in STEM (Beier et al., 2019; Newton et al., 2020; Roberts et al., 2018). Similarly, Xu et al. (2024) reported that constructivist STEM learning experiences were positively associated with secondary students' STEM interests. These studies suggest that engaging STEM experiences may play an important role in fostering students' interest in STEM learning.

2.2. STEM Self-Efficacy

While STEM interest reflects students' willingness to engage in STEM learning, STEM self-efficacy concerns students' beliefs about their capability to successfully perform STEM-related tasks. Bandura (1997) defined self-efficacy as individuals' judgments of their ability to organize and execute actions required to achieve desired outcomes. Self-efficacy plays a critical role in motivation, persistence, and performance. In STEM education, self-efficacy has been consistently associated with student engagement and achievement (Brown et al., 2016; Nugent et al., 2015; Rittmayer & Beier, 2008). Students who possess stronger STEM self-efficacy are more likely to pursue advanced STEM coursework, and persist through academic challenges. Conversely, students with lower self-efficacy may avoid STEM learning opportunities despite possessing the necessary academic skills.

Although STEM interest and STEM self-efficacy are related, they represent distinct concepts. Students may express strong interest in STEM while lacking confidence in their ability to succeed, or they may possess confidence in STEM-related skills without intending to pursue STEM opportunities. Both constructs have been identified as important predictors of STEM participation (Nugent et al., 2015; Luo et al., 2021). Recent NSF-funded research further highlights the importance of examining STEM interest and STEM self-efficacy simultaneously when evaluating STEM learning experiences (Xu et al., 2025).

2.3. Informal STEM Learning Experiences with College Student Mentoring

Informal STEM learning experiences occur outside traditional classroom settings and include STEM camps, outreach events, museums, competitions, field experiences, and university–community partnerships. These environments often emphasize exploration, collaboration, authentic problem solving, and exposure to real-world STEM applications. The National Research Council (2009) emphasized the important role of informal learning environments in promoting scientific literacy, engagement, and lifelong learning.

Research has documented numerous benefits associated with informal STEM learning experiences (Hussim et al., 2024). Students participating in STEM camps and outreach programs often report increased interest in STEM subjects and greater confidence in their ability to engage in STEM learning (Beier et al., 2019; Roberts et al., 2018). However, most evidence originates from multi-day camps or sustained interventions. Chiang et al. (2022), for example, reported improvements in self-efficacy and task value following participation in online STEM camps, while Habig et al. (2020) documented the long-term benefits of sustained informal STEM engagement.

Comparatively fewer studies have examined one-day STEM outreach experiences. M. Archer et al. (2020) noted that many STEM engagement efforts consist of short, one-off interventions and argued that more evidence is needed regarding their educational impact. Similarly, Kaggwa et al. (2023) described STEM outreach events designed to broaden participation in STEM among under-resourced schools but focused primarily on access and exposure rather than STEM self-efficacy outcomes. Although Sripaoraya et al. (2022) reported positive changes in science attitudes and self-efficacy-related outcomes following a short-term science outreach experience, evidence regarding middle school students participating in one-day STEM outreach events remains limited.

The one-day informal STEM learning experience investigated in this study was distinguished by two additional features: guidance from college student mentors and a field-based learning experience at the Museum of Illusions. Near-peer mentoring provides role models and social support that may enhance engagement and confidence. Field-based learning opportunities expose students to authentic STEM environments that may otherwise be inaccessible. Museum-based learning experiences represent another form of informal STEM education that can complement hands-on STEM activities. Museums provide opportunities for observation, inquiry, and exploration of scientific phenomena in authentic settings. Research suggests that museum experiences can support students' curiosity, critical thinking, and engagement with scientific concepts (Greene et al., 2014). In the present study, the Museum of Illusions was incorporated as a field-based learning experience intended to expose students to concepts related to perception, spatial reasoning, and cognitive science while demonstrating the interdisciplinary nature of STEM. Together, these experiences may contribute to positive perceptions of STEM learning and future STEM opportunities.

2.4. Research Gap and Purpose of the Study

The present study addresses this gap by examining middle school students' perceptions following participation in NSF STEM Day, a one-day informal STEM learning experience that integrated hands-on STEM activities, college student mentoring, and a field-based learning experience at the Museum of Illusions. By examining students' STEM interests and STEM self-efficacy, together with college student mentors' reflections, this study contributes new evidence regarding the educational value of short-duration informal STEM outreach experiences.

2.5. Research Questions

Building on the literature on STEM interest, STEM self-efficacy, and informal STEM learning, and addressing the limited evidence regarding one-day STEM outreach experiences, this study examined middle school students' perceptions following participation in NSF STEM Day. Specifically, the study addressed the following research questions:

RQ1: What STEM interests do middle school students report following participation in NSF STEM Day?

RQ2: What STEM self-efficacy perceptions do middle school students report following participation in NSF STEM Day and do these perceptions differ by grade level, gender, or ethnicity?

RQ3: How do college student mentors describe their learning experiences during NSF STEM Day?

