Exploring Constructive Learning Environments for Secondary Girls' STEM Learning

Abstract

The purpose of the study is to explore and theorize the constructivist learning environment for secondary female students' STEM learning. The study was built on a funded program featured a tiered-team structure, hands-on experience, and interactive mentorship for engaging female students from Grades 6-11 in a five-week Summer Camp to learn Arduino programming & Robotics Design and integration of these tools to conduct projects in ubiquitous intelligent systems. In conducting this study, we used the case study method to provide a more multifaceted perspective on the camp, and how these perspectives inform an understanding of how the project's features impacted the students. All 37 female students participated in the survey, and eight participated in the interviews. The findings indicate that students were able to heighten their self-confidence and motivation. The themes of the learning environment were identified: knowledge enhancement, STEAM experience, as well as support and encouragement. The program had significant impacts on students' identity related to STEM identity, motivation and interest, and self-confidence. It also significantly impacts their sense of belonging, including peers' and mentors' sense of belonging. The study provided research evidence for designing STEM learning projects to enhance female STEM learning.

Keywords Constructivist learning environment; secondary female students; STEM learning; STEM identity; sense of belonging

Statement and Declarations

Funding

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Conflicts of interest/Competing interests

We have no conflicts of interest to disclose.

Ethics statement

We confirm the manuscript includes a description of all necessary ethics approvals. The University IRB committee approved the proposal, #1531812.

We confirm all subjects have provided appropriate informed consent and details on how this was obtained are detailed in the manuscript.

Availability of data and material

The dataset of this study is available upon request.

Code availability

Not applicable

Introduction

Studies (Salto, 2014; Scott, 2012) confirm that students who are exposed to “higher quality” STEM education, such as “hands-on” experiences, or who are in STEM-focused schools or programs, display an increased interest in pursuing a STEM career. Due to gender stereotypes, fewer females, particularly female minority students, participate in STEM than males because they lack self-confidence and support. Nevertheless, female students working in a single-gender group gain more benefits in terms of developing positive attitudes toward engineering than in a mixed-gender group in which males often take the lead (Sahin et al., 2015). We argue that a constructivist learning environment of a female group is important to female students’ academic self-confidence and motivation for STEM.

Increasing informal STEM learning activities and establishing a constructivist learning environment is very important for secondary female students who are at the age of constructing their identity. Students’ confidence is an important component of a learner’s self-concept and self-efficacy. Many studies showed that academic self-concept influences students’ academic achievement (Cokley, 2002; March et al., 1999; March & Graven, 2006). Males tend to exhibit higher academic self-concept in science/technology courses, while females are in non-science/technology courses (Marsh, 1989). We believe it is more important to understand what learning opportunities and teachable moments in a constructivist learning environment enhance female students’ knowledge and skills in computing and engineering and further their academic self-concept and identity.

The program featured a tiered-team structure, hands-on experience, and interactive mentorship for the five-week Summer Camp (the Camp) for female students in Grades 6-11 to learn Arduino programming & robotics design and integration of these tools to conduct projects in ubiquitous intelligent systems. Although the constructivist learning theory offered major theoretical perspectives of project and research design, we argue that for secondary girls and female students of color, there should be some different principles of the constructivist learning environment theory. Built on the National Science Foundation grant, we not merely examined secondary female students’ knowledge, skills, and interests in the computing and engineering field, further their academic self-confidence or self-efficacy and identity and self of belonging; but more importantly, we will explore and develop new components and concepts of constructivist learning environment for the students.

Theoretical Framework and Literature Review

Constructivist learning environment

We used a constructive learning environment theory to guide our project design and research. De Kock et al. (2004) defined the features of a constructivist learning environment as three tenets: constructive activity, situated contextual activity, and social activity. A constructive activity pertains to the process of 'learning to learn' because it is believed that learning occurs during meaningful and perplexing problem-solving in real-life situations and incorporates higher-order meta-cognitive learning approaches to knowledge. Alt (2015) explained it as conceptual conflicts and dilemmas, motivation toward reflections and concept investigation, and making meaningful, real-life examples. Engineering practices, including design and evaluation, are emphasized in secondary Next Generation Science Standards. This NSF project offered opportunities to learn computing and engineering knowledge & skills and application to engineering projects.

