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# How Constructivist Learning Impacts Secondary Girls' STEM Career Interests

Yonghong Jade Xu [1], Mei Yang [2] Shaoan Zhang[3], Venkatesan Muthukumar[2]

[1]College of Education, University of Memphis, Memphis, Tennessee, USA

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

[3]Department of Teaching and Learning, University of Nevada at Las Vegas, Las Vegas, Nevada, USA

Correspondence: Yonghong Jade Xu, Counseling, Educational Psychology and Research, Ball Hall 100, University of Memphis, Memphis, TN 38152, USA.

Correspondence: .

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**Abstract**

This is a quantitative study that examines how constructivist learning in a summer camp impacted middle school and high school girls' STEM knowledge, self-efficacy, and ultimately, their interests in future STEM learning and growth. An online survey was used to collect information from thirty-one girls at the end of a five-week summer camp. The results are mostly confirmative of past studies that used student-centered project-based authentic STEM learning with significant gains in students' understanding of STEM, self-efficacy, and interests in STEM for future development. The unique contribution of the study, though, is the finding that, when given the opportunity to engage in active learning and problem-solving, girls' interest in STEM subjects could be substantially boosted; the constructivist learning environment along with their gains in STEM knowledge can compensate any insufficiency in self-efficacy in this regard. This study provides insight about the importance of instructional approach in STEM education.

**Keywords:** STEM education, girls in STEM, constructivist learning, informal learning environment

## 1. Introduction

### *1.1 Introduce the Problem*

Interest in STEM careers among middle school students is a critical issue in today's society given the increasing demand for STEM-related skills in the workforce (Roberts et al., 2018; U.S. Bureau of Labor Statistics, 2018). Studies have shown that middle to high school is a crucial time for developing students' interest in STEM fields, and that a lack of interest during this time can lead to a decreased likelihood of pursuing STEM careers later in life (Archer et al., 2012; Han et al., 2021; Poirier et al., 2009; Roberts et al., 2018; Tai et al, 2006). One major concern is the already present clear gender gap in STEM interest among middle schools' students (Potvin & Hasni, 2014). The consensus in the literature is that girls are less likely to express an interest in STEM subjects than boys, and this gap tends to widen as students progress through high school (Lubienski et al., 2013; Wang & Degol, 2017). Interventions are critical to increase girls' participation in STEM activities and learning during this period because it happens to be the time when students begin to think and make decisions about their future academic and career paths (Wang & Degol, 2017).

### *1.2 Explore Importance of the Problem*

According to the National Research Council (2011), there is a shortage of STEM talents in the current labor force, in contrast with the anticipation that the labor demand in STEM occupations will continue to grow in coming decades (Langdon et al. 2011; U.S. Bureau of Labor Statistics, 2018). One primary cause of the workforce gap in many STEM professions is the educational deficit in STEM areas (Brown et al., 2016; Han et al., 2021; Takeuchi et al., 2020). STEM education therefore becomes a national priority as a major undertaking for the U.S. to remain competitive in innovation and technology (Han et al., 2021; Macun & Işik, 2022). To increase supply of STEM talents, one important task is to strengthen women's interest and broaden their participation in STEM fields.

In the current study, a five-week summer camp was provided to a group of girls in grades 6-11. The camp activities were designed for the participants to learn Arduino & C++ programming (block- and text-based) during the first three weeks; in the last two weeks, the girls were given the opportunity to integrate these tools to conduct projects in ubiquitous intelligent systems (UIS, Márquez, Perikos, & Karuppusamy, 2021)[1]. All activities were designed to ensure that learning took place in a constructivist environment and were supported by mentors who had been trained before the summer camp took place. With the collection and analyses of survey data, the objective of this study is to examine whether and how a constructivist learning environment impacted the girls' STEM interests beyond their gains in STEM knowledge and self-efficacy. The goal is to provide explicit attention to integrating computing with STEM education as research in this interdisciplinary area is "relatively scarce and recent" (Takeuchi et al., 2020, p. 12).