2.6. NSF STEM Day Event

2.6.1. Background

We employ an inventive approach that integrates amusement and fun factors into learning sciences, technology, and engineering design. The Las Vegas strip itself is an open

lab per se featuring some of the most innovative technologies in the entertainment and hospitality sectors. The learners of our project were middle school students (grades 6, 7 and 8). For the past three summers, over 120 of these students participated in 3-week summer camps to learn about the basics of object-oriented programming and sensors, and microcontroller-based design, made field trips to Las Vegas sites and shows, interviewed professionals, learned about science and technology with faculty, conducted lab work with college student mentors, and developed hands-on team projects inspired by the site visits. The program prepared engineering college student mentors with the knowledge and tools to bring hands-on microcontroller and STEM-based projects into their classrooms and after-school activities. They expressed readiness to implement what they learned and a strong desire for continued professional development, particularly in emerging technologies, real-world applications, and interdisciplinary teaching strategies. The workshop empowered college student mentors with foundational technical skills and inspired actionable classroom applications. Sustained support, advanced training, and structured follow-up will amplify impact and deepen integration into secondary STEM education.

2.6.2. STEM Day at UNLV

In spring 2025, the authors organized NSF STEM Day at UNLV in commemoration of the 75th Anniversary of the NSF. The goal was to gather a large number of students, teachers, and caregivers in person to demonstrate how STEM knowledge can create fun projects and make life safe and comfortable. The objectives are: (a) demonstrate practical applications of STEM in entertainment and hospitality projects designed in informal settings; (b) show how science can create visual illusions at the Museum of Illusions in Las Vegas; (c) motivate STEM education; and (d) publicize NSF's investment in STEM learning.

The event (<https://stemlab.sites.unlv.edu/stem-day-unlv-may-10/>, accessed on 9 July 2026) was widely promoted through CCSD and public channels, including billboards and the local newspaper. Webinars were held to outline the event activities, explain the NSF's mission in STEM education, present the agenda of NSF STEM Day, and detail what participants could expect, including assessment surveys.

In informal STEM learning, students respond positively to college-aged mentors (Radcliffe & Bos, 2011). Two main activities of the events included (a) UNLV (Demonstration Sites) and (b) the Las Vegas Museum of Illusions. Twenty UNLV undergraduate and graduate students developed projects and worked with small groups of students. Below are the eight projects developed for demonstration, highlighted in Figure 1:

1. Sphero Bolt demonstrated block coding for the Sphero Bolt and provided examples of navigating the robot.
2. Tello Edu Drone demonstrated gesture control and remote control of the drone.
3. The Robotic Dog kit demonstrated various ways to program and control a robot dog, including using both Java and block-based coding on the Micro:bit website. The students used a mobile app to interact with and control the robot.
4. Micro:bit demonstrated development of games on the micro:bit utilizing the arcade controller and little bots.
5. Robotic Arm/Hydraulic Hand and Arm Ball Caddy demonstrated a robot searching for the nearby tennis balls, picking them up, and dropping them at the desired spot.
6. SmartFarm demonstrated the use of a microcontroller and sensors, and showed the functions of the farm.
7. DMX Lighting fixtures with the control console demonstrated how DMX lighting fixtures can be controlled through software or a physical control board and explained how it works in the entertainment industry.

8. FM Radio kits, Walkie-Talkies, and Bluetooth speakers explained the concepts of wireless communication and the technology that uses it, such as phones, radio, and Wi-Fi.

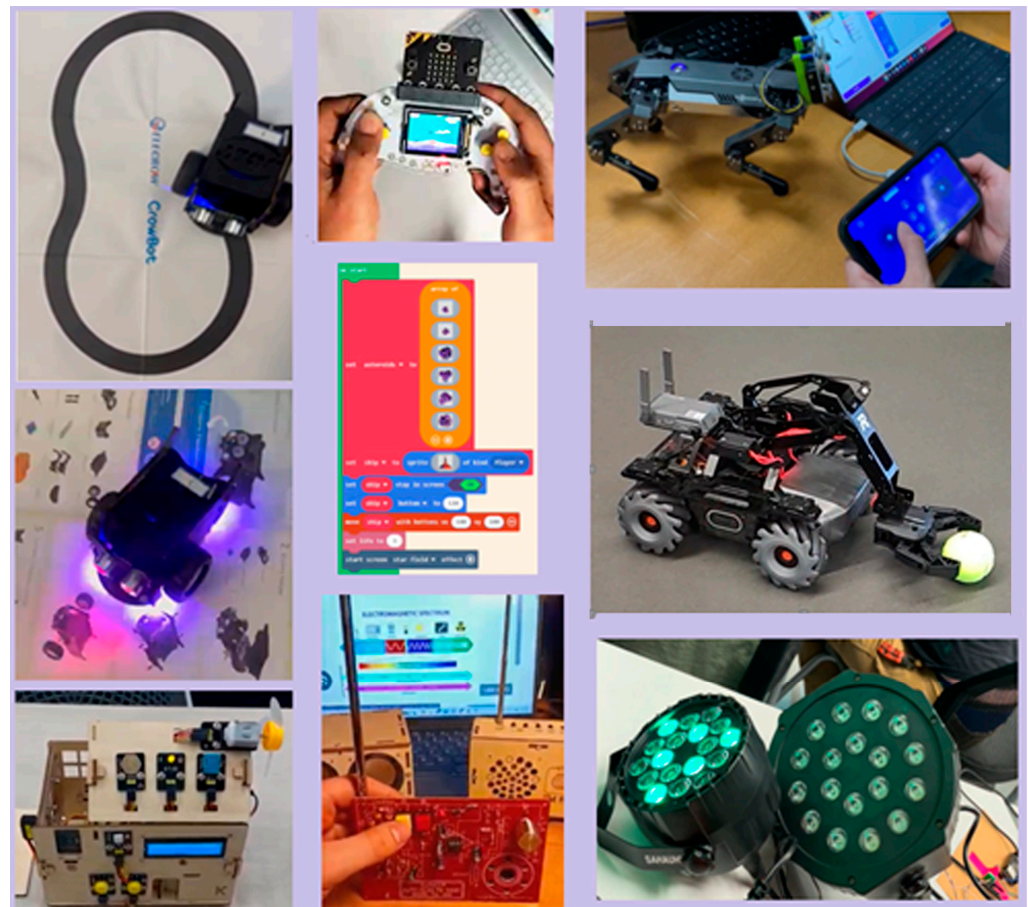


Figure 1. Selected components used in the projects.