A situated contextual activity focuses on the self-regulated learner and on shifting external control over the learning process, as emphasized in traditional settings, to the student's internal control for learning. Alt explained it as materials and resources targeted toward solutions and meeting students' needs (Alt, 2015). During the Camp, the female students conducted engineering projects in ubiquitous intelligent systems in tiered teams. Each team includes two middle school students and one/two high school students. One college student of an engineering major will be identified as the mentor for the team, and one secondary STEM teacher will work as a co-mentor who will assist the college student in developing their mentoring skills, and provide scaffolding for the secondary students. This team structure motivates female students to identify their role models and long-term mentors. A virtual learning community through Discord was built to enhance the formal and informal interactions with their tiered peers developing their self-regulated learning.

A social activity emphasizes the cooperative dialogical nature of the learning process aimed at promoting new forms of learning. Alt (2015) explained social activities as arguments, discussions, debates, and sharing ideas with others. We believe that the tiered team structure provided an informal environment that immerses the participating female students of the Camp in cooperative social activities.

The researchers designed a tiered team structure to enable students and mentors to work in groups with different learning experiences and mentoring strengths. Tiered teams co-mentored by college students and STEM teachers completed challenging projects. Participants were secondary students and mentors of public school teachers and engineering students. All mentors were trained before the project. Middle and high school students were recruited, emphasizing minority students. The Camp included three weeks' classes on Arduino and Robotics Design and a 2-week STEM group project and lab visits. In the first three weeks, two talks given by guest speakers, and several educational activities for team building such as writing poems & essays, and crochet were also organized.

Self-concept and motivation

Academic self-concept is referred to students' perceptions about their levels of competencies within the academic realm (Eli, 2012; Wigfield & Eccles, 2000). Academic self-concept influences students' academic achievement (Cokley, 2002; Marsh & Graven, 2006). Males and females possess different conceptions about their competencies in academic abilities (Ireson & Hallam, 2001). Males tend to exhibit higher academic self-concept in science/technology courses, while females in non-science/technology courses (Marsh, 1989). It is important to understand female secondary students' learning knowledge and skills in computing and engineering fields and further their academic self-concept.

Students who are exposed to "higher quality" STEM education, such as "hands-on" experiences, or who are in STEM-focused schools or programs, display an increased interest in pursuing a STEM-related career (Sahin et al., 2015; Salto et al., 2014). The underrepresentation of female students in computing and engineering fields is attributed to factors such as a lack of self-concept, the stereotype of gender, and a lack of family and cultural support. One significant characteristic of female students is that they perceive less contextual and conceptual connections with real-world phenomena than their male peers (Cokley, 2002). Female students respond positively to male and female STEM teachers who are "caring, challenging, passionate, fair, and linked to the actual practice of science in some concrete way" (Cokley, 2002). Nevertheless, female students working in a single-gender group gain more benefits in developing positive attitudes toward engineering than in a mixed-gender group in which males often take the lead (Sahin et al., 2015). We argue that a single-gender constructivist learning environment is important to female students' interests, motivation, and self-efficacy.

Sense of belonging and STEM identity

Studies of sense of belonging showed that positive personal relationships and high-quality communication indicate a high sense of belonging in students (Baumeister & Leary, 1995). When students feel they belong, they have more enjoyment and perceived usefulness of experiences and further maintain engagement in learning (O'Neel & Fuligni, 2013); in comparison with boys, girl students decrease their sense of belonging as they age. It is important to identify the factors that trigger girls' sense of belonging in STEM learning.