### *1.3 Describe Relevant Scholarship*

#### 1.3.1 STEM Interest

STEM interest refers to an individual's inclination to pursue further education or desire to pursue a career in fields related to science, technology, engineering, and mathematics (Potvin & Hasni, 2014). Studies have found that interest is the main driver and a key factor in students' career decisions and that students' interest in STEM declines with school years (Kim et al., 2018; Potvin and Hasni, 2014). Researchers found that ages 10-14 to be a key transition point where students begin to lose interest in STEM, and girls are more likely to shy away from math and science subjects (Archer et al., 2012; Han et al., 2021; Kim et al., 2018; Poirier et al., 2009). According to the literature, factors that contribute to the gender gap in STEM interest in adolescence include occupational stereotypes, lack of female role models, and lack of social and academic supports for girls (Beier et al, 2019; Kim et al., 2018). Past research has also suggested that, in order to address the gender gap in STEM interest in secondary school, one important approach is to provide girls with opportunities to engage with STEM subjects and to see themselves as capable and valuable contributors in these fields (Ayre et al., 2013; Çakır et al., 2017; Wang & Degol, 2017).

In the STEM Task Force Report (2014), the use of problem-solving and project-based frameworks in educational programs was highlighted as means to enhance STEM motivation and interest because they help students to make real-world connections. Many programs that used hands-on activities to stimulate analytical thinking and problem-solving provided empirical support to this claim (e.g., Beier et al., 2019; Leonard et al., 2016; Macun & Işik,2022; McDonald, 2016). For example, researchers (Beier et al., 2019; Leonard et al., 2016; Morton & Smith-Mutegi, 2022; Shang et al., 2023) provided strong empirical evidence to show that students who participated in programs that promoted analytical thinking and problem-solving skills were more likely to grow an interest in STEM careers and more likely to pursue STEM degrees and careers than those who did not. For example, a study by Beier and colleagues (2019) found that students who participate in hands-on activities, such as building and designing projects, are more likely to be interested in STEM careers. In addition, a review of STEM education programs conducted by the National Academy of Engineering and National research Council (2014) found that programs that provide students with opportunities to engage in hands-on STEM activities, such as robotics and coding, can increase their interest in STEM careers. The review also found that programs that expose students to diverse STEM career pathways can help them understand the relevance of STEM subjects to real-world problems.

#### 1.3.2 Self-efficacy and STEM Career Interest

One important aspect of STEM education is the development of students' self-efficacy. Self-efficacy, which refers to an individual's degree of confidence in their ability to succeed in a specific task or domain, is a concept first introduced by Bandura (1994). Self-efficacy is based largely on an individual's task-specific experience and related mastery experience (Bandura, 1994; Huang, 2013; Luo et al., 2021; Rittmayer & Beier, 2008). In other words, self-efficacy is personal belief about efficacy in specific domains and it can be fostered through mastery experiences, vicarious learning, and social persuasion (Rittmayer & Beier, 2008). STEM self-efficacy involves a student's judgment and faith in her ability to complete tasks or actions in STEM subjects and closely related to STEM career interest (Rittmayer & Beier, 2008; Shang et al., 2023). Research has shown that individuals with high STEM self-efficacy tend to take more courses related to STEM subjects and have greater interest in pursuing STEM careers (Han et al., 2021). The evidence suggests that individuals with high self-efficacy in STEM tend to believe that they are capable of performing well in STEM-related tasks and activities (Rittmayer & Beier, 2008). High STEM self-efficacy also makes students more likely to persist in the face of challenges or setbacks, which can lead to increased confidence in their ability to pursue STEM education and careers as well as greater motivation to engage in STEM-related activities (Shang et al., 2023).

The evidence is strong that self-efficacy is an important predictor of STEM interest and success, highlighting the importance of building self-efficacy in STEM education and outreach programs (Rittmayer & Beier, 2008). For example, a study by Wang, Eccles, and Kenny (2013) found that middle-school students who had higher levels of STEM self-efficacy were more interested in STEM fields and were more likely to pursue STEM-related activities outside of school. The extant literature not only confirm STEM self-efficacy as a powerful contributor to students'

STEM interest and success (e.g., Beier et al, 2019), but also support the effectiveness of certain instructional approaches and well-designed interventions in improving adolescences' STEM efficacy (Beier et al, 2019; Rittmayer & Beier, 2008). For example, a study (Samsudin et al., 2020) explored the impact of STEM-based project learning on high-school students' self-efficacy and academic performance. The results showed that students who participated in STEM-based project learning had higher levels of self-efficacy and performed better academically than students who did not participate in the program. The authors suggest that this type of hands-on, project-based learning can help to increase students' interest in STEM fields and improve their STEM self-efficacy.

