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It Says STEM so it must Work for Everyone: Experiences, Beliefs, and Career Choices across the STEM Disciplines

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Abstract

The development of interest and aspirations to pursue STEM careers has been a focus of recent educational research and action. This study used Social Cognitive Career Theory as the framework to explore how types of learning experiences in and out of school prior to college affected undergraduates' STEM beliefs and intent to pursue a career in a STEM field. A sample of 312 students at a large university were surveyed about the experiences in which they had participated, their perceptions of those experiences, and their self-efficacy, outcome expectations, and interests in science, mathematics, and engineering. The results indicated experiences that predicted beliefs across all STEM areas, but also some key experiences that differed depending on the subject. Experiences revolving around family and career-specific activities were important for science and engineering beliefs, the opportunity to build and create was important for mathematics and engineering beliefs, and varied instructional techniques were valuable for mathematics and science beliefs. This paper details the relationship between these experiences and STEM beliefs and career choices along with recommendations for educators looking to develop experiences to enhance STEM career pathways.

Introduction

The development of interest and aspirations to pursue STEM careers has been a focus of research and action for the last decade as a result of initiatives such as the *Next Generation Science Standards* (NGSS Lead States, 2013) and the White House's call for improved STEM education (Office of Science and Technology Policy, 2016). The STEM community has largely responded through a movement to advance STEM education with an emphasis on career development (Blustein et al., 2022). This process is not without its issues, and inspiring students toward a STEM career is not a straightforward endeavor. Students who pursue a STEM career often follow a complex path involving intrinsic characteristics, environmental conditions, and learning experiences (Burt & Johnson, 2018; Lent et al., 1994; Maltese et al., 2014).

In an effort to meet these varied needs, many in the education arena have initiated programs and experiences focused on STEM career development. These experiences happen in a variety of contexts in and out of school, often with the intent of introducing students to STEM careers, raising STEM achievement, and increasing students' interest and confidence in STEM (Guzey et al., 2019; Mohd Shahali et al., 2019; Roberts et al., 2018; Scott-Parker, 2019). These interventions have shown promise for improving interest in and pursuit of STEM careers, but many tend to combine all the disciplines in STEM to singular descriptions of their experiences, learning, and outcomes (Martín-Páez et al., 2019). While the combination of STEM disciplines is a common and often reasonable practice among educators, there are also situations in which this combination may confound the results. Grimalt-Álvaro, et al. (2022) studied over one thousand high school students and found that students who are inclined to study STEM typically either had a preference toward science or a preference toward engineering and technology. Meschede et al. (2022) found that students who participated in a robotics program were likely to be interested in technology or engineering in college but not biological or health sciences. Furthermore, Usher et al. (2019) found that some rural students developed mathematics and science self-efficacies from different sources. These studies indicate that STEM doesn't always work well as an umbrella term, but should sometimes be studied differently based on individuals' interests and interactions with STEM subjects and activities.

The existing literature involving STEM learning experiences has examined how these experiences affect STEM career paths, and many of these studies informed the development of this research (Burt & Johnson, 2018; Dou et al., 2019; Maltese et al., 2014; Maltese & Tai, 2010, 2011). However, these studies sought outcomes specific to a single discipline or the integration of all STEM disciplines. They were also conducted in an exploratory manner to determine how experiences affected students' STEM pathways and interests. We used prior research as the foundation for this study with the intent to determine which learning experiences are influential in the development of beliefs in science, engineering, and mathematics and aspirations toward a career in different STEM fields.

Theoretical Framework

This study is rooted in Social Cognitive Career Theory (SCCT), a framework for the study of career choices and actions by Lent et al. (1994). SCCT describes career choice as a complex and evolving interaction of personal inputs, background and contextual factors, experiences, and beliefs that lead to goals and actions. The theory is based on social cognitive theory, in which a mutually dependent triadic relationship forms between traits, behaviors, and external factors to explain how choices are made (Bandura, 1986). SCCT takes the concepts from social cognitive theory and integrates social learning theory (Mitchell & Krumboltz, 1990), subject-specific self-efficacy (Hackett & Betz, 1981), and career choice.