Although the research mainly focuses on girls' STEM knowledge, skills, and interests in STEM, we attempt to examine the factors significantly related to the constructivist learning environment for female students' learning, such as identity and sense of belonging. Teenagers begin their identity development and often face issues in a new environment, particularly in STEM learning. Identity building encompasses many social aspects, including community and sense of belonging, the feeling or perception of belonging, the sense of making a difference, and shared emotional connection (McMillan & Chavis, 1986). Identity building boils down to students' perceptions of peer support, connectedness, acceptance, communication, and being valued.

We implemented the project with meaningful components of racial-related initiatives. in recruitment, we intentionally recruit more students, mentors, and parents as underrepresented minorities, particularly Latina, who represent the minority population of local communities. We have provided a series of videos of discussions about the female minority scholars' success, inviting the female scholars of STEM to guest speak so that they see their role models. As part of the project, we believe these experiences may impact students' cultural identity.

Program and Projects

The constructivist learning environment for the project consists of a tiered team structure, hands-on experience, and long-term mentorship. The Camp was designed to teach secondary female students computing and programming skills, the Internet of Things (IoT), and robotics. The following activities were organized: 1) one-week Mentor Training (MT) Workshop to train mentors to learn new technologies in ubiquitous intelligence, robotics, and mentoring skills as well as promote the development of real-world open problems and projects suitable for secondary students; and 1) three-week training courses in Arduino & IoT and Robotics Design interweaved with guest talks and educational activities; and 2) two-week project development by integration of these tools to conduct projects in ubiquitous intelligent systems in tiered teams co-mentored by college students and STEM teacher. Specifically, students learned Arduino programming, IoT system and Vex V5 robotics. Arduino is an open-source electronics platform based on easy-to-use hardware and software, which is very suitable for beginners to learn. Technically, Arduino is a programmable logic controller that can interact with the world through electronic sensors, lights, and motors. Arduino and their convenient support are attractive for female learners to build up their visuospatial abilities, which are important for learning engineering fields. Learning Arduino and its integration will allow the students to learn the design, development, and analysis of ubiquitous intelligent systems with broad applications in smart city environments. During the Camp, students used Arduino to implement projects in three categories: smart citizen services (e.g., autonomous attendance checking system), intelligent transportation system (e.g., smart parking lot system), and intelligent energy planning (e.g., intelligent solar tracker). The project description starts from an application scenario followed by a basic solution with questions on how to expand the design to solve a real-life problem. This helps motivate students to propose their own design and think about the design considerations and constraints.

More importantly, students also engaged in non-STEM activities, such as poem-writing, origami, and crochet, to integrated arts in their STEM learning experience. During their project demo on the last day, all teams decorated their showcases with crochet or painting pieces. Figure 1 shows the project demo showcase of the smart gardening system. We argue that art activities are very useful in stimulating female students' interests and gluing them to work together. Students are mentored by educators in their local school district and college students majoring in an engineering-based program. In the final weeks of the program, students are placed in groups with their peers to complete an original, culminating engineering project using what they learned in the course of the Camp.

Fig. 1 Smart gardening system

[Insert Figure 1 in here]

Methods

In conducting this study, we used the case study method to provide a more multifaceted perspective on the program, and how these perspectives inform an understanding of how the project's features impacted the students. A case study allows for significant data to be analyzed for evidence of personal, sociocultural, and professional experiences (Yin, 2003) that create the learning environment and outcomes.

Participants

The study investigated a five-week summer camp that occurred in the summer of 2022. The Camp was for grades 6 - 11 students, where they learned Robotics and Arduino programming (block- and text-based) and the integration of these tools to conduct projects in ubiquitous intelligent systems. Thirty-seven secondary school-aged female students within a state school district participated in the Camp and in surveys given throughout the course of the Camp that measured their experiences. These students were diverse in race and personal background. Eight of these students, representative of the 37-student population, were sampled to be interviewed face-to-face.

identity Data sources

The data sources included qualitative surveys and interviews. The use of these two sources allowed for triangulation of data and ensured validity and reliability (Yin, 2019). Qualitative surveys help find out the issues, needs, experiences that can be further explored in an interview. The survey questions focused on students' experiences. Specifically, students were requested to evaluate the content knowledge presentation (Robotics and Arduino lectures and learning activities) and organization of the group activities such as Origami, poem and essay writing, etc. They were also requested to report their perspectives of the learning environments including the use of Discord, and how they were developing their interests, self-confidence, and motivations for STEM.

