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ORIGINAL ARTICLE

Crochet: Engaging Secondary School Girls in Art for STEAM's Sake

Portia York[1]*, Shaoan Zhang[2], Mei Yang[3], Venkatesan Muthukumar[3]

[1]Department of Art and Art History, York Creative Education Group and University of North Carolina, Charlotte, North Carolina, [2]Department of Teaching and Learning, University of Nevada, Las Vegas, Nevada, [3]College of Engineering, University of Nevada, Las Vegas, Nevada

***Corresponding Author:** dryork@yorkcreativeeducation.com

ABSTRACT

Recent STEAM programs have made accomplishments in recruiting K-12 girl students to participate in STEAM activities. Educational researchers have called for studies of how STEM programs engage girls. However, little research has embedded STEM education with girl education such as their emotional needs, identity, and self-expression. This study examined how crochet that was embedded in a STEM summer camp impacted their sense of belonging (SoBL), creativity, well-being, and STEAM learning. For this qualitative study, surveys were conducted with 37 student participants and Discord was used as part of the data sources. Findings indicated that crocheting enhanced students' SoBL, creativity, and well-being, as well as STEM learning. This study contributes to the STEM learning program design for girls in secondary schools with two closely related theories: Constructivist learning environment theory and SoBL theory. This study added new knowledge to the research of crochet in girl education and STEM program design.

KEY WORDS: Constructivist learning environment; crochet; sense of belonging; STEAM education

INTRODUCTION

The quality of STEM education is unsatisfying due in part to the shortage of qualified teachers in urban schools. Noticeably, the percentage of secondary school girl student participation in STEM activities is low (Sahin et al., 2014; Sahin et al., 2015; Scott, 2012). The national science foundation (NSF) sponsors research grants that enhance girl students' motivations for STEM through meaningful learning experiences. Our project, Engaging Girls in Ubiquitous Intelligence and Computing (GUIC), aimed at advancing the efforts of the NSF innovative technology experiences for students and teachers program to broaden the participation of girl students in ubiquitous intelligence and computing through the constructivist learning environment. We explored the integration of Art to STEM education, STEAM. As fiber artistic expressions and creativity have traditionally been more girl/woman oriented, we embedded crochet into the program. Our research explored how crochet can enhance girls' sense of belonging (SoBL) that may influence their confidence and identity.

STEAM for advancing learning in STEM disciplines mainly was designed to engage racial minority and female STEM students (e.g., Kant et al., 2018). Perignat and Katz-Buonincontro (2019) reviewed relevant literature of STEAM and found that STEAM activities enhance creativity and thinking skills, but creativity is rarely measured or assessed as part of STEAM education, and educators often overlook the creative process for the final product. Based on the constructivist learning and SoBL theories, we designed the crochet workshop and offered the Discord tool for online communication. Discord is a computer software program that allows for managed communication between groups. The research question was: What are the effects of crochet on secondary girls' SoBL, creativity, and well-being, as well as STEM learning? As a result, we show a case of how the crochet activity could be integrated into the STEM learning methods and become a process and product of STEAM.

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

Literature Review

The crochet craft has been around for centuries and boasts many benefits (Taimina, 2018). Of great interest to the invested researchers of the GUIC camp is the impact that practicing crochet has on secondary school girls' emotional and artistic expression, and creativity; particularly those who are immersed in a STEM camp. This interest has given rise to the outlet of introducing crochet to the girls at the summer camp. The literature showed crochet not only increases well-being but also enhances creativity. Burns and Van Der Meer (2021) found most of the 274 women of 41–60 year old reported that crocheting made them feel calm and happier. Pickrem (2019) experimented with opening a local studio in Canada for women to gather and create a connection to each other through participating in crochet circles. The women were creating conversations through crochet and found a happy place at the studio. Bonding with others in a safe place while exploring creativity through the crochet craft was also witnessed during

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an experiment by an advocate for women against domestic violence (Sehdev, 2020).