For each project, there were a set of exercises and exploration mini-tasks. Eight demo stations for the above eight projects were located in two Engineering buildings. Each project involved 15 min activities. Students explored how to use a conversational AI ChatBot—Humanoid Pepper—presented by an industry partner, RobotLab. Figure 2 shows the organization of the activities on campus and the flow of participant groups.

As part of the STEM Day experience, participants visited the Museum of Illusions. The museum component was designed to complement the engineering and technology activities by exposing students to scientific principles related to perception, observation, spatial reasoning, and cognitive processing. Students explored how scientific inquiry can be applied to understanding human perception. The experience was intended to promote curiosity and illustrate the interdisciplinary nature of STEM fields, including connections to physics, mathematics, neuroscience, engineering, and emerging areas such as artificial intelligence and computer vision.

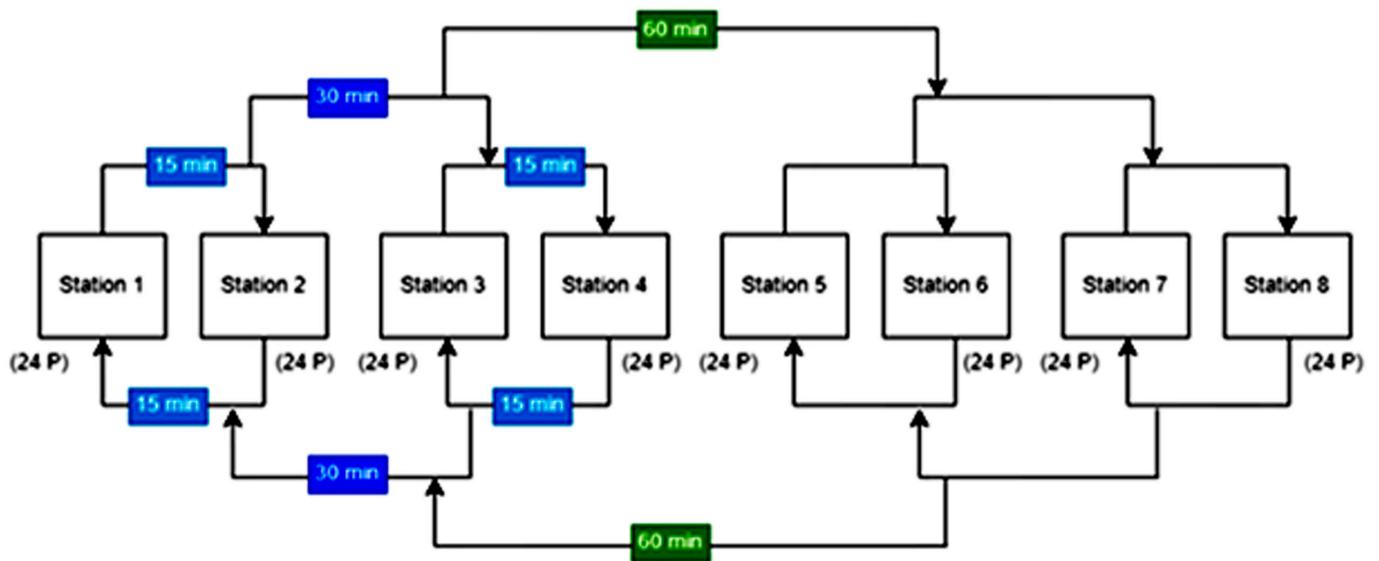


Figure 2. Organization of eight project stations. Note: Each station is located in a separate classroom; Stations 1, 2, 3, 4 are adjacent in one building, and Stations 5, 6, 7, 8 are adjacent in another building.

3. Methods

3.1. Participants of the Study

Out of 150 students attending the event, 58 students submitted the pre-survey. Of these, 19 (32.75%) were enrolled in sixth grade, 19 (32.75%) were in seventh grade, 11 (19.0%) were in eighth grade, and 9 (15.5%) fell outside these grade levels. Based on the post-survey, 34 valid grade-level responses were obtained ($N = 34$). Of those respondents, 14 (41.2%) were in 6th grade, 9 (26.5%) were in 7th grade, 7 (20.6%) were in 8th grade, and 4 (11.7%) were classified as Others. The pre-survey sample ($N = 58$) included 23 male respondents (39.7%) and 35 female respondents (60.3%). In the post-survey sample ($N = 34$), there were 12 male respondents (35.3%), 21 female respondents (61.8%), and 1 respondent (2.9%) who preferred not to disclose gender.