Interview as a qualitative data source provides rich and in-depth information (Creswell, 2009). Semi-structured interviews were conducted with eight students at the end of the Week 5 of the program. Interviews expanded these students' survey responses to develop a stronger understanding of their personal experiences with the learning environment of the Camp, as these experiences related to their self-confidence, motivations, interest, and sense of belonging, as well as the development of knowledge and skills in Robotics and Arduino.

Data collection

Before conducting research, the researcher gained approval from the University Institutional Review Board (IRB), which deemed the study exempt. The research conducted had little or no risk and ensured confidentiality of all participants. In this research paper, any information about students and their schools were removed from the data and the pseudonyms were used to ensure confidentiality.

The first-author was the co-principal investigator of the funded project. He conducted the survey data collection at the end of the first three weeks. To reduce the biases and create reader confidence in the accuracy of the findings, the second author conducted the interviews with students at the end of the Camp (the fifth week).

Data analysis

The three-weekly surveys were analyzed with content analysis. Content analysis is appropriate as we aimed at finding trends about how students felt about their learning. Responses were reviewed using open coding to organize and become familiar with the interview responses. Then, selective coding was used to identify trends. Finally, data were analyzed for themes.

A second analysis was conducted of the student interview. In triangulation, these analyses were used to identify primary themes and subthemes present in both datasets. However, some subthemes were present in only one dataset but were strong enough to include as support for the primary theme. For instance, the subtheme of STEM and Art (STEAM) connections under the primary theme, Learning Environment, is present in students' interview transcripts but was not directly asked in the survey. Triangulation of these datasets was also used to most accurately define primary and subthemes in the context of students' perspectives, experiences, and verbiage.

The cross-case analysis was completed by two researchers working collaboratively. After primary themes and subthemes, consistent across all three weeks of the survey and in the interview, were identified, they were then assigned a color code. Salient sections of answer text or transcriptions—designated by key phrases or words—were then coded and grouped by theme. For instance, in student S16's response for Week 1, she states:

"I think the learning environment at the Camp is great. Everyone here is very helpful, kind, and supportive, and it feels like they're all your friends. My questions never go unanswered, and I feel like I can always ask for help. My self-confidence in relation to STEM has definitely improved. I understand how code works much better now, and learning a programming language doesn't seem that intimidating anymore."

Keywords such as *helpful*, *kind*, and *supportive* in relation to S16's experience with other individuals would be grouped under the primary theme, Sense of Belonging, while her description of her experience learning about STEM and a programming language would be grouped in the subtheme, Self-Confidence, which is under the primary theme of Identity.

A within-case analysis of student interview transcripts and the interviewed students' survey responses were used to identify especially unique perspectives of their experience. In the within-case analyses, two criteria for defining unique perspectives were created and followed. First, in their survey response, the student answered the question in-depth while relating their answer to personal experiences outside of the Camp. Second, in either their survey response or their interview, the student cited the impact of the Camp on either their STEM identity as a minority or their STEM identity as a female. Unique perspectives were identified in each subtheme. Both researchers worked collaboratively on the datasets in defining and identifying themes, as well as designating unique perspectives. The researchers discussed their perspectives in-depth to ensure clear communication in their analyses. Through this, the reliability of both the cross- and within-case analyses was strengthened.

