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Evaluating SPARK: Outcomes of a summer STEM program for middle school girls

Dr. Andri Christodoulidou, University of Connecticut

Dr. Andri Christodoulidou is an Assistant Research Professor in the University of Connecticut College of Engineering. She holds an MPhil in Educational Research Methods and a PhD in Education from the University of Cambridge, UK. Her doctoral research at Cambridge was funded by the prestigious Economic and Social Research Council (ESRC) through a competitive proposal-based grant.

Dr. Christodoulidou has presented her research at major peer-reviewed international conferences, including the British Educational Research Association (BERA), the Association for Psychological Science (APS), the European Association for Research on Learning and Instruction (EARLI), and Cambridge's own "Kaleidoscope" research conference.

In her previous role as Director of Impact Assessment at UConn's Vergnano Institute, she developed evaluation methodologies to assess the outcomes of diverse educational outreach programs.

Currently, she is a member of the National Institute for Undersea Vehicle Technology (NIUVT) research team that designs and leads studies examining the impact of K–12 and college-level outreach initiatives aimed at promoting interest in naval STEM fields. She is also a core faculty member in the PhD Program in Engineering Education at the University of Connecticut.

Dr. Zeynep G Akdemir-Beveridge, University of Connecticut

Dr. Zeynep G Akdemir-Beveridge completed her undergraduate and master's studies at Bogazici University, Turkey and she received her PhD degree in the specialization of Curriculum and Instruction at Purdue University. She had a chance to work with engineers at Purdue's School of Engineering Education during her doctorate studies. She is now a postdoctoral fellow at the University of Connecticut. Her first year of postdoctoral work has focused on developing an engineering creativity assessment tool (ECAT). Currently, she is developing curriculum and working on several research projects in the context of STEM and engineering education at UConn's Naval Science and Technology Program. Additionally, Dr. Akdemir-Beveridge enjoys finding ways to teach complex science and engineering topics in simple, conceptual ways at the K-12 level and to non-academic audiences.

Dr. Stephany Santos, University of Connecticut

Stephany Santos is a Ph.D candidate in biomedical engineering at the University of Connecticut. In addition to her research in biomechanics, she is currently an advisor of the Engineering Ambassadors outreach group.

Dr. Alexandra Hain, University of Connecticut

Dr. Lexi Hain is an Assistant Professor in the School of Civil and Environmental Engineering at the University of Connecticut (UConn) and has served as the Director of the UConn Navy STEM Education Program since 2021. She received her Ph.D. in Civil Engineering with a focus in Structural Engineering from UConn in May 2019. Dr. Hain's work emphasizes workforce development through innovative educational programming, interdisciplinary collaboration, and hands-on research engagement. She has led initiatives designed to recruit, retain, and prepare students for careers in naval engineering, skilled trades, and related technical fields, fostering sustainable talent pipelines in support of Department of Defense priorities. In addition to her education leadership, her research focuses on novel construction materials, including ultra-high performance concrete (UHPC), and innovative inspection and repair techniques for civil infrastructure. She has served as principal investigator (PI) on projects supported by the Department of Defense, Office of Naval Research, the National Science Foundation, Connecticut Department of Transportation, and industry partners, integrating technical research with educational and workforce development objectives.

Evaluating SPARK: Outcomes of a summer STEM program for middle school girls

(Research to Practice)

Abstract

The study evaluates SPARK, a residential summer outreach program hosted at the University of Connecticut, designed to foster middle school girls' interest in and intent to pursue science, technology, engineering, and mathematics (STEM) education and careers, as well as their confidence in STEM skills. The program engages participants entering grades 7–10 in one or more of three independent, week-long sessions, each featuring experiential, hands-on activities and project-based challenges that introduce diverse engineering concepts and disciplines.

Using a mixed-methods, repeated-measures survey design with embedded qualitative data, the evaluation examined outcomes for the 2024 cohort. Forty-two participants completed both pre- and post-program surveys assessing attitudes toward engineering, an engineering career, and self-efficacy in engineering design and in presenting design projects. The post-program survey also included closed- and open-ended items capturing participants' perceived growth in self-efficacy in STEM skills and motivation.

Quantitative analyses indicated significant positive gains from pre- to post-program across several targeted constructs, while thematic analysis of open-ended responses provided corroborating insights into the role of hands-on engagement and project-based challenges in enhancing self-efficacy in STEM skills.

Overall, the findings suggest that structured experiential learning activities within this program are associated with gains in both the affective and cognitive dimensions of pre-college STEM education, while also offering insights for the design and improvement of similar outreach initiatives.

Background and Motivation

Brief global and national STEM workforce trends

Rapid technological change, automation, and the green transition are reshaping global labor markets and increasing demand for advanced technical skills. The World Economic Forum's Future of Jobs Report 2025 projects significant workforce transformation through 2030, with strong growth expected in technology and engineering-related roles, including those tied to the energy transition [1].

In the United States, national employment projections similarly signal strong demand for STEM talent. The U.S. Bureau of Labor Statistics (BLS) projects STEM occupations to grow 8.1% from 2024–2034, outpacing non-STEM occupations growth (2.7%), and to offer substantially higher median wages [2].

