Creating a Constructivist Learning Environment to Enhance Secondary Female Students' Engagement in STEM Activities

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Abstract

Female students participate in STEM activities at a low rate compared to males. Educational researchers have called for studies which examine the factors that influence STEM participation. The purpose of this study is to examine how a unique learning structure built on the principals of constructive learning environments might impact students' sense of belonging and encourage them to participate in more STEM activities. For this qualitative study, interviews were conducted with 12 mentor and 17 student participants. Findings indicated that a constructive learning environment enhanced students' sense of belonging. Programs which enhance female students' sense of belonging impact their confidence to participate in more STEM activities. This study contributes to research in learning environment theory and STEM education practice.

Key Words: sense of belonging, constructive learning environment, STEM learning

1. Purposes and Rationales

STEM workers are in high demand. In education, fewer female students participate in STEM related activities than males (Kim, ND; Sahin, Gulacar, & Steussy, 2015). This underrepresentation of females in STEM fields may be attributed to lack of confidence in STEM related to their self-concept, gender stereotyping, or lack of cultural/family support (Cokley, 2002). This study is part of an NSF program that focuses on engaging secondary female students in a constructive learning environment (CLE) to enhance their self confidence in STEM related fields and encourage interest in STEM learning.

Because fewer female students engage in STEM activities than males in secondary environments (Sahin, Gulacar, & Steussy, 2015), it is critical to understand how the learning environment can impact female participation. The purpose of this proposal is to examine the factors that influence female students' self-confidence in STEM within a CLE. The following research questions will be examined: (1) How do the program activities contribute to a constructive environment?; and (2) How does the constructive learning environment impact students' sense of belonging in STEM learning and thereby their success?

2. Literature Review and Theoretical Framework

2.1 Constructivist Learning Environment (CLE)

Constructivism views knowledge as ever changing, impacted by social and cultural experiences (Brooks & Brooks, 1993), and that learning is influenced by prior knowledge and perspectives. Learners contextualize their understandings by linking new ideas to existing ones (Naylor & Keogh, 1999). Key learning activities within a CLE include constructive activities, situated contextual activities, and social activities (de Kock et al., 2004). In constructive activities, students 'learn how to learn,' solving meaningful and challenging problems related to real life (Alt, 2015). A situated contextual activity allows the learner to bring their own strengths to the table to strengthen a student's sense of control over their learning (Alt, 2015). Social activities emphasize the importance of communication and relationships in learning (Alt, 2015). Small group projects can effectively provide opportunities for students to use their strengths to enhance learning in situated contextual activities and provide opportunities for relationship building in social activities (Alt, 2015).

Sense of belonging (SoBL) has been found to impact students' emotional, social, and academic learning (Glass, et al., 2015; Walker, 2019). SoBL is a person's perceived value within a group (Baumeister & Leary, 1995). Belongingness is a basic human need (Maslow, 1968). Whether a person perceives themselves as a valued member of a team or community such as a classroom impacts their experiences. In a learning environment, a strong SoBL can give a student the confidence to ask for help, seek resources, and feel that they are working towards success (Strayhorn, 2019). Positive personal relationships and high-quality communication are indicators of strong SoBL in students (Baumeister & Leary, 1995; Walton & Cohen, 2007).

A strong SoBL can be an indicator of school enjoyment and perceived school usefulness and is important for maintaining engagement in school for older students (O'Neel & Fuligni, 2013). Dichotomously, where males' SoBL remains steady throughout secondary schooling, female students' SoBL has been found to decrease as they age (O'Neel & Fuligni, 2013). Studies have related this inequity to learning environments which do not meet students' unique needs (Eccles & Roeser, 2009). For example, while female students' developmental need for positive relationships with mentors increases throughout teenage years, schools often provide little opportunity for developing mentor relationships (Eccles et al., 1993; O'Neel & Fuligni, 2013).

Within a CLE, students are engaged in reflective learning which relies on meaningful feedback from mentors. This helps students and mentors create persistent, positive relationships which are key to a strong SoBL (Baumeister & Leary, 1995). We theorize that student SoBL is strengthened in a unique, tiered team CLE, thus enhancing student learning.