Findings

Our study explored the learning environment in which female students and students of color are engaged in STEM learning. We created two cases and related the themes of findings to the themes. The names in these case studies are pseudonyms to protect each student's identity. Additionally, dialogue lines are constructed from students' surveys and interviews, though the verbiage is altered to provide a cleaner, more natural narrative form. The findings indicate that students were able to heighten their self-confidence and motivations in STEM as either a hobby or future career by developing a strong foundation in the STEM concepts explored. Students' involvement in crochet, poem writing, and origami STEAM activities also enhanced their learning of STEM concepts and thus made for a more multifaceted and effective STEM learning experience. We use Case 1 to report the theme of the learning environment and subthemes: knowledge enhancement, STEAM experience, and support and encouragement. We use Case 2 to report identity and sense of belonging with subthemes: STEM identity, motivation and interest, and self-confidence. The theme, sense of belonging, includes peers' and mentors' sense of belonging.

Case 1 vignette: Maria's STEAM learning environment

I am a first-generation Hispanic-American high school student and aim to be the first college graduate of my family. In addition to seeking higher education, I also wish to represent two strong identities of hers—being a minority and being a woman—in the field of STEM by pursuing a college degree in engineering. While I had already entered the Camp with the desire to pursue STEM as a career, my experiences in learning the concepts made me realize how broad the engineering field was and what more I could consider when choosing my major in the future. I began to consider electrical engineering as a possibility after working with Arduino.

As the Camp went on, I felt my STEM Identity grow not only as a result of STEM-based learning but also through my experiences with peers and mentors. One of the most memorable experiences was my time spent working and hanging out with peers. “The other girls—they support me in every way, shape, or form,” and “Girls will support girls, always.”

I felt a sense of belonging grow in my interactions with mentors, especially female mentors. One of my favorite mentors was from Vietnam. Seeing someone like her, “that is also from another place”, who succeeded in STEM, made me feel more motivated to pursue my dreams. This mentor also increased my sense of belonging in the Camp. Another mentor was an educator from my high school. One of my mentors suggested that I begin—and be captain of—a girl’s robotics team at my school when I returned in the fall semester. Hearing an educator support my dreams and provide me opportunities to grow made me even more determined to gain knowledge and experience to lead my future robotics team to success—and to take that first step into a STEM leadership role, which I hoped would be the first of many.

Subthemes of the learning environment

Knowledge enhancement. Each training course covers several topics. Taking the example of the Arduino & IoT course, the content covered include the following topics: Arduino programming basics & basic components, Arduino, IDE, and simulation using TinkerCad, programming sensors (including push button, buzzer, LDR, flame sensor, ultrasonic, temperature & humidity), introduction to IoT, ESP32 board, communication interface and cloud platform. Each topic contains several lectures, programming exercises,/hands-on circuit construction and mini project. Each lecture covers a specific topic with several examples each composed of detailed code and/or circuit demo. In their survey responses and interviews, students often stated that there was an increase in their STEM knowledge due to participating in the Camp's lectures and activities. Many cited Arduino and C++ as examples of new knowledge, and as enhancements of skills that they already had an introduction to through extracurriculars or previous STEM experience. S21 mentions that the Camp strengthened her coding skills. Her previous experience in middle school was "mostly blocked code"; in the Camp, the focus was primarily on writing code, and thus she learned to write code more efficiently.

During the lecture and project session, students are encouraged to ask questions, and conduct investigations to answer questions and build their understanding of STEM concepts. To complete the group project, students are encouraged to generate hypotheses, propose solutions, overcome challenges, and find solutions. Other students also felt that the Camp strengthened other skills not explicitly related—but vital—to STEM. A skill S1 mentions developing as a result of the Camp was perseverance. She states that "perseverance can be one skill that I learned because … both in the robotics and Arduino … portions of the Camp, perseverance was key. I had to use perseverance to … figure out problems."