1.3.3 Constructive Learning as the Conceptual Framework

Almost all programs that offer students authentic STEM learning experiences featured hands-on activities and student-centered learning (e.g., Beier et al., 2019). Formally or informally, many studies adopted constructivist learning in their STEM programs, even though different names might have been used (e.g., active learning, inquiry-based instruction, or project-based learning; see Menekse et al., 2013). The core of constructivist learning emphasizes the active role of learners in constructing their own understanding of new information and concepts (Menekse et al., 2013). The constructivist learning theory suggests that learners actively build their knowledge and understanding through a process of constructing meaning based on their prior knowledge, experiences, and interactions with the environment (Driver & Oldham, 1986). According to the theory, learner-centered approaches, in which students meaningfully engage with the material and build their own understanding of new information, can be achieved through activities such as hands-on experimentation, problem-solving, and collaborative learning. The key point is that learners need to be active participants in the learning process and that effective teaching requires attention to learners' prior knowledge, experiences, and interactions with the environment (Driver & Oldham, 1986; Kim, 2005).

A number of studies have examined how constructivist learning may play a role in changing adolescence's interest in STEM careers. For example, a number of studies (e.g, Chang & Brickman, 2018; Ellis, Fosdick, & Rasmussen, 2016; Pedrosa-de-Jesus et al., 2019) have found that constructivist learning increased students' understanding of STEM concepts and enhanced their ability to apply these concepts to real-world problems. Furthermore, middle school students who participated in a constructivist learning program showed increased interest in STEM careers compared to those who did not participate in the program. They also were more likely to pursue STEM-related coursework in high school, showed increased confidence in their ability to succeed in STEM fields, and had a greater motivation to pursue STEM-related majors in college.

Overall, the literature suggests that constructivist learning have a positive impact on middle school students' interest in STEM careers (Kim, 2005). By providing hands-on and interactive activities that emphasize real-world problem-solving, constructive learning can help students develop a deeper understanding of STEM concepts and increase their motivation to pursue STEM-related coursework and careers. Furthermore, research has suggested that there may be a reciprocal relationship between STEM self-efficacy, constructivist learning, and STEM interest. For example, a study by Pajares and Miller (1994) found that middle-school students who had higher levels of self-efficacy in math were more likely to engage in constructivist learning activities, which in turn led to increased interest in math. However, it remains unclear whether and how constructivist learning, as an instructional approach, may contribute to STEM interest independent of knowledge gains and personal attributes (such as self-efficacy), especially for adolescent girls. A better understanding of the benefits of constructivist leaning will contribute to the development of effective interventions and strategies to promote STEM interest among adolescences.

Given the primary objective of the current study is to examine how constructivist learning contributes adolescent girl's STEM interest, controlling for their STEM self-efficacy, successful implantation of a constructivist learning environment became the key to a valid study design. Therefore, all summer camp activities were carefully structured to focus on student-centered learning guided by the constructivist learning theory. According to de Kock et al. (2004), the three tenets of a constructivist learning environment are constructive activity, situated contextual activity, and social activity. Constructive learning activities occur during meaningful and perplexing problem solving in real-life situations (Menekse et al., 2013). Problem-solving that incorporates conceptual conflicts and dilemmas can stimulate higher-order meta-cognitive learning and enable learners to engage in reflections and concept investigation, subsequently make meaningful, real-life connection to knowledge. In this study, summer camp participants were arranged in tiered teams to work on projects in the UIS[1] system. The hands-on interactive activities provided a constructivist learning environment that emphasized real-world problem-solving as well as an opportunity to connect STEM concepts with authentic applications. Students in the constructivist environment were co-mentored by STEM teachers and college students who assisted them with solving potential conflicts and dilemmas.

Situated contextual activities require a setting that encourages self-regulated learning by shifting external control of the learning process (e.g, as emphasized in traditional settings) to the student's internal control of the learning process. For this purpose, the current study structured tiered teams as the situated context and used peer interactions to enhance self-regulated learning such as self-assessment, time management, and use of academic resources. The tiered-team design also served well as a structure to facilitate the social activity requirement that emphasizes the cooperative dialogical nature of the learning process. Team members were encouraged by the mentors to have arguments, discussions, debates, and idea-sharing as new forms of learning. Additionally, a virtual learning cloud, Discord, was implemented for the students and mentors to have informal communication during the 5-week summer camp as a supplemental social context for discussion and support.