3. **Methodology**

3.1 Modes of Inquiry

Qualitative methods are useful for understanding participants' perspectives of their experiences (Creswell & Poth, 2018). In this study, qualitative case study was used to explore how SoBL may impact students' experiences in a CLE. Case study allows for significant data to be analyzed for evidence of personal, sociocultural, and professional experiences (Yin, 2003) that impact student SoBL.

3.2 Participants and Context of the Study

The studied program was a five-week summer camp for female students in Grades 6-11 where they learned Python and Arduino programming (block- and text- based) and integration of these tools to conduct projects in ubiquitous intelligent systems. Tiered teams co-mentored by college students and STEM teachers completed challenging projects. Participants of the camp included 44 students and 20 mentors. Ten mentors were public schoolteachers, and ten mentors were college engineering students. They participated in the training in spring 2021. The mentors included males and females. 21 middle and 23 high school students were recruited with an emphasis on minority students from Title 1 schools. A total of 17 students and 12 mentors were interviewed for the study. The camp included classroom learning, guest speakers, lab visits, team-building activities, mentorship, and a 2-week STEM competition. Participants were engaged in a variety of computer-science focused learning experiences and educational activities designed with CLE theories. The tiered-team structure enabled students and mentors to work in groups of different learning experiences and mentoring strengths.

3.3 Data Sources and Data Collection

Individual interviews were conducted with mentors at the conclusion of the summer camp to better understand their perspectives of their group's dynamics, student participants' SoBL, to learn how students supported each other and how mentors supported student learning. Focus group interviews with student groups were also conducted at the conclusion of the camp to learn about students' perspectives about whether and how the camp enhanced confidence in STEM activities, whether the learning environment encouraged positive and productive relationships, and how their own gender or cultural background impacted their experiences.

Because the study involved human subjects, prior approval was granted from the IRB. Informed consent was explained and collected from all adult participants, and assent and parent permission forms were collected for student participants. Interviews and focus groups were conducted in a quiet space and were recorded on a digital recording device. The transcripts were analyzed using qualitative computer software to identify similarities and differences between participants' perspectives that impact students' SoBL in the constructive learning environment.

Additional data were collected. At the conclusion of the interviews and focus groups, the researchers summarized the content of the interviews into field notes. These notes were used to make broad generalizations about the responses of the participants and informed the preliminary findings in this proposal. During the training camp for mentors and the summer camp for mentors and students, digital text communications platforms were used to connect teams remotely. These were exported and coded using computer software and will be explored through content analysis to support the findings.

3.4 Data Analysis

Content analysis was used to explore the interviews, focus groups, and researcher notes. Content analysis was appropriate for this study because we were interested in finding trends about how students felt about their learning, group dynamics, and experiences. After the interviews were conducted, the data was transcribed using software, then checked for accuracy by the researchers. The transcriptions were uploaded to qualitative analysis software (NVIVO) and saved on a secure device. First, responses were reviewed using open coding to organize and become familiar with the interview responses. Next, selective coding was used to identify trends. Finally, these codes were analyzed for themes which provided insights about how the activities created a constructive environment and how students' SoBL was impacted by the learning environment. Two researchers independently reviewed the data to find strong examples for each research question and to support intercoder reliability. Once the themes were determined, the researchers applied the theoretical framework to determine whether the camp constituted a constructive environment and whether the environment impacted the students' sense of belonging in the STEM context.

4. Findings

We theorized that a CLE for secondary female students, using a unique tiered-team and unique mentoring structure, would enhance students' SoBL and therefore their academic success. A constructive learning environment is effective when it includes constructive activities, situated contextual activities, and social activities (de Kock, et al., 2004). The innovative structure of the camp allowed students to build positive relationships, enhancing their SoBL, and helped the participants feel more confident in participating is STEM activities in the future. However, while the camp used situated contextual activities and social activities effectively, students did not effectively communicate the relationship between their learning and the real-world (constructive activities). This may have weakened the constructive learning environment and stunted students' acquisition of a SoBL within the camp and tiered teams.