Within STEM, engineering remains a core workforce domain that links scientific and mathematical knowledge to real-world technologies and systems. Reflecting this role, the BLS projects architecture and engineering occupations to grow faster than average from 2024–2034, with roughly 186,500 annual openings and a median wage of $97,310 (May 2024), highlighting both strong labor-market demand and economic opportunity [3].

Female underrepresentation in STEM learning pipeline

Despite strong workforce demand, participation in STEM particularly in engineering remains uneven across demographic groups, indicating a persistent "pipeline" and equity challenge. Importantly, disparities in who imagines themselves in engineering careers do not begin at college entry; rather, research suggests that students' STEM career thinking and course-taking trajectories begin to take shape during the middle school years. For example, Tai et al. found that students who express interest in science careers in middle school are more likely to complete STEM-related degrees later, underscoring the importance of early motivational and identity-related factors [4].

International evidence echoes that early interest gaps are meaningful and often gendered. Using data from PISA 2015, OECD reports that by age 15, boys are more than twice as likely as girls to expect to work as engineers, scientists, or architects, and that 4.8% of boys versus 0.4% of girls expect to work as ICT professionals on average across OECD countries [5]. These patterns suggest that engineering-related aspirations can diverge well before students reach critical high school or college decision points, making early interventions especially consequential for broadening participation. Additionally, national data shows that women remain underrepresented in engineering-related occupations (approximately 1 in 6 in recent U.S. estimates), indicating targeted efforts are warranted [6].

Early K–12 participation and interest gaps

What participation in engineering looks like in K–12 can differ from participation in more established STEM subjects. National reviews of K–12 engineering education note that, historically, engineering has lacked a widely shared vision and consistent standards across states and districts, leading to highly variable and often local, program-dependent opportunities for students [7]. In many K–12 settings, students' engineering exposure occurs through project-based "engineering design" activities embedded within science, technology, or integrated STEM units rather than through a dedicated, sequential engineering curriculum [7]. Recent policy shifts (e.g., the NGSS) explicitly elevate engineering design by integrating it into K–12 science education “to the same level as scientific inquiry,” while also acknowledging that the standards emphasize design practices necessary for all students rather than a complete engineering pathway [8]. Consistent with this landscape, the National Academies also describe how informal channels (e.g., contests, after-school programs, and summer programs) have become prominent venues for engineering engagement and can stimulate interest and awareness. However, participation and representation in these initiatives have often not been proportional for girls and other underrepresented groups, reinforcing the need for intentional design for equity [7].

STEM Summer Camps

National Research Council syntheses emphasize that informal environments can support sustained engagement with STEM ideas and practices across diverse contexts and learners [8]. In the out-of-school-time (OST) space specifically, National Academies guidance further highlights that effective programs are designed to be engaging and responsive to youth and to connect learning experiences to learners’ lives and communities [9]. Informal STEM learning broadly refers to learning that occurs outside traditional required classroom instruction, often in settings such as museums, after-school programs, community programs, and summer camps.

A growing research base suggests that such informal and out-of-school STEM programs can positively influence learners’ attitudes, interest, intentions, value beliefs, self-efficacy, and motivation [10], [11], precisely those affective and motivational constructs that often shape longer-term participation pathways. Recent meta-analytic evidence supports these associations. Xia et al. synthesized decades of U.S. K–12 studies and reported an overall positive association between informal science education experiences (including after-school programs and summer camps) and students’ STEM interest and attitudes, noting that effects vary by program type, grade level, and STEM subject area; importantly, their synthesis also attends to outcomes such as self-efficacy and STEM-career–related constructs [10].

Complementing this broad evidence, engineering-specific camp research also points to developmental benefits for pre-college participants. Robinson et al. found that participation in introductory engineering summer camps was associated with changes in middle and high school students’ engineering interest and identity formation, reinforcing the plausibility that well-designed engineering camps can shape the kinds of beliefs and intentions that precede later course-taking and career decisions [11].

Focusing on the middle school years, a formative period when students’ STEM interests and aspirations are emerging [12], Hite and Taylor found that participation in out-of-school time (OST) STEM programs supported students’ interest and motivation through hands-on learning opportunities, collaborative problem solving, and exposure to authentic STEM practices. Participants described greater enjoyment of STEM and increased motivation to engage in STEM learning, particularly when activities allowed for autonomy, teamwork, and real-world relevance [12]. Similarly, a middle school girls–focused STEM summer camp study reported significant gains in participants' scientific self-efficacy, with career-interest items exhibiting ceiling effects, highlighting OST programming as an important context for confidence-building and strengthened intention to persist in STEM [13].

Taken together, this body of work reinforces the logic of early, engineering-explicit interventions that can broaden access to authentic design experiences and deliberately support girls' self-efficacy in STEM as well as future intentions, particularly during key developmental periods such as early to mid-adolescence when trajectories begin to form.

Program Overview

Goals and intended outcomes

In response to persistent inequities in STEM learning and the recognition that early adolescence is a formative period for developing engineering self-concept and future-oriented intentions, SPARK was intentionally designed as a girls' engineering/STEM camp. It aims to provide a supportive context for early engineering learning, confidence-building, motivational growth, and a sense of belonging.