### *1.4 Research Objectives*

It has been widely acknowledged that the challenge of increasing women's participation in STEM begins well before college and entry into the workforce. The extant literature highlights the urgent needs to use effective interventions to boost girls' interest in STEM during the key transition point in middle and high school (Archer et al., 2012; Poirier et al., 2009). Despite the usefulness of evidence that support constructivist learning as an effective instructional approach in STEM education (e.g., Menekse et al., 2013), understanding is lacking about how specially designed instructional interventions might support students' interest in STEM (Drymiotou et al., 2021). In particular, it remains unclear whether any specific instructional approach contributes to improving STEM interest beyond its positive contributions to students' knowledge gain and STEM self-efficacy. Therefore, this study is to examine how the constructivist learning approach impact girls' STEM interest, taken into consideration their gains in STEM knowledge, skill, and self-efficacy. The specific research questions to be answered are:

1) How did camp participants evaluate their learning outcomes in the constructivist-learning based summer camp?

2) How did the constructivist learning/instructional approach contribute to camp participants' gain in STEM knowledge and skills, controlling their reported self-efficacy?

3) How did the constructivist learning/instructional approach in the summer camp influence secondary girls' interest in STEM fields, controlling for knowledge gain and self-efficacy?

## 2. Method

The study was to examine how constructivist learning activities in a UIS-based summer camp may enhance adolescent girls' STEM self-efficacy, knowledge, and interests in learning computing and engineering. In the section below, the design of study, the target population, selection of participants, intervention, data collection and analytical procedures are described in detail.

### *2.1 Target Population*

Since middle to high school is the critical period during which students grow their career interests, this study targeted female students in middle and high schools (grades 6-11) from a large school district in the southwest region of the U.S. An emphasis was placed on the recruitment from Title 1 schools with large percentage of underrepresented minority students.

### *2.2 Participant and Sampling Procedures*

During the preparation of this project, the research team made recruitment trips to Title 1 middle/high schools in the district. In the Spring of 2022, a program announcement flyer was first publicized in local school district's monthly newsletter. Then, the research team made phone calls to principals, counselors, and teachers at the targeted schools to encourage students and teachers to apply. Recruitment was initiated through flyers emailed to target MS/HS schools and on-site visit with MS/HS STEM teachers. Qualified STEM teachers and college students were invited to serve as mentors in the summer camp. These teachers were asked to help recruit students for the summer camp. Discussions with these mentors were organized to learn the expectations of teachers and students in the local school district. Interested students were asked to complete an application form and submit one-paragraph statement of interests, school transcripts, along with a letter of recommendation from the science teacher. Eventually, a total of 37students who met the selection criteria were accepted to the five-week summer camp. The participants were divided into ten tiered teams and each team was led by two mentors, one of them was a college student in engineering major and the other was a STEM teacher from a local school.

#### 2.2.1 Interventions

The summer camp was designed to teach secondary female students computing and programming skills, Internet of Things (IoT), and robotics. Particularly, the first three weeks were dedicated to training students with computing & engineering knowledge and skills. Two course modules were offered in sequence: Arduino Programming & IoT and Robotics Design. Each course module comprised 1.5 weeks of lectures/discussions as well as and hands-on mini-labs/projects. After the training session, the students formed tiered teams (3-4 girls per team) and worked with their mentors in the UIS engineering projects. If possible, each team was composed of two middle school students and two high school students; their project development activities were mentored one STEM teacher and/or one college student. Integrating the knowledge and skills from the 3-week training and applying them in hands-on projects, the teams worked on a UIS project of chosen daily for two weeks. At the end of the summer camp, each team is asked to present their work on the project and showcase a workable prototype system along with a poster based on their work.

All project teams' presentations and live demos of their prototype systems were evaluated by a Panel of Judges composed of one industry expert, one camp course instructor, and one STEM teacher representative from the local school districts. The top three tiered-teams were awarded Amazon gift cards. To facilitate the communication between the girls and their camp mentors, a virtual learning cloud was adopted with the intention to cultivate long-term mentoring relationships.

The summer camp activities were meticulously crafted in alignment with constructivist learning theory, fostering an environment conducive to hands-on exploration, authentic problem-solving, and collaborative interactions within tiered teams. Throughout the camp, participants engaged in structured activities aimed at nurturing stable mentoring relationships and facilitating meaningful learning experiences. For instance, a highlight of the program was the team-based UIS engineering project conducted during the final two weeks. Each team was empowered to select a unique project, fostering ownership and autonomy among the students. While mentors provided guidance and support, students assumed leadership roles, actively engaging in idea sharing, conflict resolution, and plan implementation. This emphasis on active participation and practical application, bolstered by mentorship, exemplified a holistic approach to constructivist learning. It is worth mentioning that mentors went through a one-week mentor training workshop to get familiar with technologies used in the camp as well as mentoring skills that promote students' engagement in self-regulated learning and activities suitable for their cognitive abilities.

