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. Preliminary 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

Proposal Title

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

Shaoan Zhang[1], Daniel Unger[1], Mei Yang[2], Venkatesan Muthukumar[2], Yonhong Xu[3]

[1]Department of Teaching and Learning, University of Nevada, Las Vegas

[2]Department of Electrical and Computer Engineering, University of Nevada, Las Vegas

[3]Department of Counseling, Educational Psychology, and Research, University of Memphis

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 project activities enhance the participating students' knowledge, skills, and interests in STEM fields?; and (2) How does the project experience impact secondary female students' attitudes toward participation in STEM learning?

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, 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. For future study, the transcripts will be 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

Researcher notes from the interviews were analyzed to find preliminary data for this proposal (Interview and focus group data will be further analyzed using qualitative computer software NVIVO to generate subthemes to strengthen the preliminary findings). Content analysis will be used. Content analysis is appropriate for this study because we are interested in finding trends about how students felt about their learning, group dynamics, and experiences. First, responses will be reviewed using open coding to organize and become familiar with the interview responses. Next, selective coding will be used to identify trends. Finally, data will be analyzed for themes which provide insights about how students' SoBL was impacted by the learning environment.

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 preliminary 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 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.

4.2 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 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.

This kind of relationship is a key builder of student SoBL (Glass, 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. The students reported that the camp was a positive experience. They were able to effectively communicate details of the projects they were working on and the role that they played. 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. 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. Interviews with mentors also supported the strength of the situated contextual activities. Mentors reported that 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, 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. 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.

Mentors saw clear connections between the learning activities and the real world. However, some students were able to relate their camp experiences to the real world, yet others did not report a connection. For example, where one student noted that they wanted to pursue STEM in high school and the camp made her feel more confident, another reported that the

“activities were too basic and felt like it wasn’t ‘real’ STEM activities.” This finding suggests that the purpose of the activities needs to be communicated more clearly.

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.

References

Alt, D. (2015). Assessing the contribution of a constructivist learning environment to academic self-efficacy in higher education. *Learning Environments Research, 18*(1), pp.47-67.

Baumeister, R. F., & Leary, M. R. (1995). The need to belong: Desire for interpersonal attachments as a fundamental human motivation. *Psychological Bulletin, 117*(3), 497-529.

Cokley, K. (2002). Ethnicity, gender, and academic self-concept: A preliminary examination of academic dis-identification and implications for psychologists. *Cultural Diversity and Ethnic Minority Psychology, 8*(4), 378-388.

Creswell, J. W., & Poth, C. N. (2018). *Qualitative inquiry and research design: Choosing among the five approaches*. Sage.

de Kock, A., Sleegers, P. & Voeten, M. J. M. (2004). Learning and classification of learning environments in secondary education. *Review of Educational Research, 74*(2), pp. 141-170.

Driver, R. (1989). Students' concepts and the learning of science. *International Journal of Science Education, 11*, 481-290.

Glass, C.R., Kociolek, E., Wongtrirat, R., Lynch, R.J., & Cong, S. (2015). Uneven experiences: The impact of student-faculty interactions on international students' sense of belonging. *Journal of International Students, 5*(4), 353-367.

Hartle, R. T., Baviskar, S., & Smith, R. (2012). A field guide to constructivism in the college science classroom: Four essential criteria and a guide to their usage. *Bioscene: Journal of College Biology Teaching, 38*(2), 31-35. Retrieved from https://files.eric.ed.gov/fulltext/EJ1002158.pdf

Jenkins, E. W. (2000). Constructivism in school science education: Powerful model or the most dangerous intellectual tendency? *Science & Education, 9*, 599-610.

Jones, M. G., & Brader-Araje, L. (2002). The impact of constructivism on education: Language, discourse, and meaning. *American Communication Journal, 5*(3), 1-10. Retrieved from https://pdfs.semanticscholar.org/f674/80594ca2ab46e25777653a8cc4f05fbe3135.pdf

Kim, S. (ND). New research shows declining interest in STEM. Retrieved from http://www.govtech.com/education/k-12/New-Research-Shows-Declining-Interest-in-STEM.html.

O'Neel, C. G., & Fuligni, A. (2013). A longitudinal study of school belonging and academic motivation across high school. *Child Development, 84*(2), 678–692. https://doi.org/10.1111/j.1467-8624.2012.01862.x

Reynders, G., Lantz, J., Ruder, S. M., Stanford, C. L. & Cole, R. S. (2020). Rubrics to assess critical thinking and information processing in undergraduate stem courses. *International Journal of STEM Education, 7*(1), 1-15.

Sahin, A., Gulacar, O., & Stuessy, C. (2015). High school students' perceptions of the effects of international science Olympiad on their stem career aspirations and twenty-first century skill development. *Research in Science Education*.

Sewell, A. (2002). Constructivism and student misconceptions. *Australian Science Teachers' Journal, 48*(2), 24-28.

Strayhorn, T. L. (2019). *College students' sense of belonging: a key to educational success for all students* (2nd ed.). Routledge.

Walker, S. M. (2019). *A constructivist grounded theory of the influences and practices that are thought to promote a sense of belonging in a primary school context.* ProQuest Dissertations Publishing.

Yin, R. K. (2018). *Case study research and applications: Design and methods* (6th ed.). SAGE Publications, Inc.

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.