Table 1 summarizes the ethnic composition of the pre- and post-survey respondents. In the pre-survey ($N = 58$), 19 participants (32.8%) were identified as Asian, 17 (29.3%) as White, 8 (13.8%) as Hispanic/Latino, 8 (13.8%) as Black/African American, 5 (8.6%) as Other, and 1 (1.7%) as Pacific Islander. No respondents were identified as Native American.

Table 1. Participant ethnicity distribution.

Option	Pre-Survey		Post-Survey	
	Count	Percentage	Count	Percentage
Hispanic/Latino	8	13.8%	3	8.9%
Native American	0	0%	0	0%
White	17	29.3%	6	17.6%
Asian	19	32.8%	14	41.2%
Black/African American	8	13.8%	5	14.7%
Pacific Islander	1	1.7%	0	0%
Other	5	8.6%	6	17.6%
Total	58	100%	34	100%

Note. All percentages are rounded to the nearest tenth: In the post-survey ($N = 34$), the largest group was Asian (14; 41.2%), followed by White (6; 17.6%), Other (6; 17.6%), Black/African American (5; 14.7%), Hispanic/Latino (3; 8.9%), and Pacific Islander (0; 0%). No post-survey respondents were identified as Native American.

3.2. Instrument Development

The pre- and post-surveys (see Appendix A) were developed to assess participants' STEM interest and STEM self-efficacy following participation in NSF STEM Day. Instrument development was informed by both theoretical and empirical literature. Items measuring STEM interest were grounded in the literature describing interest as students' curiosity, engagement, and willingness to pursue future learning opportunities in STEM fields (Hidi & Renninger, 2006). STEM self-efficacy items were informed by Bandura's (1997) theory of self-efficacy, which emphasizes individuals' beliefs about their capability to successfully perform specific tasks and persist when encountering challenges.

The survey design was further informed by previous NSF-funded research conducted by the authors examining STEM interest and STEM self-efficacy among secondary students participating in informal STEM learning experiences (Xu et al., 2024, 2025). In Xu et al. (2024), survey instruments were developed, reviewed by domain experts and an external evaluator, and administered to secondary students participating in STEM summer camps. The resulting scales demonstrated strong internal consistency reliability, including STEM Interest ($\alpha = 0.884$), Constructivist Learning ($\alpha = 0.866$), Learning Outcomes ($\alpha = 0.909$), and acceptable reliability for STEM Self-Efficacy ($\alpha = 0.712$). Building on this prior work, the current study adapted selected items to examine participants' STEM interests, STEM-related activities, and self-efficacy in the context of a one-day informal STEM learning event. Due to space constraints, the study focused primarily on STEM interest and STEM self-efficacy and did not examine other potentially relevant constructs.

The pre-survey and post-survey collected demographic information, including gender, ethnicity, and grade level, and assessed participants' understanding of STEM, general interest in STEM subjects, participation in STEM-related activities, specific STEM topics of interest, and intentions to pursue future STEM studies. The post-survey additionally included three items (Q7, Q8, and Q9) (see Appendix A) assessing STEM self-efficacy, including students' perceived ability to apply scientific principles, confidence in learning STEM concepts, and persistence when encountering challenges in STEM learning. These items were selected to align with Bandura's (1997) conceptualization of self-efficacy and outcomes commonly examined in informal STEM learning research.

Given the one-day nature of the event and the age of participants, the survey was intentionally designed as a brief program-evaluation instrument to minimize respondent burden while capturing key outcomes associated with informal STEM learning experiences. The instrument was adapted for the context of NSF STEM Day and was not intended as a comprehensive psychometric assessment of STEM interest or self-efficacy. Therefore, findings should be interpreted as exploratory and descriptive of participants' perceptions following the event.

3.3. Data Analysis

Statistical analyses were performed using IBM SPSS Statistics, Version 29 (IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated separately for the pre- and post-survey samples. Categorical variables (gender, ethnicity, grade level, NSF awareness, and STEM interest) were summarized with counts and percentages. Comparative analyses focused on changes in STEM interest (Q2, see Appendix A). Because pre- and post-survey responses could not be matched at the individual level, these comparisons were interpreted as descriptive differences between survey administrations. Responses to the open-ended survey question (Q3, see Appendix A), "Please write which subjects you are particularly interested in," were analyzed with qualitative content analysis. Similar responses were grouped into common STEM subject categories, and the frequency of each category was summarized descriptively.

Likert-scale constructs (STEM self-efficacy) were summarized with means and standard deviations. Inferential analyses used one-way analysis of variance (ANOVA) to determine whether self-efficacy scores for Q7, Q8, and Q9 (see Appendix A) differed by gender, ethnicity, and grade level. Before conducting standard ANOVAs, Levene's test was used to assess the homogeneity of variance assumption. When Levene's test was non-significant (e.g., self-efficacy items across all demographic factors), standard ANOVAs were conducted. Significant omnibus effects ($p < 0.05$) were followed by Tukey's HSD post hoc comparisons to identify which groups differed.

3.4. Limitations

Several limitations should be considered when interpreting the findings. First, the pre-survey and post-survey responses could not be matched at the individual level; therefore, comparisons between the two surveys should be interpreted as descriptive observations of independent samples rather than evidence of individual change. Second, because participants reported high levels of STEM interest prior to the event, this high baseline level suggests the possibility of a ceiling effect, which may have limited the ability to observe substantial differences in post-survey STEM interest responses. Third, response rates were modest and all measures relied on student self-reports, which may introduce response bias. Finally, the study employed an exploratory program-evaluation design with a relatively small sample size. Accordingly, the findings should be interpreted as preliminary and descriptive rather than causal or broadly generalizable. Future studies using matched longitudinal data and larger samples are needed to further examine the effects of informal STEM learning experiences.