4.1 Constructive Learning Environment

Alt's (2015) concept of contextual, social, and constructive activities guided the researchers' interpretations of learning activities, experiences, and their learning outcomes. Through focus groups with students and individual interviews with mentors, the students' experiences were examined to determine how the program activities impacted the constructive environment. These findings are summarized in Table.

Constructive activities included coding of real-world projects such as parking sensors and programming and construction of robots. Students were asked to relate a STEM skill they learned in the program to a real-world application. Students reported that they did not believe the projects were advanced enough to apply to real situations. Mentors were asked whether the students were able to apply their learning in real world settings. The mentors believed that the tools used in the projects had clear real-world applications. Yet, few examples were provided of how a student may have applied the learning in a real setting. Although students and mentors did not see a strong relationship between the projects and the real world, the activities were designed to represent real-world STEM activities.

Situated contextual activities included tiered-team, long term projects such as learning to code, build STEM projects, and research. These activities allowed the students to bring their own strengths to the table and contribute in the group setting. Students were asked whether they believed participation in the camp would enhance their future STEM learning. The students reported that camp helped motivate them to seek additional stem activities in the future. Students were then asked to provide examples of when they felt the team supported them to complete tasks. Students used their own strengths and relied on others to complete difficult tasks. Finally, students were asked to discuss their role in the team environment. Students could communicate what they worked on and the role they played, but not specify a STEM concept or skill that they worked on that would apply to future learning or projects. Alternatively, mentors were asked how team members supported each other's learning. Students supported each other by completing tasks together. In groups where the ages were diverse, many of the older students who had participated in similar activities guided the younger students. Mentors supported the projects by providing supplies, motivating the students to complete tasks on a schedule, providing manual assistance with building physical displays, and helping troubleshoot. Teacher mentors focused on the larger goals of the project such as completing tasks on time, while engineering mentors helped program and build projects with students.

Social activities included team builders, tours of engineering labs, guest speakers, and competitions. Students were asked how often and by what means they communicated with their team during the program and reported that digital platform was used to communicate in place of in person communication when teams were at home working on projects. Students were also asked whether they enjoyed the camp. The camp was a positive experience for the participants. They felt that their social and emotional connections were strong within the community and that students could rely on each other to help complete learning goals and projects. Finally, students felt that the environment was positive because they were able to see that others who are like them share their interests and desire to learn stem related skills. Mentors were asked how the team dynamics were constructed. They reported that they used team building activities and personal discussions to build the team dynamics between students, and built strong individual relationships with the student members of the team.

4.2 Sense of Belonging

The constructive environment may have enhanced students' sense of belonging in STEM contexts. A summary of the findings can be found in Table 2. In the situated contextual activities, the tiered team structure allowed for students of different cultural and academic backgrounds to use their own strengths and rely on the strengths of their peers and mentors to learn and complete difficult group tasks. One teacher noted that "the team structure allowed kids who had different skills to contribute to the project and feel like an important part of the group."

This kind of relationship is a key builder of student SoBL (Glass, et al., 2015). In past research, it was found that secondary girls' SoBL declines as they age (O'Neel & Fuligni, 2013). The tiered team may have strengthened their belongness. One teacher noted that the "students felt comfortable in the group" environment. Sense of belonging may be strengthened when a student becomes comfortable in a formal setting (Glass, et al., 2015). Many students reported that the camp was a positive experience. They felt that their social and emotional connections were strong within the newly built community and that students could rely on each other to help complete learning goals and projects. Relationships are a key construct of belongingness in students (Baumeister & Leary, 1995). Students also noted that they felt the environment was positive because they were able to see that others who are like them share their interests desire to learn STEM-related skills. They were able to effectively communicate details of the projects they were working on and the role that they played. When students feel they are valued in a team environment, they are more likely to ask for help, seek resources, and succeed in a learning environment (Strayhorn, 2019). Interviews with mentors also supported the strength of the situated contextual activities. Mentors reported that students supported each other by completing tasks together. One mentor noted that “one student was into building, so she did most of the construction. Another student had a family background in landscaping so she shared some of his experiences with the other students which helped the group decide what to do with their project.” In groups where the ages were diverse, many of the older students who had participated in similar activities guided the younger students. These strong relationships are indicators of belongingness in the students (Glass, et al., 2015). Mentors supported the projects by providing supplies, providing manual assistance with building physical displays, and helping troubleshoot. Teacher mentors focused on the larger goals of the project such as completing tasks on time, while engineering college student mentors helped program and build projects with students.