The literature also showed that crochet can foster creativity in girls. Studies reported crochet as a great outlet for creativity (Myers 2011), and the old world craft of crochet can be used as a tool for young women to expand their creativity (Pickrem, 2019; Stalp et al., 2018). In addition, Kijima et al. (2021) present research on design thinking and integrating artistic approaches in relation to the importance of STEAM learning and how it complements STEM. Design thinking is purported to spur innovation and harness a sense of creativity. Kijima et al. (2021) explain that STEAM learning can foster greater interest in STEM among adolescent girls. Based on the review, we assume that crochet may increase well-being in these girls, encourage them to explore creativity, and feel confident to express themselves while exploring another connection to STEM learning.

Theoretical Perspectives

SoBL has been found to impact students' emotional, social, and academic learning (Glass et al., 2015; Walker, 2019). A strong SoBL can give a student the confidence to ask for help, seek resources, and feel that they are working toward success (Strayhorn, 2019). Positive personal relationships and high-quality communication are indicators of strong SoBL in students (Baumeister and Leary, 1995). 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 and Fuligni, 2013). Dichotomously, where boys' SoBL remains steady throughout secondary schooling, girl students' SoBL has been found to decrease as they age (O'Neel and Fuligni, 2013). Studies have related this inequity to learning environments which do not meet students' unique needs (Eccles and Roeser, 2011).

In Alt's (2015) conceptualization of the constructivist learning environment, constructive activities refer to students "learn how to learn," solving meaningful, and challenging problems related to real life; 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; and social activities emphasize the importance of communication and relationships in learning. Voice and text rooms exist in Discord set only for the girls and mentors as a safe space, allowing students to conference in the way best suited to their needs. Built on the constructivist learning theory, Discord channels were built as the digital learning community that encourages students to share and learn from the interactions. One part of the text channels allowed all the girls to communicate and discuss all the projects and activities: General, Robotics, Arduino, Poems and Essays, and Crochet. In the Team Channel, 10 teams were created for each student and mentor to complete STEM projects. This helps students and mentors create persistent and positive relationships which are key to a strong SoBL (Baumeister and Leary, 1995).

STEM and Crochet Project

The NSF funded the research project titled "Engaging GUIC through a constructivist learning environment." The goals of this project focused on enhancing secondary female students' academic self-concept in computing and engineering fields through a constructivist learning environment; and enhancing secondary female students' knowledge, skills, and interests in these fields. The studied program involved a 5-week summer camp for girls in Grades 6–11 to learn Robotics and Arduino programming and integration of these tools to conduct projects in ubiquitous intelligent systems in tiered teams comentored by college students and secondary teachers. The camp included 3 weeks of classes of Arduino and Robotic knowledge and application, guest speakers, laboratory visits, and several educational activities for team building, writing poems and essays, and crochet, and then a 2-week STEM team project. The engineering projects were carefully designed to address different aspects of ubiquitous intelligence and computing fields targeting smart city and environmental applications including smart citizen services, intelligent transportation systems, and intelligent energy planning.

Throughout the 5-week summer camp, we included several important activities that engaged students' artistic development and learning community building. These activities included Origami, tower building, poem and essay writing, crochet, etc. In Week 2, poem writing and Crochet workshops were offered as a creative outlet to the STEM projects, and as a complement to the STEM component of the overall camp. This study is part of a comprehensive NSF grant and is solely focused on crochet design and its effects on the girls' learning. A crochet workshop was designed specifically to provide a constructive learning environment where the girls learn the history of crochet, witness the demonstration of how math is present in crochet stitches, and more importantly, have an opportunity to display creativity through practicing the crochet art form beyond the workshop.

Crochet refers to the process of creating fabric by interlocking loops of yarn, requiring a hook and yarn (Burns and Van Der Meer 2021; Myers, 2011). The use of crochet crafts in learning number patterns can help students understand the pattern of numbers (Putri, 2020). In fact, Taimina became known for basic coral forms using hyperbolic crochet to explore mathematics through the crochet craft (Lindsay, 2012; Taiminia, 2018).