3.5. Qualitative Methods

To address Research Question 3 (RQ3), which examined how college student mentors evaluated their learning experiences and activities during the NSF STEM Day, a qualitative descriptive approach was utilized. Data were collected via open-ended qualitative reflection questionnaires administered to the mentors immediately following the event. The data collection instrument featured three targeted prompts designed to capture the structural, pedagogical, and developmental dimensions of the experience: (a) What did you demonstrate?; (b) What was the learning activity for students beyond lecture? and (c) What did you learn while preparing your demo project? Responses were analyzed using thematic synthesis to reduce redundancy while preserving the core experiential insights.

4. Results

4.1. STEM Interest

Pre-survey results indicated that most students ($N = 47$ out of 58) correctly identified what STEM stands for (81.0%), with a small increase in the post-survey (85.3%). The proportion of "no answer" responses for this item decreased from 8.6% to 2.9%.

STEM interest remained positively high before and after the program. In the pre-survey, 49 out of 54 students (90.7%) were identified as interested, compared with 27 of 30 (90.0%) in the post-survey. Neutral responses increased slightly from 7.4% to 10.0%, and "not interested" responses decreased from 1.9% to 0%. Participants reported high levels of STEM interest both before and after the event. Pre-event STEM interest was already high, with more than 90% of respondents indicating interest in STEM-related fields.

On the 1–5 interest scale, mean interest was essentially stable (pre-survey mean = 4.43; post-survey mean = 4.40). The modal response remained "very interested" (mode = 5 for both administrations), and the median shifted slightly from 5.0 to 4.5. Response variability decreased modestly (pre-survey SD = 0.72; post-survey SD = 0.67),

suggesting slightly greater consistency in ratings over time. Overall, STEM interest was consistently strong, with only minor distributional changes across administrations.

Based on survey question three, among the STEM topics reported by participants, engineering was selected by 25.6% of respondents in the pre-survey and 38.0% in the post-survey. Based on survey question five, technology and design remained the most frequently reported hands-on area of interest, with 72.7% of respondents in the pre-survey and 69.0% in the post-survey selecting this category. Coding/programming was identified by 47.3% and 48.3% of respondents in the pre- and post-surveys, respectively, while mathematics was selected by 30.9% and 31.0% of respondents.

4.2. Student Self-Efficacy

Inferential analyses examined post-event measures of STEM self-efficacy. Levene's test supported the homogeneity of variance assumption for most items. One-way ANOVAs (see Figures 3 and 4) showed no statistically significant differences by gender or ethnicity on individual self-efficacy items, although Hispanic/Latino students reported descriptively lower scores across these measures. Boxplots of STEM self-efficacy scores by gender for survey questions Q11–Q13. The boxes represent the interquartile range (25th–75th percentile), the horizontal line inside each box indicates the median, and the black × symbols represent individual student responses. Because subgroup sizes were small and uneven, these descriptive patterns should be interpreted cautiously.

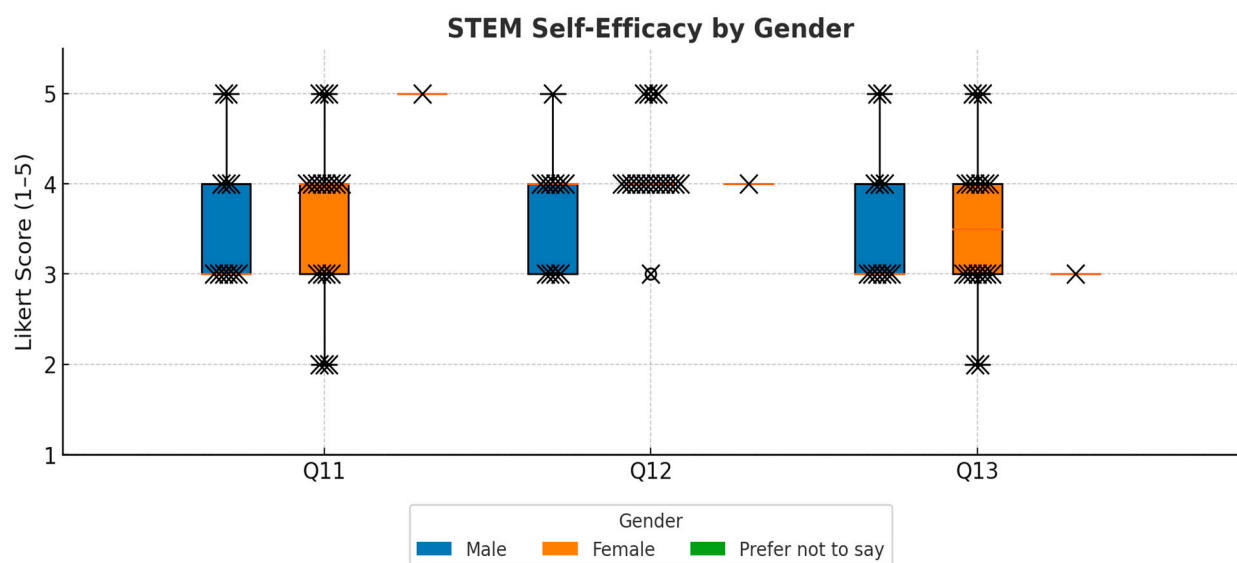


Figure 3. STEM self-efficacy by gender. Note: The survey included a “Prefer not to say” response option; however, only one participant selected this option.