The program is a residential summer camp for middle school girls (rising grades 7-10), offered across three independent, week-long sessions. Each session features distinct STEM learning activities, and participants may attend for one week with the option to return for additional sessions. It offers a hands-on experience designed and delivered by current undergraduate women studying engineering and science, with guidance from women faculty and partners at the University of Connecticut (UConn). It explicitly combines STEM learning with empowerment, creativity, innovation, and community-building [7].

SPARK is administered by undergraduate students who serve as program counselors under the direction and supervision of faculty from UConn's Vergnano Institute for Impact. Counselors receive structured training for two weeks to support the 24/7 residential experience, including community building, residence hall protocols, and behavioral management. Undergraduate counselors provide continuous supervision of participants and reside in the dormitories for the duration of the program to help ensure student safety during both daytime and overnight hours.

The 2024 SPARK program, including counselors, administrators, and other program staff, was primarily funded through the Advancing Naval Careers Through Higher-Education Outreach and Research (ANCHOR) award. Additional support was provided through a combination of small community grants, program-generated revenue, and funding from the Vergnano Institute for

Impact. Although SPARK is a fee-based program costing $1,000 per week, approximately 75% of the 2024 cohort attended at no cost due to financial support from these sources.

Experiential Learning Program Structure

SPARK provides real-world insights into engineering and innovation based on various STEM-based activities. It has a week-long residential structure with multiple full sessions. Across these sessions, the daily schedule follows a consistent cadence. Mornings begin with a "morning meeting" and then shift into a substantial block of experiential STEM activities mainly focused on building, designing, and coding. Examples of these engineering-focused experiences include constructing a mechanical drawing device that draws on simple machines (e.g., Build-a-Sketch), assembling and troubleshooting LED circuits (e.g., Light up the Night), creating a coded game using scratch (e.g., Scratch Arcade), and developing prosthetic prototypes as biomedical design activity (e.g., Bionic Builders). Collectively, these activities reflect engineering design thinking as a sequence of practice firstly starting with defining the problem/engineering challenge, then followed up by constructing prototypes, testing, evaluating, and refining designs through iteration. These steps mirror K–12 engineering practice descriptions that emphasize designing engineering solutions through the steps of development, testing, and improvement [14].

Consistent with this structure, a recurring daily component of the program is the *She Innovates* workshop, which supports girls' creative and innovative work leading to an end-of-session showcase. During this workshop, conducted in partnership with Connecticut's Invention Convention Center (CIC), students are guided to apply engineering design thinking processes to develop their own innovations, culminating in the presentation of their work as the final phase of the engineering design cycle.

The program's instructional approach maps onto experiential learning, in which learners cycle through concrete experience, reflection, conceptualization, and active experimentation [15], as campers create prototypes, test and examine outcomes, revise approaches, and share end products in a culminating format. Additionally, the program maintains a consistent team-based structure that supports the collaborative nature of engineering design work and provides repeated opportunities for shared problem solving and iterative improvement of solutions.

Afternoons typically extend the engineering experience through tours and demonstrations, including laboratory visits and applied engineering site tours, as well as invited speaker sessions in which STEM professionals share their educational and career pathways. In addition, empowerment workshops are integrated into the program to support girls' STEM goals, confidence, and aspirations. Evenings are reserved for dinner and counselor-supported community programming. The program concludes with culminating elements including a weekly STEM competition and an innovation showcase.

Purpose of the study

Aligned with the program's content and goals, this study seeks to evaluate and understand the outcomes of the 2024 implementation for participating students. The study examines changes from pre- to post-program in students' attitudes toward engineering, affective response to an engineering career (e.g., excitement), and self-efficacy in engineering design. In addition, it assesses students' perceptions of increased motivation toward STEM learning and increased self-efficacy in STEM skills after participating in the program, as well as how students explain their self-efficacy in STEM skills in relation to their program experiences. Accordingly, the evaluation addresses the following questions:

1. Do attitudes toward engineering, comprising interest, intent to pursue engineering, and perceived value of engineering, change from pre- to post-program?
2. Does excitement about an engineering career change from pre- to post-program?
3. Does self-efficacy in the engineering design process change from pre- to post- program?
4. Does self-efficacy in engineering design project presentation change from pre- to post-program?
5. To what extent do students report increased motivation toward STEM learning following participation in the program?
6. To what extent do students report increased self-efficacy in their STEM skills following participation in the program, and if so, how do they explain this change?

Methodology

Research Design and Rationale

Adhering to the view that complex problems in the social sciences often require evidence beyond only numbers or only words [16], the present evaluation employs a mixed-methods design to draw on the strengths of both quantitative and qualitative approaches. A QUAN-dominant mixed-methods embedded design was used, in which one methodological strand serves as the core component and the other is nested within it to address supplementary questions and enrich interpretation [17].