#### 2.2.2 Data Collection, Instruments and Sample Size

An online survey using both close-ended and open-ended questions were developed, reviewed, and finalized by domain experts, including the external evaluator. The survey was hosted at Qualtrics.com and used to collect students' feedback about how participation in the summer camp changes their knowledge, skills, and interests in computing & engineering fields and how the experience influences their STEM interest. In the present study, STEM interest is defined as individuals' general interest in learning more STEM in future courses and choosing STEM-related college majors in the future. For the present study, only questions related to the research questions were used, all of them had 5-point response categories (1 – strongly agree, 2 – agree, 3 - neutral, 4 – disagree, and 5 – strongly disagree). As summarized in Table 1, the questions formed four subscales measuring a) participants' evaluation of the learning outcome (5 items), b) constructivist learning experience (7 items), c) STEM interest (5 items), and d) STEM self-efficacy (3 items). The Cronbach's $\alpha$ values were .909, .866, and .884 for the subscales of evaluation of the learning outcome, constructivist learning, and STEM interest. The reliability of STEM self-efficacy (Cronbach's $\alpha$ = .712) is not as strong, but statistically sufficient.

All programs in the summer camp were approved by the Institutional Research Board. Parental consents were obtained before all camp participants were invited to complete the survey online at the end of the camp. Camp organizers sent gentle reminders to the girls during the presentation day and after the camp was over. The survey closed two weeks after the camp. After removing incomplete and invalid answers, a total of 31 valid responses were recorded, resulting in a 83.7% response rate.

#### 2.2.3 Analytical Procedures

To answer the first question about camp participants' evaluation about their learning outcomes in the summer camp, descriptive statistics of related survey questions are to be provided. In addition, their mean will be compared with 3 (neutral) using a one-sample t-test so see whether the average rating is significantly different from neutral rating. For research questions 2 and 3, multiple regression is the method of choice. In the model of Question 2, The dependent variable is participants' learning outcome measured as their gains in STEM knowledge and skills, the two independent variables are constructivist learning and self-efficacy. In the model of Question 3, the dependent variable is students' STEM interest, and independent variables are constructivist learning, gains in STEM knowledge and skills, and self-efficacy. IBM SPSS (version 28) was used to prepare and analyze the data to answer all research questions.

Table 1. Survey questions organized by subscales, and descriptive statistics

| **Evaluation of learning outcomes (Cronbach's alpha = .909)** | | Mean | Std. dev. | % of Agree & Strongly Agree |
|---|---|---|---|---|
| Q2 | Activities in the summer camp helped me understand how to apply knowledge taught in school STEM courses to solve real problems. | 1.77 | .845 | 80.6 |
| Q3 | The STEM projects in the camp offered great examples of how subjects taught in school STEM courses can be utilized in real life. | 1.84 | .820 | 80.6 |
| Q9 | The projects gave me a better understanding of the importance of STEM fields. | 1.65 | .755 | 90.3 |
| Q10 | The summer camp contained a variety of learning activities that increase my STEM knowledge and skills. | 1.42 | .564 | 96.8 |
| Q14 | Activities in the summer camp will help my performance in STEM courses in school. | 1.65 | .877 | 80.6 |
| **Constructive learning (Cronbach's alpha = .866)** | | Mean | Std. dev. | % of A & SA |
| Q25 | I was given sufficient opportunities to explore different ideas and perspectives in the summer camp. | 1.71 | .643 | 90.3 |
| Q26 | I enjoyed the collaboration among my team members during the summer camp. | 1.65 | .755 | 83.9 |
| Q27 | My mentors were good at keeping team members challenged with various tasks. | 1.87 | .922 | 83.9 |
| Q29 | Peers in my tiered team supported each other for successfully completion of the project. | 1.84 | .583 | 90.3 |
| Q31 | My mentors encouraged critical thinking through discussions and debates. | 1.94 | .772 | 80.6 |
| Q50 | The camp activities motivated me to think reflectively. | 1.87 | .806 | 61.3 |
| Q51 | I was given sufficient opportunities to share my own experiences with others in the camp | 2.32 | .909 | 80.6 |
| Q52 | The mentors provided helpful feedback for me to perform better in camp activities. | 1.71 | .643 | 90.3 |
| **STEM interest (Cronbach's alpha = .884)** | | Mean | Std. dev. | % of A & SA |
| Q43 | The experience in the summer camp makes me want to take more STEM courses in school. | 2.13 | 1.074 | 77.4 |
| Q44 | The engineering projects in ubiquitous intelligent systems (UIS) or robotics increased my interest in choosing STEM disciplines as a college major. | 2.00 | 1.017 | 80.6 |
| Q45 | Participation in the summer camp increased the likelihood of me choosing STEM disciplines as college major. | 2.03 | 1.033 | 70.0 |
| Q46 | I can see myself as a computer scientist or engineer in the future after attending the summer camp after attending the summer camp. | 1.67 | .711 | 87.1 |
| Q48 | The camp activities motivated me to engage in further learning of related subjects. | 2.07 | .828 | 80.6 |
| **Self-efficacy (Cronbach's alpha = .712)** | | Mean | Std. dev. | % of A & SA |
| Q4: | I enjoyed working on the projects in the summer camp. | 1.61 | .667 | 90.3 |
| Q16 | I gained confidence in my ability to excel in STEM courses after attending the summer camp | 1.74 | .815 | 90.3 |
| Q21 | If I work hard, I can become a successful engineering or computer scientist. | 1.52 | .677 | 83.9 |