The girls were taught four basic stitches during the crochet workshop. The intent was for the girls to start with simpler stitches and progress to more challenging stitches as they understood the concept and became more skilled at each technique. The hands-on learning experience allowed students to explore (1) the slip stitch, (2) the chain stitch, (3) the magic ring, and (4) a pom. Instructions, videos, and demonstrations were conducted for each design as the instructor moved through the room to assist with some of the challenging moments. The girls grasped the crochet techniques fairly quickly and were encouraged to support their peers through challenges.

Science Education International
33(4), 392-399
https://doi.org/10.33828/sei.v33.i4.6

This allowed for increased communication and enhanced constructive learning. A Discord channel for crochet was created so that girls could share their work in progress and their perspectives and emotions for others' work. At the conclusion of the workshop, the girls were challenged to practice the learned crochet patterns during their free time throughout the camp. They were also encouraged to be innovative, creative, and allow the crochet process to help them with expression and communication. Although they were not required to use crochet in the STEM projects, we assumed that they could incorporate it in some project designs.

METHODS

Modes of Inquiry

Qualitative methods are useful for understanding participants' perspectives of their experiences (Creswell and Poth, 2018). Case study allows for significant data to be analyzed for evidence of personal, sociocultural, and professional experiences (Yin, 2018) that influences students' identity and well-being. In this study, a qualitative case study design was used to explore how crochet impacted students' SoBL, well-being, creativity, and STEM learning.

Participants, Data Sources and Data Collection

Participants of the camp included 37 secondary school girl students. They included 11 Hispanic American (29.73%), 8 African American (21.62%), 6 Asian American (16.22%), 11 Caucasian American (29.73%), and 1 other (2.7%). Because the study involved human subjects, prior approval was granted from the institutional review board. All were the participants under 18-years-old. At the beginning of the program, girls and parents completed several forms for permission, consent, and voluntary participation: Assumption of Risk/Release of Liability Agreement and Consent to Emergency Medical Treatment (Minor Participants), Assent to Participate in Research, Parent Permission Form, and Informed Consent. All the participants signed the informed consent form for the research.

Two data sources were analyzed: Two qualitative surveys and Discord conversations. Each of the two surveys was conducted at the end of week 1 and week 2. We designed the survey questions based on the goals of the research design and the weekly activities. In addition, during the training camp, a Discord channel was opened for crochet and the Discord posts were used as a data source to examine the impacts.

Data Analysis

Content analysis was used for the survey because we were interested in finding trends about how students felt about their learning and experiences. First, responses were reviewed using open coding to organize the themes. Next, selective coding was used to identify trends. Finally, these codes were analyzed for themes. Discord functions as an application and a web interface. For Discord, Stanfill (2015) explained textual analysis as one approach of discourse analysis. The selective coding was used to identify trends that support the themes uncovered through the content analysis of the survey. Two researchers independently reviewed the data to find strong examples for each theme and to support intercoder reliability.

FINDINGS

The findings are outlined in four themes as shown in Table 1. The findings indicated that the secondary school girls found the STEAM activities to be engaging and fostered their creativity, not only while learning the crochet art form using math, but also by embellishing their group robotics projects with crocheted items. Findings from the four themes are highlighted below.

STEM Learning

Ample feedback regarding the impact of crochet on multiple areas of the girls' lives is observed as noted in Table 1. The merging of fibers with high tech or math encouraged STEAM learning (Stalp et al., 2018) and more interest in "math in real life." Three girls expressed that crochet connected to math and STEAM by including fabric in STEM creativity conversations and raising the visibility of making the connections of handicrafts to the hard sciences (Stalp et al., 2018). Student 26 exclaimed, "there are several types of art that I was surprised had a connection to STEM." Student 19 and Student 27 admitted that they explored math through crochet. Most of the girls became lively and engaged in the crochet process as they learned how to count stitches, increase and decrease stitches, and multiply stitches to create a design made of yarn. Student 17 expressed that crochet "opens our minds to new ways of STEAM."