More specifically, the core, quantitative component, a survey- based design, was implemented at two timepoints using a repeated measures approach. Repeated measures allow multiple measurements of the same variables, received by the same individuals to be taken over a period to assess change or growth [18]. The first time point involved administering the survey prior to the program, and the second timepoint the administration of the same sets of questions at the completion of the program. The collection of pre- and post-program quantitative survey data enabled examination of changes in key outcomes including students' attitudes toward engineering, excitement about an engineering career, self-efficacy in the engineering design process, and self-efficacy in engineering design project presentation (RQ1–RQ4).

At the second time point, additional quantitative and qualitative data were collected using a closed-ended, and a mixed-method, survey items. The closed-ended item assessed whether students reported increased motivation toward STEM learning following participation in the program (RQ5). The mixed-method item assessed whether students reported increased confidence in their STEM skills after participating in SPARK and prompted them to explain their response (RQ6). The embedded qualitative strand provided deeper insight into students' perspectives; these reflections helped illuminate and contextualize quantitative findings related to self-efficacy in STEM skills.

This design was deemed appropriate for investigating the program's impact because it provided an efficient framework for addressing the evaluation's research questions. The quantitative data were necessary to determine whether, and to what extent, participation in the program was associated with changes in attitudes, self-efficacy, and perceived motivation, while the embedded qualitative item allowed participants' voices to be heard and added explanatory and contextual detail to self-efficacy quantitative findings.

Survey Overview

In accordance with the evaluation's purpose and questions, we created a survey to assess the targeted variables. Using a repeated-measures approach, the same items were administered before and after the program via pre- and post-program surveys to assess attitudes toward engineering, excitement about an engineering career, self-efficacy in the engineering design process and design project presentation. Across both administrations, participants responded using a 5-point Likert type scale, rating each statement from 1 (not at all true) to 5 (very true). Engineering interest was assessed using a direct self-rating of interest on the same 5-point response scale. In the post-program survey, items were prefaced with the stem "After attending the program…" to anchor responses to a consistent reference period and to focus respondents' answers on their program experience.

Pre- and post-program survey items were either adapted from published instruments or researcher-developed to operationalize construct definitions drawn from the literature. To support the content validity, all items were reviewed and discussed with two program administrators or relevance and appropriateness. Cronbach's alpha coefficient was calculated as indicator of internal consistency for pre- and post-program responses for all subscales that included two or more items.

In addition to the repeated measures, the post-program survey included one closed-ended and one mixed-method question to assess students' reported increases in motivation toward STEM learning and self-efficacy in STEM skills. These questions were also reviewed with program administrators to confirm their appropriateness.

Survey Items

To measure **attitude toward engineering**, we drew on the definition of attitude [19] as a psychological tendency comprising affective (feelings /emotions), cognitive (beliefs, perceptions), and behavioral components (actions tendencies). In this framework, students' attitude toward engineering was measured in terms of interest (affective), beliefs (cognitive), and intentions (behavioral). Similar to other work that treats these dimensions as related but distinct constructs [20], in this evaluation interest, beliefs, and intentions were measured as separate variables, as described below.

Engineering interest: Following Unfried et al., who used direct rating scales ranging from not at all interested to very interested to assess students' interest in STEM subjects [21], we asked students to rate their interest in engineering using two 5-point rating items. One item asked, "How interested are you in engineering?" with responses from 1 (Not at all interested) to 5 (Very interested). In a second item, we used parallel wording to assess the affective appeal of engineering, asking, "How appealing is engineering to you?" with responses ranging from 1 being Not at all appealing to 5 being Very appealing.

Beliefs about engineering as a field: To assess students' cognitive beliefs about the societal value of engineering, we used three researcher-developed items. These items reflect common messages about what engineers do and how engineering benefits society. They are conceptually similar to the "Value of Engineering to Society" dimension in Lachapelle and Brennan's Engineering Interest and Attitudes (EIA) instrument [22], which includes items such as "Engineering is useful in helping to solve the problems of everyday life" and "Engineering helps me understand today's world." The evaluation has also considered descriptions of engineering used in the S-STEM survey [23] that describe engineers as using math, science, and creativity to solve problems and design products that improve people's lives. Accordingly, students in our study rated how true they found statements such as "Engineers make a difference in the world," "Engineers build things we need," and "Engineers invent and design things that improve our lives" on a 5-point Likert-type scale.

Intent in engineering: In line with prior work that conceptualizes students' intentions as their plans to pursue further learning in a STEM subject [24], we assessed intent as students' willingness to further engage with engineering learning. Students rated how true they found two statements on a 5-point Likert-type scale (1 = Not at all true, 5 = Very true). One item, "I plan to take engineering-related classes at my school," was adapted from Cappelli et al.'s item, [25] "I plan to take a lot of math classes in college." A second item, "I plan on studying engineering in the future," was added by the authors. Together, these items capture intentions to pursue engineering-related educational opportunities without requiring firm, definitive commitments to an engineering career, which would be more appropriate to assess with older students.

Excitement about an engineering career: Because beliefs and intentions related to engineering as a field are assessed as components of attitude toward engineering, and given that most participants were middle school–age students whose specific career plans and knowledge of occupational characteristics (e.g., salary, training pathways) are still forming, we focused on the affective component only for the career-specific domain. Accordingly, we included a single item capturing students' excitement about the possibility of an engineering career as an affective indicator of career-related attitudes. This researcher-developed item asked students to indicate how true the statement, "I am excited about the possibility of working as an engineer in the future" was for them.