STEAM experience

Through their interviews, girls expressed the ways in which the integration of STEM and art (STEAM), such as poem and essay writing, crochet, origami, etc., enhanced their motivation to learn concepts in the Camp. They touched on two ways in which this occurred. First, students stated how art activities allowed them to expound further basic concepts integral to success in STEM, specifically math and planning. Most students related these concepts to math in crochet, but one student (S8) also discussed how these concepts manifested in origami: "It had math in it as well, because you had to fold it [at] … certain angle and degrees, [and] because you could involve those in your [STEM] project, which is what we were doing. We're involving a chain in our project currently…"

Secondly, students also mentioned how art activities such as poem and essay writing and crochet provided them a "brain break" from STEM-based camp activities, which allowed students to "... [be] able to stop focusing so much on what [they were] struggling to learn and just learn something else. So, it feels like [they are] capable of learning more" (S16).

Support and encouragement

In the context of the student engaging experience, a majority of students who completed the Camp's survey expressed feeling encouraged and supported by their peers and their mentors through the learning process. Students work in small groups to solve problems, discuss ideas, and support each other's learning. Students felt this support during their in-person experiences as well as in their communications through Discord social media. During in-person sessions, students indicated that they felt comfortable asking questions of mentors and instructors and that they received help and support when needed from either peers or mentors. S7 noted that "the learning environment is very kind and supportive. I don't feel scared to ask someone else for help." When discussing her mentor, S7 cheerfully states: "[J] is my favorite mentor, hehe! They stuck with me in solving a problem that I had with my computer which I appreciate a lot!" Through Discord, students cite similar experiences with the cultivation of a supportive, helpful learning experience. Students who used it regularly stated its usefulness in regard to homework help, questions and answers, and project support. Even students who claimed not to use it often, such as S17 in her Week 1 survey response, state that: "[while] I haven't used discord during my time here, but I do believe it is helpful for when or if someone has a question that needs to be answered that day."

Case 2: Vignette Lillian's identity and sense of belonging

On the first day of the Camp, I was tentative—I viewed the Camp as merely another school, one where I did not know anyone or had a community where I could take my spark further. I was not sure how much of myself I could truly be. Yet, I decided to take the chance to express myself fully when June 1st—the second day of the Camp—came. I was nervous but felt it was a chance she needed to take the step to find the people I want to work with and know if the program was a place I would feel a sense of belonging.

June is Pride Month, and the Camp was during it. I was worried about what my campmates would say, but since me, my friends, and a lot of people around me are all LGBTQ+, I decided I would wear an outfit to just go all out for the first day of Pride. When I walked in, I was nervous, but what makes that day so special was that I could be fully myself. I got no negative comments on my outfit. After that, I knew that this was a good environment. This is a safe place.

Table 1. Girls' Constructivist Learning Environments
[Insert Table 1 in here]

From then, I felt safe and confident enough to succeed not only in my projects but in building strong relationships with my peers and mentors. I worked with STEM and art together after realizing the balance helped me stay engaged with instructional material. Balancing these kept me from losing focus and interest in the Camp's most important concepts. After taking a chance with my Pride outfit, I took another one by reading an original poem. I received feedback and support from my mentors and friends, who encouraged me to further explore poem writing. After that, I was more inspired to incorporate other STEAM concepts into my STEM projects, mostly in decorating my project robot, Slushy—my proudest achievement. While I'm still unsure whether I'll pursue STEM as a career, the Camp gave me the chance to experience a learning environment where I could create a strong community and experience, as one of my mentors called it, "multidisciplinary exploration."

Sense of belonging (SoBL)

We found that in the program girls feel accepted, valued, and included in the big group and small group. They feel comfortable, safe, and socially connected. and social connectedness.