Shown in Figure 5, a one-way ANOVA revealed a significant grade-level difference on STEM self-efficacy question 7 (see Appendix A), which assessed students’ confidence in applying scientific principles; $F(3, 26) = 3.76, p = 0.023$. Tukey’s HSD post hoc test indicated that eighth-grade students ($M = 4.29, SD = 0.49$) reported significantly higher confidence on this item than sixth-grade students ($M = 3.25, SD = 0.87$; mean difference = 1.04, $p = 0.048$).

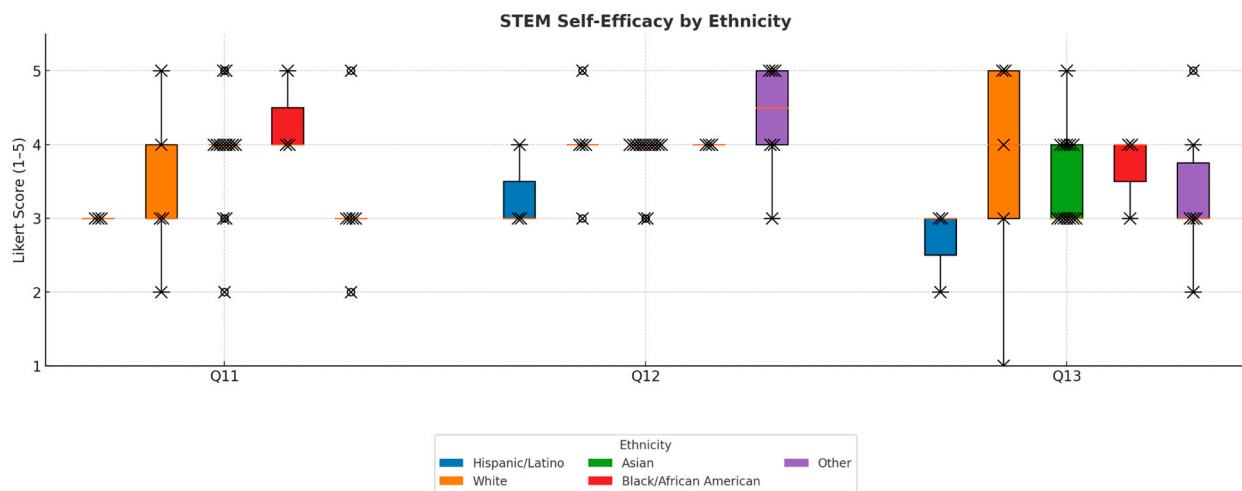


Figure 4. STEM self-efficacy by ethnicity.

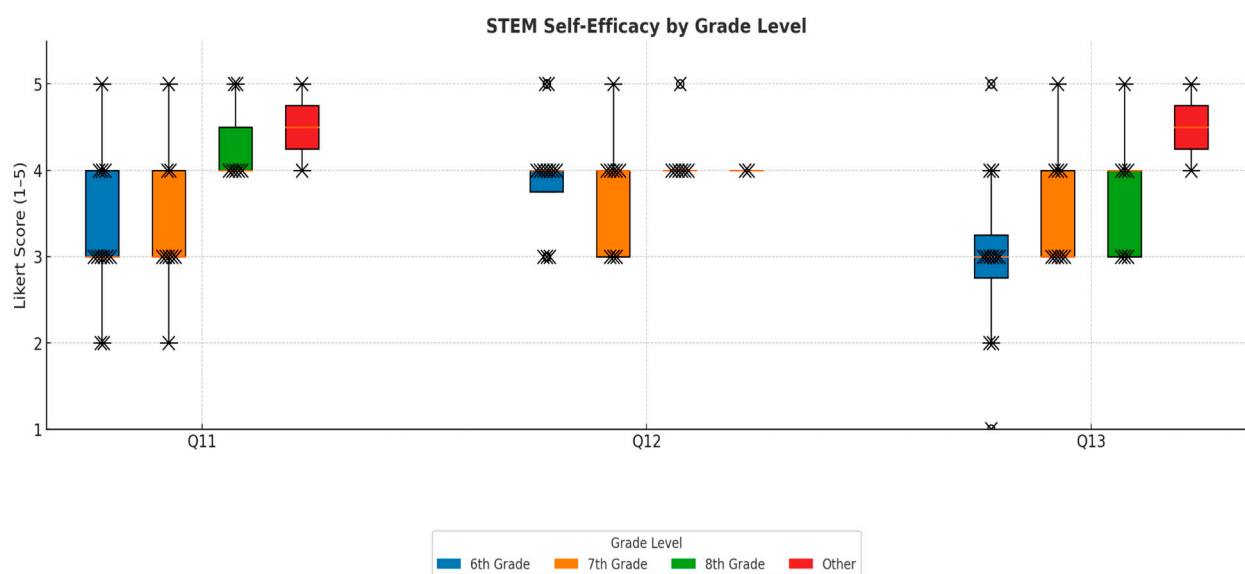


Figure 5. STEM self-efficacy by grade level.