The resulting model demonstrates how the array of constructs in SCCT interact to affect a person's career choices and actions (Lent et al., 1994). The personal inputs that go into the model include demographic factors (e.g., race, gender, socio-economic status) and background contextual affordances (e.g., access to opportunities). These constructs help direct the learning experiences that are available to individuals as well as how those experiences are perceived. The learning experiences play a role in the development of self-efficacy and outcome expectations. According to SCCT, people develop interests where they have higher self-efficacies and anticipate positive outcomes. They then set goals that align with the interests, self-efficacies, and outcome expectations developed through backgrounds and experiences. The goals, in combination with each of these other constructs, affect the actions that a person takes. As those actions are taken, the results may lead to changes in the person's outcome expectations or self-efficacy, either further strengthening their interests and goals or causing them to change. At the same time, contextual factors (e.g., peers, time and resource availability, teacher and family input) feed into each construct of the model. This constant process of interaction between constructs provides a dynamic feedback loop that changes over time, allowing goals and actions to evolve as experiences, influences, and beliefs shift within the individual.

STEM Beliefs and Career Actions

According to SCCT, the development of a person's positive beliefs regarding STEM is a crucial step in the process of deciding to pursue a STEM career. This likely happens as people choose to engage in tasks or courses that reinforce areas where they have experienced success or envision positive outcomes. Bandura (1977, 1997) described the beliefs that affected this decision-making process as self-efficacy and outcome expectations, and many of the behavioral choices people make are because they envision an outcome of their behavior, while also deciding whether they are capable of producing the actions necessary to be successful in that behavior. Studies in areas such as mathematical tasks and problem-solving demonstrate that high self-efficacy beliefs resulted in better performance on those tasks (Pajares & Miller, 1994; Tossavainen et al., 2019).

As people develop beliefs about themselves in STEM, they also begin to make decisions about the actions they will take in regard to their career pathways (Lent et al., 1994). Early experiences that lead to positive self-concept help students envision the possibility of a future STEM career (Schlegel et al., 2019), and maintenance of interest helps students persist in STEM studies and enter the STEM workforce (Bonnette et al., 2019; Burt & Johnson, 2018). Studies of students in both elementary and secondary school environments demonstrated that student self-efficacy in STEM was a predictor of STEM career interest and intention (Luo et al., 2021; van Aalderen-Smeets et al., 2019). Studies involving college students identified STEM attitudes and self-efficacy as strong predictors of students' choice to enroll in a STEM major and pursue a STEM career (Moore & Burrus, 2019; Sahin et al., 2017). Knowing that beliefs such as self-efficacy, outcome expectations, and interest are important pathways to further STEM study and ultimately career choice demonstrates the need to understand the factors that enhance these beliefs.

Learning Experiences

Bandura (1977) identifies four sources for the development of self-efficacy: performance accomplishments, vicarious experiences, verbal persuasion, and physiological arousal. Hidi and Renninger (2006) posit that interest is initiated first through a situation or experience, followed by continued external and meaningful support to develop individual interest. These theories demonstrate the importance of experiences and how those experiences interact with personal context for the development of beliefs. However, beliefs are not formed solely on the effect of one experience, but rather the sum of experiences, social influences, and values throughout a person's life (Allen & Peterman, 2019). The experiences that provide opportunities for belief development can happen in a variety of educational and informal settings (Allen & Peterman, 2019; Maltese & Tai, 2010) and are referred to here as learning experiences.

Research has demonstrated that learning experiences in a variety of contexts can lead to positive changes in people's STEM beliefs and choices. Halim et al. (2018) examined the role of various learning experiences and found that both in- and out-of-school STEM activities improved self-efficacy and interest in STEM. Maltese et al. (2014) indicated that people who pursue STEM develop their interest from an array of experiences, including early play and teacher influence.

The classroom is a common place for students to participate in STEM learning experiences, and a variety of studies have provided examples of these experiences. Students who experienced hands-on lab-focused learning improved their science self-efficacy (Lee et al., 2020), while mathematics classrooms that presented challenging problems and were focused on mastery orientation led to higher mathematics self-efficacy (Fast et al., 2010). The use of authentic and engaging problems in engineering challenges increased interest in engineering and science (Guzey et al., 2016), and a STEM-focused program for middle school students improved STEM interest (Mohd Shahali et al., 2019). Two studies examined students' interaction with STEM professionals in their schools, and noted that students attributed increased interest and choices to pursue a STEM career to those interactions (Struyf et al., 2019; Thiry, 2019).