A majority of students provided very positive feedback on their SoBL within peer groups. In both data sources, it was often mentioned that students felt that they "clicked" with one another very easily. In fact, despite not coming into the Camp with mutual friends, some students felt connected to their peers in a stronger way than the peers they see more frequently at their school. S16 states: "...the kids at my school are nice. But everyone here, it's like, I've known them for, like, three years." Students who expressed reluctance or doubts in social situations, or those who had more introverted tendencies, were also able to establish friendships throughout the Camp. S8, who felt doubtful of being accepted because she "talked a lot" when she perceived her peers as more quiet, stated in her interview that those quiet students became her "really good friends" by the end of Camp. Students also expressed feeling safe among peers, and that they could freely express themselves without feeling unsafe or judged (Table 2, Peer SoBL, S9).

Many students, in their survey responses and in their interviews, recounted positive experiences with their mentors and instructors that increased their SoBL. Students mentioned feeling encouraged and reassured when interacting with mentors, as well as connected to them in how their mentors created a more "fun" environment. Students reported feeling especially connected to mentors they could relate to in some way. When considering her interactions, S17 states that: "Talking to the mentors is like talking to your friends, because of how relatable they are."

Identity

A well-developed STEM identity can develop girls' academic achievement, motivation, and self-esteem. Girls who feel a sense of belonging in their educational environment are more likely to participate in learning activities, take risks, and persevere in the face of challenges.

When female students are encouraged to participate in STEM by peers and mentors, perceive the environment as comfortable and safe, and are given not only plenty of opportunities to learn but also a system of support to guide this process, there is a noticeable increase in their motivation, identities as women in STEM, and their self-confidence. Specifically, there is an increase in their desire to continue learning STEM as either a casual interest or—as shown most prominently in students' answers—to pursue a career in STEM fields, in robotics and engineering or even in more biological and natural sciences. In the case of students who already wish to pursue this path, they feel more confident in doing so, knowing that they have support, and are exposed to mentors and peers who are also involved in STEM.

In the context of the entire camp, many students stated that, because of their experience in the Camp, they wished to pursue, or were considering pursuing, STEM as either a hobby, such as through coding or robotics electives in school or a future career path. In these aspects, students who previously were either doubtful of their abilities in STEM or were uninterested in exploring STEM further reported an increase in their motivation to continue their STEM development beyond the Camp. S6 states in her interview, when asked if the Camp made her want to do more STEM-focused extracurriculars: "...Yeah, I do. For electives this year, I'm gonna do VEX Robotics, and 'Medical Detective.'"

Motivation and interest

Students expressed a consistent interest in the Camp's STEM and STEAM activities. When discussing these, students' responses were evenly mixed (i.e., some students would eagerly discuss an Arduino project, while others found the same spark of excitement in their poetry), but all students' reports, when speaking about activities, would be enthusiastic and expressed a strong interest in the subject area.

Students' interest and engagement with activities were especially strong when it came to project-based learning activities. The focus is on the students' needs, interests, and goals, rather than on the teacher's agenda or content. Students are engaged in hands-on, experiential learning activities that allow them to explore and experiment with STEM concepts. "I loved getting to engineer the blinking light today," S9 commented in her Week 2 survey response. "Those hands-on, build-it-yourself type things get me engaged and excited to learn."

Self-confidence

All students in the surveys and interviews reported an increase in their self-confidence. The areas in which students reported this increase were two: in STEM subjects and projects they explored during the Camp, and in their own personal development. In STEM subjects, students reported increased self-confidence when they began to understand a concept more thoroughly, or if they succeeded at a project, they felt was difficult. In her interview, S30 illustrates this in her experience with Arduino: "Arduino I didn't really [know about], so, like, it was kind of a challenge for me. So, being able to do it increased my confidence in it."

Students also discussed other aspects that impacted their self-confidence in regard to personal development, such as their ability to accomplish something they deemed worthwhile over the summer instead of, in S1's words, "doing nothing." Students also stated that meeting new people and doing things outside of their comfort zone, such as S9's experience of sharing her original poem during the poem and essay writing class. She states: "...That was the most people I shared it with at once. And it felt really good."