4.3. College Mentors' Reflections

Table 2 presents a thematic synthesis of the open-ended reflections completed by the 14 college student mentors who facilitated the activity stations at NSF STEM Day. The reflections were collected via Google Forms immediately following the event. Each row in the original dataset corresponds to an individual mentor's response; several complex projects involved multiple mentors and therefore generated multiple entries. The reflection instrument was designed to elicit mentors' descriptions of the technical content they demonstrated, the active learning activities students engaged in beyond lecture, and the knowledge and skills mentors acquired while preparing and delivering their stations. Mentors intentionally designed projects that spanned diverse areas of electrical and computer engineering, with the goals of illustrating the breadth of the discipline, engaging middle school students through hands-on experiences, and developing practical skills within a limited timeframe. Mentors observed that many middle school students assumed leadership roles within their groups, explaining procedures and assisting peers with tasks.

Table 2. Mentor survey and responses.

Project and Technologies	Pedagogical Demonstration	Student Experiential Learning	Mentor Reflection
Sphero Bolt	Block coding applications.	Programmed navigational paths and custom LED matrix designs.	Applying gamified, hands-on learning tools into pedagogy.
Micro:bit Robotic Dog Kit	Java and block-based programming for robotic kinetics.	Modified code blocks to alter robotic behavior and operated the hardware via a mobile interface.	Acquired foundational Java skills and developed strategies for simplifying complex science communication.
Micro:bit/Little Bits	Electronic hardware integration via arcade controllers.	Engaged directly in hardware programming and electronic component manipulation.	Identified that minimizing direct instruction maximizes experiential learning time.
Micro:bit, Micro:Bit Retro Arcade, Little Bits, Android Tablet	Console game development, proximity sensors, and digital displays.	Programmed proximity alarms, configured digital nametags, and explored iterative game design.	Translated complex technical concepts into engaging, age-appropriate educational curricula.
Robotic Arm/Hydraulic	Sensor-driven object retrieval and hydraulic physics.	Examined sensor utility and applied physical principles of hydraulics.	Gained practical experience in training and deploying machine learning models for object recognition.
Robot Dog/Micro:bit	Integration of software and hardware in robotic functionality.	Customized operational code and observed real-time software execution via mobile application.	Understood the granular impact of iterative software development on physical robotic operations.
Smart Farm (ESP32)	Microcontroller integration with environmental sensors.	Manipulated environmental sensors and observed real-time data feedback via tablet interfaces.	Gained proficiency in hardware modification and improved presentation strategies for non-expert audiences.
DMX Lighting Fixtures	Entertainment industry lighting control via DMX software.	Manipulated color mixing principles using physical control boards.	Recognized the necessity of simplifying complex software interfaces for novice users prior to demonstration.
FM Radio, Walkie-Talkies	Principles of wireless communication.	Tested broadcast ranges and engaged in experiential play using communication devices.	Deepened technical understanding of FM radio mechanics and wireless hardware.
CrowBot BOLT	Infrared sensor mechanics and motion detection.	Assembled robotic components and controlled sensor-driven motion detection.	Discovered an aptitude for youth-oriented STEM facilitation and classroom management.
Tello Edu Drone	Gesture-based control and programmatic drone flight.	Coded gesture controls and gained practical piloting experience via mobile applications.	Applied theoretical computer vision and machine learning concepts to functional, deployable code.

5. Discussion

5.1. Students' STEM Interest (RQ1)

In response to Research Question 1, concerning students' STEM interests, participants reported strong interest in engineering following participation in the event. According to Hidi and Renninger's (2006) model of interest development, engaging experiences that capture students' attention may contribute to the development of sustained interest in a subject area. The hands-on nature of the STEM Day activities may have provided such opportunities for engagement.

Additionally, engineering and computing-related fields were the most frequently identified areas of interest, reflecting students' enthusiasm for the hands-on STEM activities offered during the event. These findings are consistent with research suggesting that experiential STEM learning opportunities are associated with students' STEM interests and motivation by linking academic content to real-world applications (Beier et al., 2019; Samsudin et al., 2020; Xu et al., 2024; Zhou et al., 2025). From the perspective of interest development theory, engaging and personally meaningful experiences may contribute to the development of sustained interest in STEM-related subjects (Hidi & Renninger, 2006). The hands-on and interactive nature of the STEM Day activities provided opportunities for students to connect STEM concepts with real-world applications.

5.2. Students' STEM Self-Efficacy (RQ2)

Research Question 2 examined students' STEM self-efficacy perceptions following participation in NSF STEM Day. Overall, participants reported positive perceptions of self-efficacy. A statistically significant grade-level difference was observed only for the self-efficacy item assessing students' confidence in applying scientific principles (question 7) with eighth-grade students reporting higher confidence than sixth-grade students. No statistically significant differences were observed for gender or ethnicity. These findings align with Bandura's (1997) theory of self-efficacy, which emphasizes that confidence develops through repeated success, growing maturity, and opportunities for mastery. Prior STEM education research similarly suggests that self-efficacy plays an important role in students' willingness to engage in STEM learning (Nugent et al., 2015; Rittmayer & Beier, 2008). The higher self-efficacy perceptions reported by eighth-grade students may reflect greater prior exposure to STEM learning opportunities and increased confidence in applying STEM concepts.