School settings are not the only places students develop knowledge, understanding, and beliefs about STEM subjects and careers. The importance of out-of-school experiences is highlighted by Steenbergen-Hu and Olszewski-Kubilius (2017), who found that more students in their study attributed their interest in STEM to family and home factors than to school-based factors. Graduate students in STEM in a study by Burt and Johnson (2018) also indicated that family was an important factor in the development of their interest to pursue STEM. Participation in STEM-based camps, clubs, and other out-of-school experiences was also a factor in several studies. Goff et al. (2019) surveyed 750 undergraduate students in STEM and found that participation in these out-of-school experiences led to higher STEM career aspirations than those who had not, and Kitchen et al. (2018) found students were 1.4 times more likely to pursue a STEM career than others if they had participated in a summer STEM experience.

Many of these studies present vital information about how contextualized experiences affect students' STEM beliefs and career choices. They also support more comprehensive lists of learning experiences such as the study by Maltese et al. (2014) which examines a variety of learning experiences over time. However, SCCT presents career decision-making as a complex process involving many inputs, and there is a scarcity of research that examines how learning experiences in STEM contexts affect beliefs in the disciplines of science, mathematics, and engineering separately.

Purpose of the Study

The purpose of this study is to elucidate the experiences that are important to the development of science, mathematics, and engineering self-efficacies, outcome expectations, and interests along with STEM career aspirations. Overall, the study worked toward these goals by answering the following research questions:

1. Is there a significant relationship between types of learning experiences and students' self-efficacy, outcome expectation, and interest in mathematics, science, and engineering?
2. Is there a significant relationship between types of learning experiences and students' intent to pursue a career in STEM?

Methods

Participants

The sample for this study includes 312 undergraduate students from a large land-grant university in the Midwestern United States. A questionnaire was sent to a random set of 5,000 first- and second-year students at the university across different colleges and majors. A total of 375 responses were received, though 63 participants did not complete all sections. This left a final response rate of 6.2% from the original list. Survey participants were 66% female, 31% male, and 3% non-binary. Participants were 7% American Indian or Native Alaskan, 4% Asian, 3% Black, 7% Hispanic or Latino, and 79% White, and this demographic breakdown is similar to that of the overall university population. Students enrolled in a STEM major comprised 66% of participants, and those in a non-STEM major were the other 34%.

Data Collection

The questionnaire was developed by the author for the purposes of this study, informed by the SCCT framework and prior literature regarding learning experiences. This was part of a larger mixed-methods project and the parts of the questionnaire relevant to this study are described in detail below. The questionnaire was delivered via email using Qualtrics online survey platform (http://www.qualtrics.com).

Measures

Self-Reported Demographics

The first section of the questionnaire contained questions about the participants' demographics. It asked for their classification, race, gender, and college major. There was also a question regarding whether the participant intended to pursue a career in a STEM field.

Learning Experiences

The second section contained three multi-part questions regarding prior learning experiences. The first question asked participants to select the experiences in which they participated during a mathematics, science, engineering, or technology-related class in grades K-12. The experiences include statements such as "discussion of STEM careers", "lectures by the teacher", and included an "other" choice where participants could add to the list. The list of experiences used for this study was developed based on the results of prior research on learning experiences in STEM (Maltese et al., 2014; Maltese & Tai, 2010, 2011). These studies also have highlighted the importance that teacher influence can have on students' assessment of their abilities and interests. Therefore, the second question asked students to identify whether certain teacher characteristics, such as encouragement or personality, influenced their STEM interests or confidence. The third question asked participants to select the STEM experiences they had participated in outside of school throughout their lives. These experiences included statements such as "tinkering with electronics" and "reading about STEM or science fiction", along with an "other" choice where participants could add to the list. The list of experiences used for this portion of the study was developed based on the results of prior research on informal learning experiences in STEM (Burt & Johnson, 2018; Dou et al., 2019; Maltese et al., 2014; Maltese & Tai, 2010, 2011). All three questions were analyzed for reliability using Cronbach's alpha (Cohen, 1988), resulting in the in-school learning experiences $\alpha = .86$, teacher characteristics $\alpha = .59$, and out-of-school learning experiences $\alpha = .84$.