## 3. Results

In Table 1, the mean and standard deviation, along with the percentage of "strong agree" and "agree" responses, were provided for individual survey items (Table 1). It is clear that camp participants rated their learning outcomes very positively. Almost all respondents (96.8%) were impressed with the variety of camp activities and felt that they gained a better understanding of the importance of STEM fields (90.3%). Over 80% of them either agreed or strongly agreed that camp activities allowed them to make connection between STEM knowledge and real-life applications and gained confidence in future STEM performance.

Next, the average scores of the items within each of four subscales were created and used as the subscale measures. Their mean and standard deviation, along with the bivariate correlations are provided in Table 2. The means were compared to 3 (the "neutral" response in the survey) using one-sample t tests, and the results showed that all four subscale means were significantly different ($p <. 001$) from the neutral response.

Table 2. Correlations between subscale measures

| | STEM interest | Learning outcome | Self-efficacy | Constructive learning | Mean | Std. Dev. |
|---|---|---|---|---|---|---|
| STEM interest | 1 | | | | 1.98 | 0.77 |
| Learning outcome | .768** | 1 | | | 1.66 | 0.67 |
| Self-efficacy | .643** | .811** | 1 | | 1.62 | 0.58 |
| Constructivist learning | .774** | .731** | .660** | 1 | 1.88 | 0.58 |

**. Correlation is significant at the 0.01 level (2-tailed).

In order to answer the second research question about how the constructivist learning contributed to participants' gains in STEM knowledge independent of their self-efficacy, a multiple regression was run with the learning outcomes as the dependent variable, constructivist learning as the independent variable, and self-efficacy as the control variable (Table 3). The results indicated that about 72.5% of the variance ($p < .001$) in the camp learning outcomes can be explained by the constructivist learning and students' self-efficacy. Hierarchical entry of the variables showed that in addition to the variance explained by students' self-efficacy ($R^2 = .657$, $p < .001$), constructive learning explained an additional 7% of the total variable ($R^2 = .068$, $p = .014$). The standardized regression coefficients indicated that for one standard deviation increase in students' self-efficacy, the rated learning outcomes increased by .581 standard deviation; for one standard deviation increase in constructivist learning, the rated learning outcomes increased by .347 standard deviation. Both variables were statistically significant and had strong effect size.

Table 3. Regression models with camp learning outcome as the dependent variable

| Models | | b | β | t | p | $\Delta R^2$ |
|---|---|---|---|---|---|---|
| 1 | (Constant) | .137 | | .632 | .532 | |
| | Self-efficacy | .941 | .811 | 7.453 | <.001 | .657 (p <.001) |
| 2 | (Constant) | -.191 | | -.815 | .422 | |
| | Self-efficacy | .675 | .581 | 4.407 | <.001 | .657 (p <.001) |
| | Constructivist Learning | .403 | .347 | 2.631 | .014 | .068 (p= .014) |

Table 4. Regression with STEM interest as the dependent variable

| | | b | β | t | p | $\Delta R^2$ |
|---|---|---|---|---|---|---|
| 1 | (Constant) | .478 | | 1.715 | .097 | |
| | Self-efficacy | .078 | .059 | .285 | .778 | .591 (p <.001) |
| | CAMPEVAL | .826 | .720 | 3.490 | .002 | |
| 2 | (Constant) | .019 | | .065 | .948 | |
| | Self-efficacy | -.043 | -.032 | -.173 | .864 | .591 (p <.001) |
| | Learning outcome | .524 | .457 | 2.226 | .035 | |
| | Constructivist Learning | .615 | .462 | 2.886 | .008 | .096 (p =.008) |

