

Engaging Secondary Female Students in STEM Activities Through a Constructivist Learning Environment

Daniel Unger, Jinkun Shen, Shaoan Zhang, and Safiyya Bintali

Department of Teaching and Learning

University of Nevada, Las Vegas

1. Objectives or Purposes

In STEM education, fewer female students participate in STEM related activities than males (Kim, ND; Sahin et al., 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 in order to increase females in STEM workforce. The purpose of this proposal is two-fold: 1) to examine the CLE, and 2) to investigate the factors that influence female students' self-confidence in STEM within a CLE. Using both quantitative and qualitative data sources, this study addresses the following research questions: (1) What is the relationship between a CLE and STEM self-efficacy?; (2) How does students' sense of belonging impact the relationship between CLE and STEM self-efficacy; and (3) How does the project experience impact secondary female students' attitudes toward participation in STEM learning?

2. Perspective(s) or 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).

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). Studies showed that sense of belonging (SoBL) impacts students' emotional, social, and academic learning (Glass, 2015; Walker, 2019).

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). 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 should be 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. Methods, Techniques, or Modes of Inquiry

3.1 Modes of Inquiry

This study uses mixed methods to investigate the research questions. Quantitative methods are useful for investigating relationships between variables (Creswell & Creswell, 2017). For research questions 1 and 2, we used regression analysis to determine whether girls' participation in a constructive STEM environment related to their STEM self-efficacy and sense of belonging. Alternatively, qualitative methods are useful for understanding participants' perspectives of their experiences (Creswell & Poth, 2018). We used qualitative case study 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 two-year study investigated a five-week camp which occurred in summer 2021 and summer 2022. The camp was Grades 6-11 students where they learned Python and Arduino programming (block- and text- based) and integration of these tools to conduct projects in ubiquitous intelligent systems.

The tiered-team structure enabled students and mentors to work in groups of different learning experiences and mentoring strengths. Tiered teams co-mentored by college students and STEM teachers completed challenging projects. Participants of the camps included 80 students and 28 mentors. Eight mentors were public schoolteachers, and twenty mentors were college engineering students. The mentors participated in training before the summer camp. Middle and high school students were recruited with an emphasis on minority students from Title 1 schools. The camp included three weeks' classes of Arduino and Robotic knowledge and application, guest speakers, lab visits and several educational activities for team building, writing poems and essays, and crochet, and then a 2-week STEM group projects.

3.3 Data Sources and Data Collection

In Year 1, individual interviews were conducted with 17 mentors to understand their perspectives of their group's dynamics, student SoBL, how students supported each other, whether and how the camp enhanced student confidence in STEM activities, whether the learning environment encouraged positive and productive relationships, and how the students' cultural background impacted their experiences.

In Year 2, the quantitative survey was completed by 37 student participants. The survey was designed to identify qualities of the students' self-efficacy in STEM including their learning environment, confidence, and ability and to help identify the constructive learning environment.

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.

3.4 Data Analysis

Interviews were analyzed with content analysis. Content analysis is appropriate as we aimed at finding trends about how students felt about their learning, group dynamics, and experiences. Responses were reviewed using open coding to organize and become familiar with the interview responses. Then, selective coding were used to identify trends. Finally, data were analyzed for themes which provide insights about how students' SoBL was impacted by the learning environment.

For the quantitative data, the survey data was collected in Qualtrics then exported digitally to SPSS statistical analysis software. Data were transformed so that negative questions were accounted for in the analysis. Some participants did not complete the survey and their data was removed. A regression analysis was conducted using the factors of STEM self-confidence and constructive learning environments defined in the theoretical framework to see whether a relationship existed between the learning environment and the participants' STEM self-confidence.

4. Findings

4.1 Constructive Learning Environment and Sense of Belonging

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. The findings are summarized in Table 1. 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 in 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.

4.2 Constructive Learning and STEM Self-Confidence

Data were analyzed using the Spearman's rho Correlation method to determine if relationships existed between these variables, self-efficacy sub-dimensions, and constructive learning environment. The data is presented in Table 2. The data revealed moderate positive

relationships between constructive learning environment and three sub-dimensions of Self-efficacy(Independence, Teamwork experience, Emotional and physiological state).