Students also used digital communication tools to build and maintain relationships that were key to their belongingness (Glass, et al., 2015). Activities such as poem writing and learning demonstrations conducted online allowed the participants to show their learning and skills to others, enhancing relationships. Mentors used team building activities and personal discussions to build the team dynamics between students and their own individual relationships with the student members of the team. Several teams created private text chat rooms to discuss projects and complete tasks at home between physical meetings.

5. **Significance of the Study**

The STEM project aimed at building a constructivist learning environment for secondary female students to enhance interest in STEM related activities. This project provided a unique opportunity for the participating secondary female students to learn computing and programming, IoT/robotics design and gain useful engineering experience in conducting projects in ubiquitous intelligent systems. This study can enhance STEM education and encourage more women to enter STEM fields and participate in STEM activities in school. The study contributes to the research in how the constructive learning environment influences students' sense of belonging, and thereby enhances learning.

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Table 1 Evidence of a Constructive Learning Environment

	Student Focus Group Interviews	Individual Mentor Interviews (Semi-Structured)
Constructive Activities	▪ Students were asked to relate a STEM skill they learned in the program to a real-world application. Students reported that they did not believe the projects were advanced enough to apply to real situations. While students did not see a strong relationship between the projects and the real world, the activities represented real-world STEM activities.	▪ Mentors were asked whether the students were able to apply their learning in real world settings. The mentors believed that the tools used in the projects had clear real-world applications. Yet, few examples were provided of how a student may have applied the learning in a real setting.
Situated Contextual Activities	▪ Students were asked whether they believed participation in the camp would enhance their future STEM learning. The students reported that camp helped motivate them to seek additional stem activities in the future. ▪ Students were asked to provide examples of when they felt the team supported them to complete tasks. Students used their own strengths and relied on others to complete difficult tasks. ▪ Students were asked to discuss their role in the team environment. Students could communicate what they worked on and the role they played, but not specify a STEM concept or skill that they worked on that would apply to future learning or projects.	▪ Mentors were asked how team members supported each other's learning. Students supported each other by completing tasks together. ▪ In groups where the ages were diverse, many of the older students who had participated in similar activities guided the younger students. ▪ Mentors supported the projects by providing supplies, motivating the students to complete tasks on a schedule, providing manual assistance with building physical displays, and helping troubleshoot. ▪ Teacher mentors focused on the larger goals of the project such as completing tasks on time, while engineering mentors helped program and build projects with students.
Social Activities	▪ Students were asked how often and by what means they communicated with their team during the program. A digital platform was used to communicate in place of in person communication when teams were at home working on projects. ▪ Students were asked whether they enjoyed the camp. The camp was a positive experience for the participants. They felt that their social and emotional connections were strong within the community and that	▪ Mentors used team building activities and personal discussions to build the team dynamics between students and their own individual relationships with the student members of the team. ▪ Many teams created private discord servers or text chat rooms to discuss projects and complete tasks at home between physical meetings.

	students could rely on each other to help complete learning goals and projects. ▪ Students felt that the environment was positive because they were able to see that others who are like them share their interests and desire to learn stem related skills.	▪ Students were grouped in part by request, so many existing friend groups were maintained in the tiered group pairings. This created some frustrations for younger students who were not able to build strong relationships with the older counterparts.

Table 2 Impact on Students' Sense of Belonging

Experiences	**Outcomes**
"The team structure allowed kids who had different skills to contribute to the project and feel like an important part of the group."	Students of diverse cultural and academic backgrounds work constructively to complete tasks. Their sense of belonging may have been enhanced by contributing their strengths to the team environment.
"The students felt comfortable in the group."	The tiered team structure strengthened student belongingness.
"one student was into building, so she did most of the construction. Another student had a family background in landscaping so she shared some of her experiences with the other students which helped the group decide what to do with their project."	The tiered team structure allowed students to bring their own strengths to the table.