Creativity

Crochet is a great outlet for creativity (Myers, 2011). As noted in Table 1, ten girls expressed how they were able to tap into their creativity. One girl touted that she was able to use her creative mind to create items with yarn. Student 1 shared, "I practice my crochet skills and make many different designs that I like. I have always wanted to try learning crochet but I never got the chance until now." The exchange between Student 19 and Student 26 exhibits excitement in the crochet art that was created. Student 19 said, "I just finished this flower," Student 26 replied, "omg. It's so pretty." The encouragement from the group was prevalent through the dialogue. In addition, a few of the girls communicated in Discord that they were making scarves and shared pictures of their work. Beginner level crocheted scarves were displayed in the Discord communication channel. Student 8 said, "My scarf is not done but it looks pretty good in my opinion," while Student 3 replied, "that's super cool!! great job." The girls explored the stitches and pushed through the challenges to discover their own creative crochet designs. Student 26 showed her work and admitted that she made a mistake but kept working on her design. She also mentioned that it looks like a particular state. It became clear that many of the girls expressed that crochet sparked their creativity and opened a pathway to learn a new talent and create interesting things with yarn.

Science Education International
33(4), 392-399
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Table 1: Findings of effects of crocheting

Themes	Explanation	Discord examples	Survey examples
STEM Learning	Using addition, subtraction, multiplication and geometric shapes as they learned and practiced new stitches, the process of crochet helped them see math in real life, and in artistic form	S26: "There are several types of art that I was surprised had a connection to STEM. H(assistant): "I thought it was because I LOVE to sew. I'm in the middle of a project right now that's really challenging me"	S17 W2: "Open our minds to new ways of STEAM" S19 W2: "To use math" S27 W2: "How to see math in crocheting"
Creativity	Crochet provides opportunities for girls to have fun, and make their own creations during and after the camp	S1: "I'm making a scarf" S9.: "same" S1: "I'm one row in" S19: "I just finished this flower" I just finis S26: "omg. It's so pretty" S26: "Yall, I made a mistake and it looks like [the state]" S1: "My scarf" S26: "It would be cool if you had a bunch of tiny balls and crochet them into your scarf" S33: "Made a scarf" S1: I'm making a scarf too that's my thing" S33: "Darn, I was making a scarf. S29:"I'm making progress" S1 "I have the original scarf" S33: "Cool Cool. You gonna make anything else?" S1: "Probably more bracelets. S25 need them to be all the way up my arm" S33: "Nah, Both arms?" S1: "Yes" S25: Does anyone know where to get more yarn? S8: "Look what I made yesterday though" S9: "Nice" S33: "Uh. Nice scarf" S26: "omgggg. so pretty" S8: "My scarf is not done but it looks pretty good in my opinion" S3: "That's super cool!! great job" S8: "Thank you" S26: "Yooo, It looks great"	S1 W1: "Practice my crochet skills and make many different designs that I like" S1W2: "I have always wanted to try learning crochet but I never got the chance until now. I enjoy being able to practice my crochet skills and make many different designs that I like" S5 W2: "Use our creative minds to create items with yarn" S6 W2: " Fun and easy to do once I got the hang of it" S8 W2: "Artistic and fun to do" S12 W2: "I especially enjoyed making the chain" S15 W2: "Crochet helps us use our creative minds to create items with yarn" S16 W2; "Crochet can do so many things, and I want to learn more" S19 W2: "Be creative" S22 W2: "crochet had brought us a new talent" S28 W2: "It sparked a lot of creativity" S30 W2: "It allows us to make anything we want with just yarn and also be creative"
Well-being	Positive effects of crochet on mental health benefits including the calming, repetitive movements of crochet in dealing with depression, anxiety and stress	S1: "I undid my scarf. I'm restarting. I skipped the last stitches" S29: "OH NO" S1: "it was really satisfying though" S29: "Well, at least that's something" S1: "I messed it up, and it was really satisfying" S8: "It is"	S5 W2: "It took a break with the technology and stress and continued something else while still learning" S7 W2: "Bring me peace and something to do as future hobbies" S13 W2: "It is fun and calm" S15 W2: "The crochet is a fun hobby that is calming and fun to do" S16 W2: "Because it was very relaxing and I got to make a bracelet out of a crochet chain" S19 W2: "To release stress" S21 W2: "Helps me focus way more" S27 W2: "It taught me to be patient"
Communication/ Sharing	Communication with their peers as they jointly studied crochet stitches, helping each other figure out stitches, and expressed themselves in unique ways about their creative crochet ideas	S26: "I'm almost gonna just go around reading everyone's name tags. i know like 10% of y'all" S29: "I should have lied and made your quest harder" S26: "Nah your friend E snitched lol" S1: "I think this channel became more of a "get to know each other" channel than "crochet"	S9 W2: "Crochet has kept me from checking out completely so I can stay involved with the class" S20 W2: "Hands-on activities that you can use in your future and you can use it to interact with others"