After participants selected all the learning experiences in which they had participated, they were directed to a second page that contained only the experiences or factors the participants had selected. The question on this page asked participants to indicate whether each learning experience or factor increased their interest or confidence in their ability to succeed in STEM, had no effect on their interest or confidence in their ability to succeed in STEM, or decreased their interest or confidence in their ability to succeed in STEM.

SCCT Construct Instruments

The third section of the survey included questions from each of the following instruments measuring self-efficacy, outcome expectations, and interests in science, mathematics, and engineering for a total of nine construct scores. Each instrument used a 5-point Likert scale ranging from (1) strongly disagree to (5) strongly agree. The questions in this section were mixed so that the constructs were varied throughout the section.

Patterns of Adapted Learning Scales. The self-efficacy scale is based off a subscale of the Patterns of Adapted Learning Scales (PALS) (Midgley et al., 2000), which relates the learning environment to affective constructs in students. The PALS was originally written to examine patterns of learning that result in mastery and performance goals, along with the beliefs and attitudes of students and teachers and their relation to the classroom. The self-efficacy subscales measure students' perceptions of their ability to complete class work in a particular subject and includes 5 items (e.g. "I'm certain I can figure out how to do the most difficult class work in mathematics"). This revised version considers that measures for students should be subject-specific. The subscales were analyzed for internal consistency using Cronbach's alpha, with math subscale $\alpha = .91$, science subscale $\alpha = .88$, and engineering subscale $\alpha = .91$.

Fennema-Sherman Mathematics Attitudes Scales. Outcome expectations were measured using the Usefulness of Mathematics Scale, which is a subscale of the Fennema-Sherman Mathematics Attitudes Scales (Fennema & Sherman, 1976). This is a 12-item measure including both positively and negatively worded items that assesses how participants view the relevance of their studies in STEM to their future life and work. The Fennema-Sherman scale was originally designed to assess the affective variables that correspond with students' mathematics learning and course choices. Each item was listed with the subject as mathematics, science, and engineering, so that an outcome expectation score could be determined for each subject. The subscales were analyzed for internal consistency using Cronbach's alpha, with math subscale α = .90, science subscale α = .89, and engineering subscale α = .91.

Career Interest Questionnaire. Interests were measured using a subscale of the career-interest questionnaire (CIQ) developed by Christensen et al. (2014). The interest subscale measure consists of 5 items (e.g. "I will graduate with a college degree in a major needed for a career that uses science"). Each item was listed with the subject as mathematics, science, and engineering, so that an interest score could be determined for each subject. The subscales were analyzed for internal consistency using Cronbach's alpha, with math subscale α = .91, science subscale α = .94, and engineering subscale α = .95.

Results

Dimensionality Reduction

SCCT constructs were examined for relationships between the learning experiences of students and their mathematics, science, and engineering self-efficacy, outcome expectations, interests, and career intentions. The list of learning experiences contained eighteen in-school experiences, four teacher characteristics, and twenty-seven out-of-school experiences, for a total of forty-nine experiences and characteristics that may have influenced students' beliefs and intentions in the three STEM subject areas under study. While each individual experience carries some importance on its own, the number of items meant the analysis would be cumbersome and difficult to interpret accurately due to correlations between many of the experiences. To reduce the number of experiences for analysis and to develop groups of common experiences, the researcher conducted a principal component analysis (PCA).

To prepare for the PCA, the learning experiences were coded as ordinal variables according to participants' views of the experience and their value in improving confidence and interest. In this approach, a 0 indicated that the participant had not taken part in that experience, a 1 indicated that the participant had the experience with a negative perception, a 2 indicated having the experience with no perceived effect, and a 3 indicated having the experience with a positive perception of its role in STEM development. This approach had two purposes: it met the PCA assumption of multiple variables measured at the ordinal level, and it allowed for grouping by both participation in and perception of the experience.

A second assumption required for PCA is linear relationship among variables. While the number of total variables was too high to look at each combination individually, a random sample of variables was tested using scatterplots, and the variables met this assumption. The assumption of sampling adequacy was expected based on a sample size of 312 and variable number of 49, which exceeds the general rule of thumb of five participants per variable. This assumption was confirmed by the Kaiser-Meyer-Olkin measure for the analysis, KMO = .842, and KMO values for each item were above .66, greater than the acceptable level of .50 (Field, 2013). To ensure that the variables are correlated properly, Bartlett's test for sphericity was used, χ^2 (1176) = 4956, $p < .001$, and the correlation values were examined in the correlation table.

