How Constructivist Learning Impact Middle-School Girls' STEM Career Interests

Objectives

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 (Han et al., 2021; Poirier et al., 2009; Roberts et al., 2018). Of great concern is that there are already clear gender and racial gaps in STEM interest in middle school students (Potvin & Hasni, 2014). Interventions are critical to increase girls' participation in STEM 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).

This study collected data from a five-week summer camp that provided programming workshops and engineering-based group activities to girls in grades 6-11. The camp was part of the actions designed to increase girls', especially minorities', participation in computer science and engineering. All activities were designed to ensure that learning took place in a constructivist environment. With the collection and analyses of survey data, the objective of this study is to examine whether and how a constructivist learning environment impacted adolescent girls' STEM interests beyond their gains in STEM knowledge and self-efficacy.

Background and Conceptual Framework

National statistics consistently show 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 (U.S. Bureau of Labor Statistics 2018). To increase supply of STEM talents, one important task is to strengthen women's interest and broaden their participation in STEM fields. 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). 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 shun away from math and science subjects (Archer et al., 2012; Han et al., 2021; 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 (Çakır et al., 2017; Wang & Degol, 2017). In the STEM Task Force Report (2014), the use of problem-solving and project-based frameworks 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).

Another aspect of STEM education is the development of students' self-efficacy. Self-efficacy refers to an individual's degree of confidence in their ability to succeed in a specific task or domain (Bandura, 1994). STEM self-efficacy involves a student' 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). 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).

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; 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). 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. Past studies (e.g., Chang and Brickman, 2018; 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.

In this study, 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). In this study, summer camp participants were arranged in tiered teams to work on projects in the ubiquitous intelligent systems (UIS) 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 were co-mentored by STEM teachers and college seniors 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.

Research Objectives

Despite 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?

Methods

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. During the preparation of this project, the research team made recruitment trips to Title 1 middle/high schools in the district. A program announcement flyer was first publicized in 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 during the on-site visit with MS/HS science teachers; round-table discussions were organized to learn the expectations of teachers and students in the school district. Qualified teachers were invited to serve as mentors in the summer camp and also, were asked to recruit students for the summer camp. Interested students were invited 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 39 students who met the selection criteria were accepted.

In the summer camp, the first three weeks were dedicated to training students with computing & engineering knowledge and skills. Two course modules were offered in parallel: Computing Basics & Python and Programming and IoT & Robotics. Students were free to choose either course module based on their interests. After the training session, the students were divided into tiered teams (3-4 girls per team) and worked with their mentors on the UIS engineering projects for the last two weeks.

All summer camp activities were designed interventions based on constructivist learning theory. The setting was structured with tiered team interactions, hands-on learning experience, authentic applications, and stable mentoring relationship. All activities were structured to encourage participants to communicate and collaborate through sharing ideas, solving conflicts, and presenting results. Before the summer camp, mentors went through a one-week training 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.

Data collection and Instruments

An online survey was developed, reviewed, and finalized by domain experts, and hosted at Qualtrics.com. Only questions related to the research questions of this study 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 α for the subscales were .909, .866, .884, and .712**, respectively. After removing incomplete and invalid answers, a total of 31 valid responses were recorded, resulting in a 77.5% response rate.

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). 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 were positive 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 means and standard deviations, along with the 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.

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 shows that in addition to the variance explained by students’ self-efficacy ($R^2 = .645$, $p < .001$), constructive learning explained an additional 7% of the total variable ($R^2 = .068$, $p = .014$). Both variables were statistically significant and had strong effect sizes.

Finally, a multiple regression was run to examine how the constructivist learning in the summer camp influence girls’ STEM interests, controlling for their STEM knowledge gain and self-efficacy (Table 4). The results indicated 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.

Scientific Significance

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. The main connect what they learned in school with real life applications. Additionally, 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. The findings lead to a conclusion that 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.

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

Evaluation of learning outcomes (Cronbach's alpha = .909)		Mean	Std.	% of A & SA
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)				
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)				
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)				
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

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).

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

Models		b	β	t	p	ΔR²
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	ΔR²
1	(Constant)	.478		1.715	.097	
	Self-efficacy	.078	.059	.285	.778	
	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)