Self-efficacy in the engineering design process: Defined as a self-judgment of one's ability to perform a task and succeed within a specific domain [26], self-efficacy in the engineering design process was measured using three researcher- developed items. These items included statements such as: "I can contribute good engineering design ideas to a team to solve a problem," "I can invent engineering design solutions to solve problems," and "I can follow the steps needed to accomplish an engineering design project."

Engineering design project presentation self-efficacy: Following Bandura's self-efficacy definition [26] and drawing wording from Wang and Sun's Speaking Self-Efficacy scale [27], self-efficacy in engineering design project presentation was assessed using two researcher-developed items. These items included statements such as: "I can speak with confidence in public about my engineering design work" and "I am confident that I can do well presenting my engineering design project to others."

Motivation toward STEM learning: Motivation toward STEM learning was assessed using a closed-ended item administered in the post-program survey. Students were asked whether they were more motivated to take STEM classes at school, after participating in the program. As with the repeated items, the question was framed with the stem "After attending the program…" to anchor responses to their program experience.

Self-efficacy in STEM: A mixed-method question was embedded in the post-program survey to assess students' perceived changes in confidence in their STEM skills and to collect their reflections on these changes. Specifically, students were asked: "Are you more confident in your STEM skills now than before the program? Please explain your answer.

Participants

A total of 85 female students participated in SPARK, a three-week STEM summer program, with approximately equal enrollment in each weekly cohort (26 in Week 1, 31 in Week 2, and 28 in Week 3). Of these, 42 students completed both the pre- and post-program evaluation surveys and were included in the analyses. Surveys from students who attended the program for multiple weeks were excluded so that each participant was represented only once, avoiding overrepresentation of repeat attendees, and maintaining a focus on the overall program rather than individual weeks.

Most participants were middle school, rising 8th- and 9th-grade students (33% and 43%, respectively), with smaller proportions entering 10th (12%) and 7th (12%) grades in the upcoming academic year. Participants represented diverse ethnic backgrounds: 17% identified as Black/African American, 16% as Latino/Hispanic, 14% as Asian, and 38% as White. Finally, 15% of students have not provided information on their ethnic background.

Procedure

Both the pre- and post-program surveys were created and administered using Microsoft Forms. Approximately two weeks prior to the start of the program, a program administrator emailed a survey link to participating students, either directly or via their parents. The email indicated that completion of the survey was optional, was intended for evaluation, and was not a condition of participation in the camp.

The post-program survey was administered on the last day of the program using a QR code. Both surveys entailed the same items described in the Survey Items section. For the post-program administration, survey items were framed with the stem “After attending the program…” to focus students’ responses on their experience in the program. Additional closed- and open-ended questions were included only in the post-program survey.

Students’ responses were treated as confidential, and identifying information was removed prior to data analysis. This evaluation was reviewed by the University of Connecticut Institutional Review Board (IRB) and was determined not to constitute human subjects research; therefore, parental permission for participating minors was not required.

Results

Quantitative Results

Prior applying statistical analysis to ensure that collected data are appropriate to use,
item reliability was examined for scales that entailed at least two items, applying the Cronbach’s alpha internal consistency coefficient. Almost all items, across both, pre and post

program, had alpha between .70 and .90, which indicates good (70 .80) or very good internal consistency, with some items in pre-survey with acceptable alpha levels [28] as .60 -.70.

Table 1 shows the number of items measuring each construct, along with the alpha coefficient for the pre and post program surveys.

Following reliability analysis, pre- and post-program responses were matched using unique identifiers, which were removed prior to analysis. Paired responses were then exported to SPSS to conduct paired-samples t tests and effect size analyses. Participants who completed only one of the two surveys were excluded from the analysis.

Table 1

Cronbach's alpha levels per measure for pre and post program items

Variables	# Items	Pre-program alpha	Post-program alpha
Interest	2	0.90	0.88
Belief	3	0.72	0.89
Intent	2	0.75	0.76
Excitement toward a career in engineering	1	NA	NA
Self-Efficacy in the Engr. Design process	3	0.66	0.81
Self-Efficacy in engineering project presentation	2	0.90	0.91

Note. Cronbach's alpha coefficients (α) were not calculated for single-item measures

As shown in Table 2, comparisons of pre- and post-program ratings indicate changes in several targeted variables. Paired-samples *t* tests revealed statistically significant increases in mean ratings for self-efficacy in the engineering design process, design project presentation skills, and excitement about pursuing a career in engineering. In addition, Cohen's d effect sizes are minimum 0.30 for the same variables supporting the t-test findings and indicating meaningful growth from pre- to post-program. All significance tests were two-tailed.