Table 2. Sense of Belonging and Identity Development
[Insert Table 2 in here]

Discussion and Implications for Future Research

Learning environment

The constructivist learning environment theory (Alt, 2015; Kock et al., 2004) guided our project design and the key activities. The findings showed that during the Camp, the female students had opportunities to learn computing and engineering knowledge and skills and application to engineering projects. Each tied team conducted engineering projects in ubiquitous intelligent systems. Several contributions were made in the theory construction.

First, the group projects' designs tailored to students' interests and motivations and scaffolding their prior knowledge. The projects are directly connected with applications which greatly motivate students to think about how to apply the STEM knowledge they have learned to solve real-life problems. Each project involves use of new sensors. Students are able to generalize their existing knowledge to master new ones. In addition, through the guidance of mentors, students learn to apply the engineering design principles which will be useful in their future project development.

Another important component of the project is to engage female students in STEAM learning. As secondary female students are creative and artistic, it is key to link their interests to the activities. A series of activities were provided successfully: poem and essay writing, crochet, origami, etc. We found these STEAM activities not only enhanced girls' motivation to learn STEM but also created a relaxing learning environment that prevent students' fatigue (York et al., 2022).

Second, the tiered team was a successful model of building female students' community. The support and encouragement are critical to their engagement in the activities and support for their learning. The peers in the program and of the group projects provided support. The grouping of students of Grade 6 - 11 is apparently inviting to students. The students of lower grades mixed up organically without feeling intimated or bullied. The college students' mentor support students with the STEM cutting edge knowledge as the activities are related to their fields. Another part of the support from them is communication. They are very close to high school students and this allows them to communicate comfortably. Secondary teacher mentors shared their expertise with college students and lead the team to complete the projects and teamwork. Finally, the online communication in Discord social media ensured students' feeling comfortable to share their emotions, experiences, and asking questions.

Sense of belonging and STEM identity

The research significantly focuses on girls' STEM knowledge, skills, and interests in STEM, but we mainly examine the factors significantly related to the constructivist learning environment for female students' learning, such as sense of belonging and identity. Sense of belonging relates to students' academic, social, and emotional learning (Glass, et al., 2015; Walker, 2019) and gives students the confidence to ask for help, seek resources, and feel that they are working towards success (Strayhorn, 2019). We discuss the findings from these three aspects.

Academically, students' academic/STEM identity was developed through coding or robotics because they had opportunities to participate in meaningful and relevant STEM learning experiences. In our project, we designed hands-on projects that triggered students' critical thinking and problem-solving skills. Students reported their enhanced confidence in studied STEM fields as their competences. They reported excitement about their unbelievable learning of higher quality STEM knowledge and skills through the collaborative projects, which impacted their interests in STEM career (Salto, 2014; Scott, 2012). Their identification was shown through their reported motivation and interests to continue their STEM development beyond the Camp. The identity also included students' self-confidence in their ability to accomplish something they deemed worthwhile and doing things outside of their comfort zone. Although we did not have a comparison group to show whether female students working in a single-gender group gain more benefits in terms of developing positive attitudes toward engineering than in a mixed-gender group in which males often take the lead (Sahin et al., 2015), the evidences showed that the constructivist learning environment of a female group significantly enhanced female students' academic self-confidence and motivation for STEM.

Socially and emotionally, identity building encompasses many social aspects, including community and sense of belonging, the feeling or perception of belonging, the sense of making a difference, and shared emotional connection (McMillan & Chavis, 1986). Identity building boils down to students' perceptions of peer support, connectedness, acceptance, communication, and being valued. The students have developed positive personal relationships with peers and mentors which indicated a high sense of belonging (Baumeister & Leary, 1995). Mentors and instructors who interacted with students created a more "fun" environment so that students feel connected and related to them.

The students also had very positive relationships with peers and mentors and felt safe among peers, freely communicating with each other and feeling understood and supported by those around them. They can express themselves without feeling unsafe or judged (Strayhorn, 2019). This high sense of belonging led to their interests and engagement in collaborative learning of the group projects (O'Neel & Fuligni, 2013).

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