Finally, a multiple regression model was run to answer the research question how the constructivist learning in the summer camp influence girls' STEM interests, controlling for their STEM knowledge gain and self-efficacy (Table 4). In this model, STEM interest was the dependent variable, constructivist learning the independent variable, controlling for the learning outcomes and self-efficacy. The results indicated that about 68.7% of the variance ($p < .001$) in STEM interest can be explained by the linear combination of constructivist learning, knowledge gain, and students' self-efficacy. Hierarchical entry of the variables showed that in addition to the variance explained by students' learning outcomes and self-efficacy ($R^2 = .591$, $p < .001$), constructivist learning explained an additional 10% of the total variance ($R^2 = .096$, $p = .008$). The regression coefficients indicated that students' self-efficacy had little influence ($\beta = -.032$, $p = 0.864$) on STEM interest. Rather, the rated knowledge gain ($\beta = .457$, $p = 0.035$) and constructive learning ($\beta = 0.462$, $p = 0.008$) had statistically significant and practically substantial impacts on girls' STEM interests. In both regression models, the VIF values of the input variables were lower than 5, indicating the multicollinearity was not a problem.

**4. Discussion**

Middle and high school girls who attended a 5-week summer camp evaluated their camp learning outcomes and experiences in the constructivist learning-based program. Analysis of the survey data provided insight about the importance of instructional approach in STEM education. The unique contribution of the study is the clear evidence that, when given the opportunity to engage in active learning and problem-solving, girls' interest in STEM subjects could be substantially boosted; the constructivist learning environment along with their gains in STEM knowledge can compensate any insufficiency in self-efficacy in this regard. Below is the detailed discussion of the findings.

First, camp participants had very positive evaluation of their learning experience and learning outcomes; overall their ratings of STEM interest and self-efficacy were strong after the camp, as indicated by the significant results of the t tests comparisons. The girls reported that they were given sufficient opportunities to explore different ideas and share personal perspectives in the summer camp. They enjoyed team collaboration and team members supported each other in camp activities. Further, the measures of learning outcomes are very encouraging so that the summer camp activities had a positive impact on making science and engineering more meaningful to students and increased their content knowledge and likelihood to explore STEM careers. Similar findings have been reported in other studies that used hands-on and/or project-based learning (e.g., Drymiotou et al., 2021). In the meantime, the girls felt that their mentors encouraged as well as challenged them through discussions and regular feedback. It is not surprising that the positive camp experiences led to significant gains in STEM knowledge and skills. These findings are consistent with previous studies that examined project-based learning (e.g., Beier et al., 2019; Freeman et al. 2014). The results of this study suggest that the summer camp provided a safe space for collaborative inquiry, which is paramount in setting the stage for a constructivist learning environment (Grier-Reed & Conkel-Ziebell, 2009).

Respondents also felt that the variety of exercises and activities enabled them to connect what they learned in school with real life applications. With a better understanding of the importance of STEM subjects, they reported stronger confidence in future performance in STEM courses in school. In terms of STEM interest, the respondents reported greater likelihood of taking more STEM courses in school and choosing STEM disciplines as a college major as a result of attending the summer camp. In addition, stronger STEM identity was reported as well (i.e., "see myself as a computer scientist or engineer in the future") after attending the summer camp. The study provides evidence that students who engaged in deep personal exploration in a constructivist learning environment had the chance to strengthen their STEM self-efficacy and the play, comfort, and rapport were beneficial to extend their career interest (Grier-Reed & Conkel-Ziebell, 2009; Macun & Işik, 2022).

Further analysis revealed that both STEM self-efficacy and constructivist learning experience contributed significantly to the camp learning outcomes. Nonetheless, when both constructive learning experience and learning outcomes were taken into account, self-efficacy had little influence on the reported STEM interest. It is easy to understand that students' STEM interests would grow when they gain better understanding of STEM knowledge and career because previous studies have found that limited knowledge of STEM careers hinders STEM interest and career aspirations (e.g., Blotnicky et al., 2018; Drymiotou et al., 2021). More importantly though, the results of the two regression models imply that the effect of self-efficacy on girls' STEM interest was at best indirect through STEM learning. That is, their self-efficacy contributed positively to the learning gains in terms of more knowledge and better understanding of STEM as a field, and the learning gains in turn led to greater STEM interest. However, even though learning during the summer camp made girls felt more efficacious, the effect of self-efficacy on student STEM interest appears to be suppressed by the statistical effects of constructivist learning experiences and knowledge gains (e.g., Beier et al, 2019). Given the limited sample size, more sophisticated statistical approach for making causal inference (e.g., structural equation modeling) is prohibited, but the findings are not a complete surprise. As a matter of fact, conflictive conclusions have been drawn regarding the relationship between self-efficacy and STEM interests in the past. For example, some studies (e.g., Lent et al., 2018; Luo et al., 2021) found that STEM self-efficacy significantly predicted students' STEM career interest, but Nugent et al.'s (2015) study found that for students aged 10–14 self-efficacy in STEM learning had no significant direct effect on STEM interests. As Luo and colleagues (2021) observed, these discrepancies may be caused by the differences in the measurement instruments and/or age ranges of the sampled participants.