Table 2

Paired t tests and Cohen's d between pre-and post-program ratings (N = 42)

Targeted Variables	Pre-Program		Post-Program		*t*-test	*d*
	Mean	SD	Mean	SD		
Engineering Interest	7.23	1.7	7.52	1.6	$t(41) = 1.07, p > .05$	0.1
Beliefs about engineering	13.7	1.3	14.1	1.3	$t(41) = 1.7, p > .05$	0.2
Intent in engineering	7.6	1.4	7.8	1.4	$t(42) = 0.6, p > .05$	0.1
Self-Efficacy in engineering design	11.5	1.6	12.5	2.1	$t(41) = 3.6$, $^{***}p < .001$	0.5
Self-Efficacy in engineering project presentation	6.5	2.1	7.2	2.2	$t(41) = 2.5$, $^{**}p < .01$	0.4
Excitement about a career in engineering	3.64	.95	3.98	1	$t(41) = 2.3$, $^{*}p < .05$	0.3

Figure 1

Comparison of pre and post-program mean scores for variables with significant change

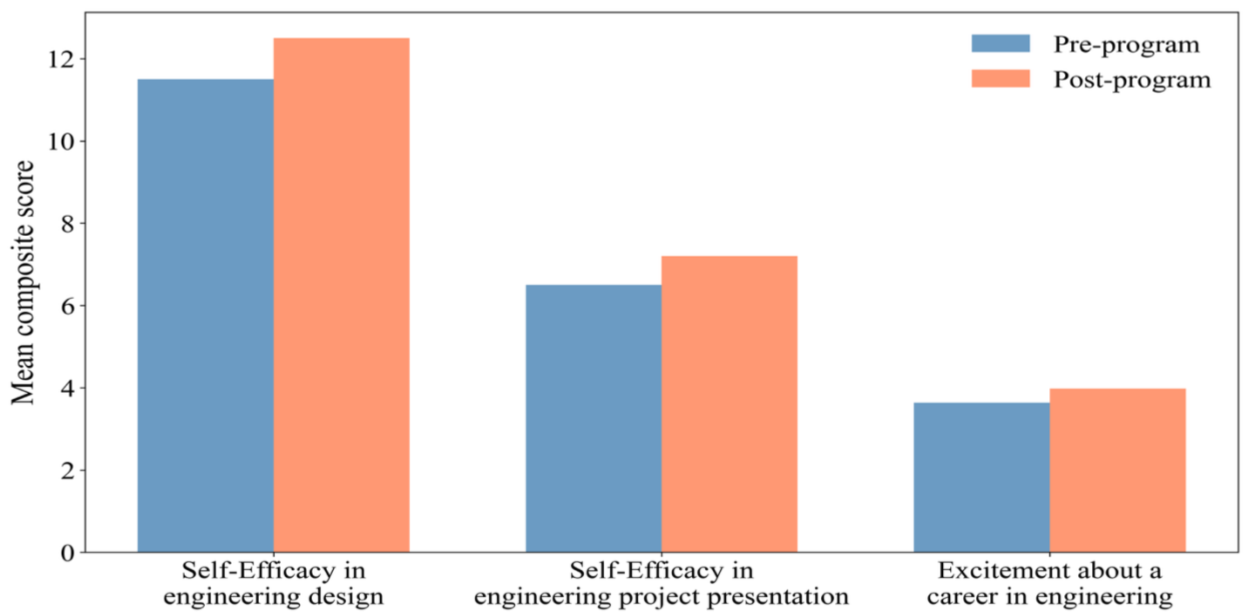


Figure 1 presents pre- and post-program average scores for variables demonstrating statistically significant change following program participation. Self-efficacy in engineering design and project presentation are composite measures based on three and two survey items, respectively (maximum possible scores of 15 and 8). Excitement about a career in engineering was assessed using a single survey item with a maximum score of 5.

In response to the closed-ended question asking whether participation in the program increased students' motivation to take STEM classes at school, most students (86%), as shown in Figure 2, reported increased motivation**.** An additional 7% indicated that they had already planned to take STEM classes but felt more excited about doing so after attending the program, 5% reported being unsure, and 2% reported that they were not more motivated