Students experienced mastery through project completion, observed successful demonstrations through mentor modeling, received social encouragement, and participated in an engaging learning environment. These elements have been identified as important contributors to STEM self-efficacy development in previous STEM education research (Bandura, 1997; Xu et al., 2025). The finding that more than 70% of students believed they could replicate the projects they observed may reflect positive perceptions of STEM self-efficacy and confidence in applying what they learned.

Although much of the existing literature on STEM self-efficacy has focused on multi-day camps and sustained interventions, the present findings suggest that participants in a one-day STEM outreach experience reported positive perceptions of STEM self-efficacy. These findings contribute additional evidence regarding the potential value of short-duration STEM learning experiences.

5.3. Mentor-Led Hands-On Projects (RQ3)

The qualitative findings were organized into three themes: (a) engaging middle school students in STEM learning, (b) mentors' professional growth and communication skills, and

(c) project ownership and authentic engineering practice. Table 2 is the mentors' post-event mentor survey results. Analysis of mentor reflections revealed several recurring themes.

Mentors identified designing and demonstrating the STEM projects as one of the most meaningful aspects of their participation, which promoted a sense of ownership and collaboration. This autonomy enabled them to present topics with passion, resulting in a diverse and creative set of demonstrations. Mentors also described the preparation, implementation, and interaction with middle school students as valuable learning experiences that strengthened their communication, teamwork and leadership skills. Particularly, mentors reported that facilitating the sessions was enjoyable and helped them recognize their capacity to work effectively with younger learners, communicate complex engineering concepts clearly within a short period, and decompose multifaceted projects into manageable components. Several mentors highlighted the value of incorporating question-and-answer exchanges and providing students with opportunities for open exploration. Mentors also described gains in practical skills, including debugging and customizing code, with some encountering sensors and microcontroller programming for the first time.

In summary, mentor reflections suggest that the program provided meaningful opportunities for STEM communication, project development, and professional growth. Together, the mentor reflections suggest that the mentor-driven, hands-on model may support STEM communication, student engagement, and professional growth for college student mentors.

5.4. Implications for Practices

The findings from the NSF STEM Day event have several important implications for STEM educators, university outreach programs, and policymakers seeking to broaden participation in STEM and foster early interest in robotics, computer science, and engineering among middle school students.

First, the findings suggest the value of hands-on, context-based informal learning in building students' confidence and interest in STEM. Organizers of similar initiatives should prioritize interactive demonstrations that connect STEM concepts to real-world applications, particularly in emerging fields such as robotics and digital communication. Aligning activities with students' everyday experiences—such as entertainment technology and sensor-driven devices—helps demystify complex concepts and makes STEM more accessible and engaging.

Second, eighth-grade participants' positive perceptions of STEM self-efficacy suggests that tailoring content to students' grade levels and providing opportunities for STEM identity formation through peer and near-peer mentorship may further support engagement. Third, the event underscores the value of university–community partnerships in addressing equity gaps in STEM education. Higher education institutions can serve as vital hubs for outreach by leveraging faculty expertise, student volunteers, and research infrastructure to create inclusive and inspiring STEM experiences. Events like STEM Day offer scalable models for collaboration among colleges of engineering, college of education and local secondary schools. Expanding these efforts to include parents, teachers, and community organizations would further reinforce learning outcomes and support long-term STEM pathways.

5.5. Discussion and Conclusions

This study examined middle school students' STEM interest and self-efficacy perceptions following participation in NSF STEM Day, a one-day informal STEM learning experience. In relation to RQ1, participants reported consistently high STEM interest, with engineering reported more frequently in the post-survey than in the pre-survey. In relation to RQ2, participants reported high levels of STEM interest and positive self-efficacy percep-

tions following participation in NSF STEM Day. In relation to RQ3, college student mentors described the event as a meaningful opportunity to develop technical communication, project facilitation, and youth-oriented STEM engagement skills

Additionally, this event involved training engineering college students for project development, efficient (short time, simplified) presentation of complex concepts, handling groups, organizing them and being involved into the learning process. Not only did many of the mentors acquire new knowledge and skills, whether it was programming using a new environment, sensors or new principles of operation and analytical apparatus (such as machine learning, for example), they also discovered abilities to teach and ignite curiosity and excitement in middle school students.

Given the unmatched survey responses, modest response rate, and small post-survey sample, the findings should be interpreted as exploratory evidence that can inform the design and evaluation of future one-day informal STEM outreach experiences.

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Appendix A. Survey Questions

STEM Interest Comparison (Pre- and Post-Survey)

1. Do you know what “STEM” stands for? (Yes/No)
 2. How interested are you in STEM subjects? (Not interested 1, Very interested 5)
 3. Please write which subjects you are particularly interested in. (Open-ended)
 4. How often do you participate in STEM-related activities outside of school? (Very Often—weekly; Sometimes—monthly; Rarely—a few times a year; Never)
 5. What aspects of STEM interest you the most? (Check all that apply) (Science Experiments; Robotics; Coding/Programming; Technology/Design; Mathematics; Space Exploration; None)
 6. Do you see yourself pursuing a STEM study and career in the future? (No; Maybe; Yes; Haven’t decided yet)
- STEM Self-Efficacy (Strongly Disagree 1, Strongly Agree 5)
7. I am good at using scientific principles to explain things I see in everyday life.
 8. I am confident that I can overcome challenges when learning STEM subjects.
 9. Compared to my classmates, I think I know a lot about STEM subjects.

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