Practical Implications

It is clear that the constructivist learning experience in the camp changed girls' perception of STEM subjects and contributed to greater STEM interests. The results are encouraging for educators given that self-efficacy is relatively stable personal trait, whereas instructional methods are more accessible and easier to modify. Around the time students get into middle school, they begin identity formation and become aware of stereotypes and start perceiving STEM occupations as male-dominant (Aschbacher et al., 2010; Grover et al, 2014; Hughes & Roberts, 2019). Effective instructional interventions are critical to cultivate girls' efficacy and interesting in STEM during this time. One important characteristic of the summer camp is the authentic learning experience. Participants engaged in solving real-world and student-centered projects, and their experiences provided them with valuable insight into STEM tasks and got a sense about jobs in computer science and engineering fields. Therefore, findings of this study are informative for guiding middle school and high school science teachers to a constructivist instructional approach that emphasizes hands-on participation, problem-solving projects, and team collaboration (Drymiotou et al., 2021). In other words, constructivist practices can be applied to STEM education in which the classroom is made up of active, engaged students who act as collaborators in the process of teaching and learning and who are encouraged to search for novel solutions to problems (Gray, 1997). In addition, collaborative group-work is a useful classroom arrangement to trigger and maintain students' STEM interests. When students are allowed to work in groups, individuals are given freedom and equal opportunity to participate in the learning process, they can gain a stronger sense of belonging, feel being supported and build greater self-efficacy (Bahufite et al., 2022; Drymiotou et al., 2021).

Changes to current STEM teaching should not be placed solely on the shoulder of teachers. Supports are needed from school and district administrators to provide resources and create opportunities for teachers to build school-industry collaborative activities. The system needs to work as a whole to introduce changes to the current STEM curricula and provide both formal and non-formal educational activities in order to explicitly support students in developing their STEM interest and acquiring more realistic understandings about STEM careers (Drymiotou et al., 2021).

Limitations

This research has some limitations worth noting. First, the small sample size made it impossible to use more advanced statistical procedures, such as structural equation modeling, to examine potential interaction and causal effects between variables. Second, without a comparison/control group, the contribution of camp activities to learning outcomes and STEM interests cannot be statistically isolated from confounding variables and potential selection effects. Finally, the participants were from volunteer samples and the findings had limited generalizability. This study is hopefully to be replicated with future research of large sample, pre-post measures, and a control group in order to address these limitations.

## 5. Conclusions

Using data collected from participants of a five-week summer camp, the present study concludes that it is important to invest in constructive learning activities in middle and high school STEM courses. Efforts and investment in authentic STEM projects and student-centered instructional pedagogies will pay off in the long run by increasing girls' engagement and career interest in STEM. As previously discussed, the demand for STEM professionals is expected to continue growing as technology advances and new fields emerge. Educators and policymakers can support these efforts by providing opportunities for students to engage in hands-on STEM activities, promoting positive attitudes towards STEM, and providing resources and support to help students develop their STEM interest, skills and knowledge.

## Notes

Note 1. Ubiquitous Intelligence (UI) is an emerging research field, the core concept of which is to connect small internet and inexpensive computers to help with everyday functions in an automated fashion. The goal of Ubiquitous Intelligence

System (UIS) design is to use many "smart things" to create smart environments, services and applications.

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**Authors contributions**

Dr. Yonghong Xu led the data collection, analysis, and initial drafting of the manuscript. Dr. Mei Yang assumed the role of project leader, overseeing the summer camp activities and other related programs. Dr. Shaoan Zhang and Venkatesan Muthukumar supported Dr. Yang in managing the summer camp operations. All team members played a crucial role in refining and editing the manuscript.

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**Data availability statement**

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

**Data sharing statement**

No additional data are available.



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