Figure 2

Distribution of student responses to the closed-ended motivation question

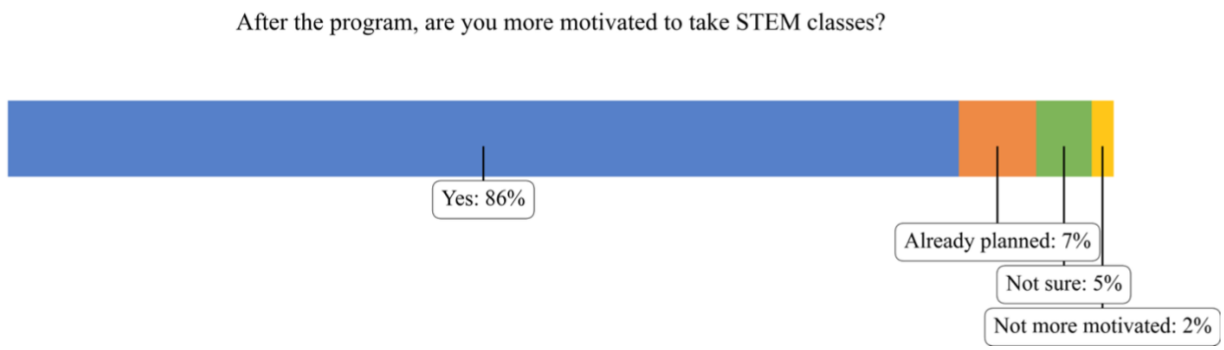
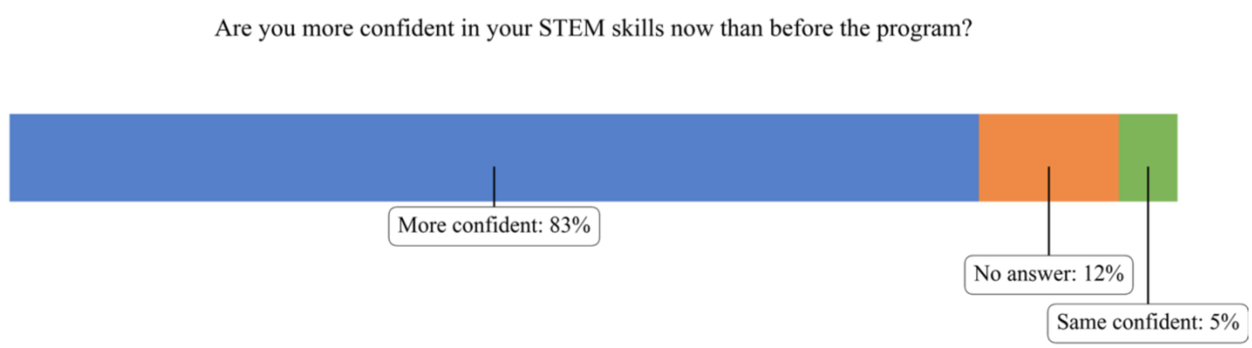


Figure 3

Distribution of student responses to the closed-ended confidence question



The final post- program survey item asked students whether they were more confident in their STEM skills after participating in the program and invited them to explain their response. Figure 3 presents the percentage of respondents to the closed-ended portion of this item. Thirty-five students (83% of participants) reported feeling more confident, two students (5%) reported that their confidence remained about the same, and five students (12%) did not respond.

Qualitative Results

Thirty-three of the thirty-five students who reported being more confident also responded to the qualitative component of the item, providing written explanations. Qualitative analysis of these reflections, in which students explained why their confidence had increased after the program, yielded five themes. Table 3 summarizes the themes that emerged from students' explanations, along with their frequencies and illustrative quotes.

Table 3

Themes and illustrative quotes from students' explanations of increased confidence (N = 33)

Theme	N	%*	Example Quotes
Deeper understanding of STEM concepts	11	33	"I feel as if I have a better understanding of some more science materials" "I learned more (like bones and skeletons) and things I was confused about made more sense after attending"
Understanding and applying the engineering design process	8	24	"I learned how to engineer and invent things to solve problems" "I have learned ways to be more efficient when designing inventions"
Development of hands-on technical skills	6	18	"I have learned how to code better and am definitely more confident now" "I have learned how to build with wood and pipes"
Personal growth including enhanced presentation skills	5	15	"Yes because I know that everyone struggles with it throughout their time with STEM" "I learned how to express my projects to other people''
Teamwork and collaboration	3	9	"I learned to work in a team. I'm more confident teamwork-wise"

*Note. *Percentages may not total 100 due to rounding*

As it is shown on Table 3 the most frequent theme was deeper understanding of STEM concepts (33%), followed by understanding and applying the engineering design process (24%), development of hands-on technical skills (18%), personal growth (15%), and teamwork and collaboration skills (9%).

Theme Descriptions

Theme 1: Deeper understanding of STEM concepts

Approximately one-third (33%) of the 33 students attributed increased confidence in terms of having learned and understood more STEM content. They described gaining clearer understanding of topics such as computers and coding, bones and skeletons, bone growth, DNA and the brain, often noting that previously confusing material became clearer after participating in the program. As one student explained, “I’m more confident because I learned more (like bones and skeletons) and things I was confused about made more sense after attending [the program].” Similarly, another noted: “I am more confident now, I definitely understand computers more.” Another participant also reported a broader view of engineering as a field emphasizing increased awareness of how engineers design everyday items: “I am, I have learned about how everyday items are made by engineers…now I will definitely look into engineering in the future.” Taken together, reflections in this theme suggested that increased STEM knowledge and conceptual clarity were central reasons why students felt more confident after the program.

Theme 2: Understanding and applying the engineering design process

About one-quarter (24%) of students elaborated on their increased confidence by describing growth in their ability to invent, design, and solve problems efficiently. They reported “learning ways to be more efficient when designing inventions,” “learning how to engineer and invent things to solve problems,” and “knowing the engineering design process” as contributing to feeling more capable. For example, one student wrote, “Yes, I am more confident because I have learned ways to be more efficient when designing inventions,” while another emphasized gaining understanding of “the process and the technicality of engineering,” noting, “I’ve learned more about the process and the technicality of engineering. I feel like I am closer to becoming an engineer.” Collectively, the reflections in this theme suggest that actively applying the engineering design process and seeing their ideas turn into tangible solutions was a key source of increased confidence in their STEM skills.