The regression analysis indicated that participation in a constructive learning environment is a meaningful predictor of factors of self-efficacy. The regression analysis result is presented in table 3. Constructive learning environment ($M=3.99$, $SD=0.41$) is a statistically significant predictor of Self-efficacy E ($M= 4.04$, $SD=0.32$), Self-efficacy I ($M= 4.04$, $SD=0.54$), and Self-efficacy T ($M= 3.80$, $SD=0.59$).

Our quantitative result suggested there should be a factor(SoBL) that can mediate or moderate the relationship between constructive learning environment and self-efficacy. Therefore, we used the qualitative research method to study how SoBL impacts the relationship between CLE and Self-efficacy.

4.3 Activities and Learning Outcomes

Alt's (2015) concept of contextual, social, and constructive activities guided the researchers' interpretations of learning activities, experiences, and their learning outcomes. In the situated contextual activities, the tiered team structure allowed for students of different backgrounds to use their strengths and the strengths of their peers and mentors to learn and complete difficult tasks. This kind of relationship is a key builder of student SoBL (Glass, 2015). Researchers have found that secondary girls' SoBL declines as they age (O'Neel & Fuligni, 2013). The tiered team may have strengthened their belongingness. Mentors reported that students supported each other by completing tasks in groups. Mentors supported the projects by providing supplies, providing manual assistance, and helping troubleshoot. Teacher mentors focused on the larger goals of the project while engineering college student mentors helped program and build projects with students.

Students also used digital communication tools to build and maintain relationships. Activities such as poem writing and learning demonstrations conducted online such as Discord and Canvas allowed students to share with peers, thus enhancing relationships. Mentors used team building activities and personal discussions to build the team dynamics between students. Several teams were actively participating in Discord discussions about projects.

Sense of Belonging and the Relationship Between CLE and Self-Efficacy

The qualitative data indicated that the camp impacted the students' sense of belonging. When asked for examples of how the students learned to work together to accomplish their goals, mentors replied that they had worked with the students to build relationships and plan for actions to accomplish their goals. One mentor noted that "at first the girls in [my] group were quiet and kind of not engaged, but they started talking over Discord and actually created a group to chat with the other members of the group. Once they were talking and laughing by the end of the first couple days they got right to work and actually did a great job with the project." Another mentor explained that the girls in her group "felt very comfortable together... one of the girls said she couldn't make it to the final two days, the older student offered to give her a ride to the camp." These examples show that as the girls' belongingness was strengthened in the constructive environment, their experience with the camp was impacted.

In the quantitative analysis, we found that indicators of CLE experienced by secondary girls can also mean that the experiences enhanced the girls' self-efficacy in STEM. This relates to the qualitative findings because the girls' sense of belonging is enhanced by the constructive

environment. The quantitative findings enhance the qualitative findings, indicating a strong relationship between the development of students' sense of belonging in STEM environments and their self-efficacy in STEM.

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 study explored the CLE model that engage secondary female students' learning about computing and programming, robotics design. This study can enhance STEM education research regarding sense of belonging and self-efficacy.

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Table 1 Summary of Researcher Notes Following Student and Mentor Interviews

	Student Focus Group Interviews	Individual Mentor Interviews (Semi-Structured)
Constructive Activities	Students did not see a strong relationship between the projects and the real world.	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.
Situated Contextual Activities	- Camp helped motivate them to seek additional stem activities in the future. - Students used their own strengths and relied on others to complete difficult tasks. - 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.	- 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	▪ Digital platform was used to communicate in place of in person communication when teams were at home working on projects. ▪ 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. ▪ 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 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 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.
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Table 2. Correlation between SI, ST, SE, and CLE

Variables	Self-Master(n=37)	Self-I	Self-T	Self-E
SI	0.146			
ST	0.203	0.564**		
SE	0.227	0.658**	0.511**	
CLE	0.250	0.739**	0.499**	0.633**

SI = Self-efficacy Independence, ST = Self-efficacy Teamwork experience, SE = Self-efficacy Emotional and physiological state, CLE = Constructive Learning Environment. ** p<0.01

Table 3. Regression Analysis: Constructive Learning Environment as a predictor to predict SD, ST, and SE.

SI		B	t	Sig	R ²	N
	CLE	0.975	6.483	<0.001	0.546	37
ST		B	t	Sig	R ²	N
	CLE	0.721	3.406	0.002	0.249	37
SE		B	t	Sig	R ²	N
	CLE	0.500	4.833	<0.001	0.400	37