The PCA was conducted initially using both varimax and promax rotations, but after analysis, the correlations between some of the factors indicated that they were not independent, so the promax rotation was used for the final results. The factors were established based on the factor loadings in the rotated pattern matrix (Table 1). Eleven factors were retained based on analysis of the scree plot (Figure 1) and identification of factors with eigenvalues greater than one. Thirteen factors were in the original model, but two containing single variables were dropped. In the end, three variables were removed from the analysis, and the remaining were retained in the eleven factors. The retained factors are described in greater detail in Table 2.

Table 1. Factor Loading for Principal Component Analysis

	Factor												
Variable	1	2	3	4	5	6	7	8	9	10	11	12	13
Hands-on activities	.869												
Science demos	.725												
Projects	.674											.403	
Step-by-step labs	.626												
Computers	.540												
Cooperative groups	.524												
Field trips	.413												
Models	.319												
Zoo/aquarium		.843											
Museum		.732											
National park		.624											
Outdoors		.620											
Animals		.602											
Plants		.590										.340	
Volunteer work		.452											.366
Fixing toys			.872										
Construct/build			.779										
Tinker			.698										
Mechanics/engines			.613									.303	
Models/legos			.581										
Always interested				.764									
Math/logic games				.732									
Class performance				.557									
Relevant content					.237								
Memorization					.825								
Problem solving				.304	.687								

Variable	Factor												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Science fair					.562								
Further study					.439	.378							
Professional speak.						.758							
STEM careers						.726							
After school prog.							.811						
STEM camp							.782						
STEM club							.553						
Teacher encourage								.805					
Teacher comments								.712					
Teacher personality								.641					
Teacher style								.487				.309	
STEM media									.714				
STEM books									.699				
Video games			.399						.508				
Stars									.436				
Family pressure										.831			
Family talk										.662			
Family activities							.397			.527			
Lectures				.468							.656		
Paper assignments											.640		
Student design labs						.302					.551		
Home science kits												.712	
Compuers/web													.858