(Contd...)

Science Education International
33(4), 392-399
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Table 1: ***(Continued)***

Themes	Explanation	Discord examples	Survey examples
		S26: "My goal is to know all your faces and names by July 1st."	S23 W2: " Express myself and it was very fun and enjoyable"
		S25: "What school do you guys go to?"	S32 W2: "I loved doing crochet too because it gives me a new way to express myself"
			S38 W2: "Crochet was fun"

Materials Needed

- Classroom
  - Shoebox
  - Carpet classroom floor - crocheted
  - Windows - lego parts
  - Flat piece of cardboard
- School Landscape
  - Green, almost like a forest
  - Trees
    - Stick the crocheted pompom to the top
    - Pom-pom - add color for flowers & fruits
    - Painted brown pencils
  - Normal garden outside
    - Bricks in a square
    - Flowers coming out of it
  - Flowers
    - Hole-puncher cutout shapes
    - Origami flowers
- STEAM - Modern Classroom
  - Whiteboard inside
  - Clock
  - Projector, made out of legos
  - Sticker Posters
  - Desk Materials
    - Legos
    - Square piece of paper on top of a small object
  - Reading Area
    - Crocheted bean bags
    - Shopkins Books
- Greenhouse (if we have extra time)
- Students & teacher
  - Lego figures/Mini-origami people
- Legos to build the actual school & for the people

Figure 1: Smart classroom materials

Well-Being

The impact of crochet on well-being was brought to light. Eight girls shared how crochet was a stress reliever, and enhanced calming and peaceful effects for them (Burns and Van Der Meer, 2021). Students 13 and 15 said "it was a fun hobby that is calming." Six girls indicated in the survey that practicing crochet helped them "feel calm," "relaxed," and "relieved stress." In the Discord communication, girls talked about how the crochet process was "very satisfying," even when they made a mistake and had to start over with their project. Student 27 mentioned that crochet taught her to be patient while Student 21 expressed how crochet helped her focus better. Crochet was credited to each of the behaviors and emotions connected to the well-being of the particular girls that expressed positive impact.

Communication and Sharing

Research indicates that crochet can bring a sense of community and agency for people (Mayne, 2016). In the survey, five girls expressed how practicing crochet helped them interact with their peers more freely and allowed for easy self-expression. Student 23 shared that crochet allowed her to "express myself and it was very fun and enjoyable." Student 32 said, "I loved doing crochet too because it gives me a new way to express myself." These findings confirmed with the previous research that crochet improves interaction, social confidence, and feelings of belonging (Mayne, 2016; Pickrem, 2019; Sehdev, 2020). When the Discord platform was used to communicate about crochet, the girls became more engaged in varying conversations, in addition to crochet, that allowed for more engagement, enhanced communication, allowed a SoBL as explained in this exchange between several girls. Student 1 said, "I think that this channel became more of a "get to know each other" channel than "crochet." Student 26 said,: "My goal is to know all your faces and names by July 1.," Student 25 said, "What school do you guys go to?"