Theme 3: Development of hands-on technical skills

About one fifth (18%) of students linked their increased confidence to the concrete, hands-on STEM skills they gained during the program. They described "learning how to build and make things" and "build with wood and pipes," as well as learning "how to code," and "how to use different apps". Overall, these reflections indicate that opportunities to build, code, and work with tools and materials were central to students' sense of technical growth and increased confidence.

Theme 4: Personal growth

When explaining why their confidence in STEM skills had increased after the program, 15% of students described experiences of personal growth. They noted feeling confident or way more confident, often linking this to learning more about themselves and how they handle challenges. Several students emphasized realizing that "anyone can do anything" and that "everyone struggles with STEM," suggesting that normalizing difficulty helped them view themselves as capable STEM learners. Others highlighted growth in their ability to manage situations and present their work (e.g., "I learned how to present a STEM project well"), indicating that for some students increased confidence was tied not only to skill development but also to a broader personal development.

Theme 5: Teamwork and collaboration skills

Several students, about 10%, pointed to growth in their ability to work with others. In their reflections they described "learning to work in a team" and becoming "more confident teamwork-wise," suggesting that collaboration itself was an area of development. Students highlighted learning "how to work in a group more efficiently and combine ideas," indicating that they became more capable integrating different perspectives. Within this theme, this successful collaboration reinforced student sense of capability in STEM (e.g., "I am more confident in my skills than before entering SPARK. I learned a lot about how to work in a group more efficiently and combine ideas".

Discussion

Both quantitative and qualitative findings indicate that SPARK was associated with meaningful outcomes for participants. Specifically, statistically significant gains were observed in girls' self-efficacy in the engineering design process and in engineering design project presentation, as well as in excitement about an engineering career. Additional quantitative evidence from participants' responses to post-program closed-ended questions indicated that most students reported strengthened confidence in their STEM skills, which complemented the observed gains in engineering design self-efficacy. Moreover, most students also reported increased motivation to enroll in STEM classes, further supporting the overall pattern of positive program outcomes.

The reported increases in confidence and motivation align with Bandura's theory, which posits that mastery experiences strengthen self-efficacy beliefs and influence motivation [29]. Students' mastery experiences through daily practice of STEM skills appear to have strengthened their self-efficacy, which in turn may have enhanced their motivation to persist in STEM learning. Notably, insight into increases in motivation was limited by the quantitative nature of the closed-ended survey items. The collection of additional qualitative data could help provide deeper insight into how these learning experiences contribute to motivational growth.

Nevertheless, qualitative data corroborated and further illuminated gains in self-efficacy. Students' reflections frequently emphasized that developing a deeper and clearer understanding of STEM concepts, learning technical skills, and having opportunities to apply the engineering design process contributed to enhanced confidence in their STEM abilities. Hands-on design work and opportunities to present projects functioned as mastery and performance experiences, which are widely recognized as powerful drivers of self-efficacy development [30], [31]. These results highlight the value of program features that prioritize experiential activities, authentic design experiences, and communication opportunities as mechanisms for strengthening students' confidence and engagement in STEM.

In addition to gains in STEM skills, students' reflections highlighted personal growth and collaboration as meaningful contributors to increased confidence. Experiences that normalized struggle, encouraged teamwork, and supported shared problem solving appeared to reinforce students' beliefs in their ability to engage successfully in STEM learning contexts. These findings suggest that, alongside individual mastery experiences, social interaction, collaborative work, and personal development functioned as complementary pathways through which the program supported students' confidence in STEM.

Interestingly, students' interest, intent, and beliefs about STEM remained stable from pre- to post-participation. Although students reported heightened motivation to pursue STEM learning and increased excitement about the possibility of an engineering career, their broader attitudes (operationalized as interest, beliefs about the value of engineering, and intent or plans for engineering learning) did not change significantly. This pattern may be attributable to students entering the program with already positive attitudes toward engineering, leaving limited room for measurable growth on these broader attitude measures. At the same time, exposure to engineering projects and role models might have made an engineering career feel more concrete and personally relevant, contributing to increased affective excitement about this specific career pathway. Future evaluations with larger samples may help clarify these patterns.

The absence of change in interest, intent, and beliefs may also reflect the relatively short duration of the program experience and the timing of measurement. Unlike self-efficacy and motivation, which are often responsive to brief mastery experiences, interest, intent, and beliefs about STEM careers are conceptualized as more distal constructs that develop over time through repeated learning experiences [32], [33]. Accordingly, increases in motivation toward STEM learning may emerge prior to measurable changes in students' stated plans or intentions, which are often shaped by structural and curricular constraints. As such, these more distal outcomes may require longer-term exposure to shift meaningfully. Nonetheless, gains such as increased self-efficacy in STEM skills, motivation toward STEM learning, and excitement about STEM careers are meaningful and important, as they may represent early steps toward later changes in interest, identity, and behavioral intentions.

Finally, although the findings of the present evaluation are specific to SPARK 2024 and limited by a small sample size and reflect statistically significant changes associated with participation rather than definitive causal effects, they underscore the importance of longitudinal research. Future studies using longitudinal designs could extend this work by investigating whether these short-term gains translate into sustained outcomes, including continued STEM engagement, course-taking, and the development of engineering identity over time.

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