The girls were placed into teams and given a challenge to build a system using the new robotics knowledge they learned and then asked to embellish the system in an artistic way. This paper shares the findings of one of the team's completed projects. The team's project was to design an automatic attendance checking system consisting of the radiofrequency identification (RFID) card, token, RFID card reader, Arduino Uno with WiFi module (or ESP32 board), and a micro-serv for efficiency in attendance checking in a smart classroom with the objective of being less time intrusive on teachers. Teachers can focus on teaching. Once the robotics details were completed, the girls did a fabulous job artistically enhancing the classroom demonstration. They determined the materials needed to create their Smart Classroom demonstration as shown, see Figure 1.

Dialog within Discord displayed their collaborative creativity as they designed and enhanced their Smart Classroom demo including yarn and crocheted items, for example:

- Student 3: "We are going to definitely paint the walls and Julie will make the rug (Figure 2) but that's a starter"

Science Education International
33(4), 392-399
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Figure 2: The Carpet

Figure 3: Automatic attendance checking system for smart classroom demonstration

- Student 8: "If anyone has a paint brush, please bring it if we are going to use paint. "I have paint. Washable though"
- Student 6: "May be I can make a pompom and use it as a brush, since I have the yarn"
- Student 6: Oh also do you guys have any extra grass another group can borrow?
- Student 3: Okay, cool! Do they mean the green yarn that we used for the trees?
- Student 6: "Ohh ok I'll let them know! Do we have any green yarn left?

Throughout this dialog, the girls were using Discord to communicate about their project design. They allocated assignments to group members, created a materials needed list, and used techniques learned in the crochet workshop (Pom-pom and single crochet) to create a finished product of a Smart Classroom (Figures 3 and 4).

Figure 4: Automatic attendance checking system for smart classroom demonstration 2

DISCUSSION

Our research was part of a STEM project sponsored by the NSF. At the end of the summer camp, students were asked to give feedback on team projects. All students reported that they were interested in engineering after the 2-week engineering project development. The experiences made them feel able to do computing and engineering and are able to use imagination and creativity to solve problems. All the students also reported that they feel more motivated to learn STEM in the future. The team projects also inspired them to consider pursuing STEM when they apply for college. In terms of female students' confidence in STEM learning, the consensus was seen that their confidence was definitely enhanced. In this discussion, we explained the findings that are more related to crochet rather than the whole summer camp. This section includes two parts: (1) creativity, well-being, and STEAM; and (2) communication, sharing, and SoBL.

Creativity, Well-Being, and STEAM

The previous studies showed that crochet allowed females, particularly, African American females to create arts (Burns and Van Der Meer, 2021; Myers, 2011; Pickerim, 2019; Sehdev, 2020; Stalp et al., 2018). This study used crochet as one of the significant educational activities that align with the GUIC program for teenage girls. Both students' survey and the Discord interactions showed that crochet, together with other learning activities, allowed students to socialize, learn about STEM and STEAM, and have fun. For girls, crochet is a great outlet for creativity (Myers, 2011). They were also given space to expand their creativity (Pickrem, 2019; Stalp et al., 2018). They explored the slip stitch, the chain stitch, the magic ring, and a pom. Some of the benefits were that they had fun, made their own creations, and further expressed their emotions during and after the camp. Innovative activities combined art and STEM where not only the stitches and patterns related to math, but also helped them express themselves as an emotional outlet during their participation. While the program did not focus on spurring innovation and advancing art in crochet, students created several significant products that relate to the STEM projects.

Our study echoed with Kijima et al. (2021) in designing thinking and integrating artistic approaches in STEM and fostering greater interest in STEM among adolescent girls. In girls' STEM education, confidence is crucial to their participation and interest development. Conventionally, men or male students tend to dominate the learning process so that women do not feel engaged and relaxed. Studies have related this inequity to learning environments which do not meet students' unique needs (Eccles and Roeser, 2011).

The findings showed that the girls in the camp felt relaxed, calm, satisfied, and interested in the activities. Our study confirmed the previous research that crochet can enhance women's well-being (Burns and Van Der Meer, 2021; Mayne, 2016; Sehdev, 2020) and that female students working in a single-gender group gain more benefit in terms of developing positive attitudes toward engineering than in a mixed-gender group in which males often take lead (Sahin et al., 2015). Our research design aims at creating a positive constructivist learning environment in which all girls have the same opportunities to work and collaborate on the learning activities.

More importantly, through the exploration of the integration of art into STEM, we created a case of STEAM to address the remaining issues raised by Perignat and Katz-Buonincontro (2019). Our STEAM case not only enhanced creativity and thinking skills, but also measured or assessed as part of STEAM education to some extent, and we observed the creative process for the final product.

Constructivist Learning Environment: Communication and Sharing versus SoBL

In the Discord channels, students shared their crochet work which encouraged them to continue the project. They were open with each other, understood each other and comfortable with each other in learning the new craft. The girls asked each other which schools, they were from and got to know each other (Baumeister and Leary, 1995; O'Neel and Fuligni, 2013). In this encouraging learning environment, they were able to see that others who are like them share their interests and desire to learn STEM related skills. Discord and the surveys of the students provided evidence for students' communication, sharing, and SoBL. 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. To conclude, Discord used in the program allowed students to use their strengths to enhance learning in situated contextual activities and provided opportunities for relationship building in social activities (Alt, 2015) and increased a strong SoBL (Baumeister and Leary, 1995; Glass, et al., 2015; Walker, 2019).

At the end of the program, all students reported that their interests and/or motivations in STEM have increased or increased significantly as a result of the camp. Many students also reported an increased motivation to pursue a career in the STEM fields, which was seen in students' answers as linked to their increased self confidence in STEM. Some students also reported a feeling of support and belonging from primarily their mentors, but also their peers, which led to them thriving in the environment, as well as creating/involving themselves in the community. In the past 2 weeks' team projects, students interacted with their peers and collaborated with each other under the mentorship from college student mentors and school teacher mentors in each team. In some teams, crochet became part of the projects. Through crochet and other STEM and educational activities, girls became less shy and learned about themselves and further saw themselves as a valued member of the team or community. In this positive constructivist learning environment, a strong SoBL gave each girl the confidence to ask for help, seek resources, and work toward success (Strayhorn, 2019).

CONCLUSION

The summer camp projects provided a unique opportunity for the participating secondary female students to learn computing and programming, Internet of Things (IoT)/ robotics design, and gain useful engineering experience in conducting projects in ubiquitous intelligent systems. The study of crochet in this program is significant in several ways. First, our study contributes to the STEM learning program design for girls in secondary schools with two closely related theories: Constructivist learning environment theory and SoBL theory. Embedding artistic activities into the STEM learning activities may interest girl students more. Second, Discord was used for students to communicate. This tool served as a platform for communication and sharing; in this study, it also offered significant examples for students' interactions and learning. Third, the study found positive effects of crochet on secondary girls' SoBL, creativity, and well-being, as well as STEAM learning; these findings added new knowledge to the research of crochet in girl education and STEM program design.

Several lessons were learned for our continued work. First, more specific requirements for the crochet art form should be offered so that we can clearly see levels of crochet projects that can be performed during the 5-week summer camp. Second, we should give the girl participants explicit guidance on how to integrate crochet into the STEM projects. We encouraged them to continue working on crochet but did not further guide them to add crochet into the STEM process. Finally, we need more data for the evidence of interactions between the girls beyond Discord. In this way, our findings can better explain the constructivist learning environment. Crochet, as a valuable component of STEAM, can serve as a conduit for inspiring more girls to explore and embrace science, technology, engineering, and math. Further research is needed to capture pertinent data. For the future research on the impact of crochet on girls in STEM, specific steps on the girls learning crochet techniques that can be used to create products pertaining to their identity will be studied. This approach will allow researchers to assess how crochet can be utilized as a valuable part of STEAM studies for girls.

Science Education International
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ETHICAL STATEMENT

This research was conducted by the approval of the Division of Research, University of Nevada, Las Vegas. The researchers obtained a written informed consent form from all the participants and their parents to conduct this study.

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