**Note:* All blank cells have factor loading values less than .300.

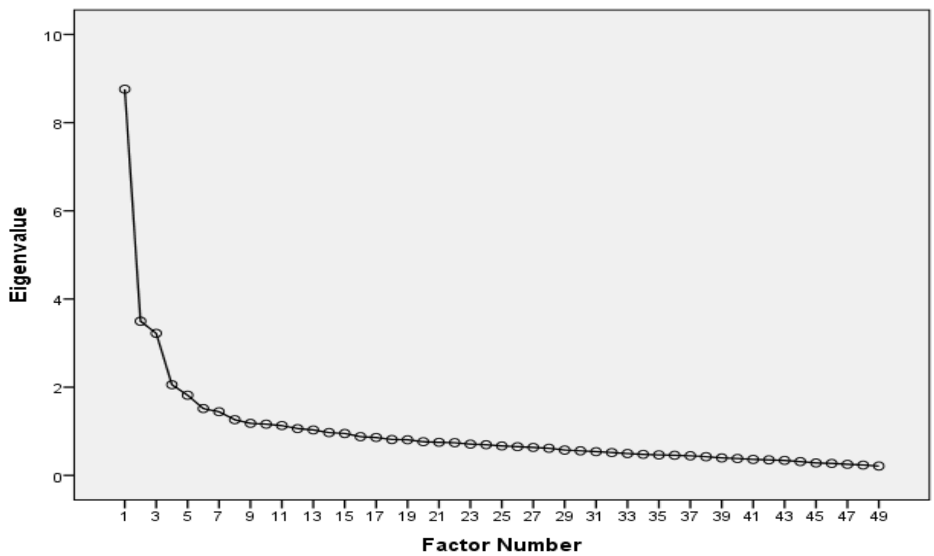

Figure 1. Scree Plot for Principal Component Analysis

Table 2. Lists of Items Contained in Each Factor

Factor	Description	Items
1	Classroom Instruction	Hands-on activities
		Lab experiments directed step-by-step
		Science demonstrations by the teacher
		Use of computers for class assignments/projects
		Creating models by hand or with a 3D printer
		Projects
		Cooperative learning or group discussions
		Field trips or other enrichment activities
2	Nature and Community	Taking care of or training animals
		Planting, taking care of, observing plants
		Playing or spending time outdoors
		Visit to a zoo or aquarium
		Visit to a museum or other learning center
		Visit to a state/national park
		Volunteer/work related experience
3	Tinkering and Building	Tinkering with electronics
		Taking apart and/or fixing toys
		Building models/legos
		Construction/measuring/building
		Fixing mechanical objects/engines/cars
4	Innate Interest and Ability	I performed well in a STEM class
		Having interest in mathematical problems or logic games
		I have always been interested in science, math, and/or engineering
5	Class Content	Class content that was relevant to me
		Took a class with an emphasis on problem solving
		Took a class with an emphasis on learning/memorizing facts
		Science competition/science fair
6	Careers and Future	Speakers from professional STEM fields
		Discussion of STEM careers
		Took a class with an emphasis on further study in STEM
7	STEM Extracurriculars	Participation in STEM clubs or groups
		Attendance at a STEM camp
		Participation in after-school STEM program
8	Teacher Influence	Teacher encouragement
		Teacher comments (about ability, future, careers, etc)
		Teacher personality
		Teacher style of instruction
9	STEM Media	Watching movies, shows, or videos about STEM or science fiction

Factor	Description	Items
		Reading about STEM or science fiction
		Observing or studying stars or other astronomical objects
		Playing video games
10	Family Influence	Family member or close friend talking about STEM
		STEM was a part of family activities
		Pressure from family or peers to pursue STEM
11	Direct Instruction	Lectures by the teacher
		Paper assignments (worksheets, etc)
		Lab experiments designed by students

Learning Experiences and SCCT Constructs

This study examined the learning experience factors in relation to self-efficacy, outcome expectations, and interests in the three subjects of mathematics, science, and engineering. A multiple regression analysis was used to predict the scores on each of the constructs based on participation in learning experiences in each factor generated by the PCA. The factor scores for each of the eleven PCA factors were predictors in the regression and the outcomes were each of the constructs for each subject.

Self-Efficacy

The regression model was performed to determine whether the factors produced by the PCA were predictors of mathematics, science, and engineering self-efficacy. Each model produced a significant result and explained 24%, 22%, and 35% of the variance, respectively. Multiple variables were significant predictors for self-efficacy in each subject, and the results can be found in Table 3. The factor *Innate Interest and Ability* contributed significantly to self-efficacy in all three subjects. *Direct Instruction* was a positive predictor of self-efficacy in mathematics and science, *Family Influence* and *Careers and Future Study* were positive predictors of self-efficacy in science and engineering, and *Tinkering and Building* was a positive predictor of self-efficacy in engineering only. There were two factors that were negative predictors toward self-efficacy, *Nature and Community* in engineering and *STEM Media* in mathematics.

Table 3. Linear Model of Predictors for Self-Efficacy

	Mathematics			Science			Engineering		
Variables	B	SE	β	B	SE	β	B	SE	β
Fixed	4.092	.046		4.133	.041		3.428	.051	
Classroom Instruction	.043	.057	.047	-.020	.051	-.025	-.030	.064	-.027
Nature and Community	-.066	.049	-.072	.031	.043	.039	-.187	.054	-.170*
Tinkering and	.085	.051	.092	-.010	.045	-.012	.446	.056	.408**

Variables	Mathematics B	SE	β	Science B	SE	β	Engineering B	SE	β
Building Innate Interest/Ability	.390	.056	.426**	.213	.050	.268**	.141	.062	.129*
Class Content	.029	.058	.031	.050	.051	.063	-.024	.064	-.022
Careers and Future	.020	.052	.021	.129	.046	.162*	.119	.058	.109*
STEM Extracurriculars	-.016	.053	-.018	-.030	.047	-.038	.080	.058	.074
Teacher Influence	-.058	.051	-.063	.010	.045	.013	.052	.057	.048
STEM Media	-.107	.051	-.117*	.036	.045	.045	.018	.057	.017
Family Influence	.072	.052	.079	.104	.046	.130*	.238	.057	.217**
Direct Instruction	.126	.049	.137*	.095	.044	.119*	.003	.055	.003

Note: Mathematics Self-Efficacy – R = .494, R^2 = .244, F(11, 300) = 8.792; Science Self-Efficacy – R = .463, R^2 = .215, F(11, 299) = 7.430; Engineering Self-Efficacy – R = .588, R^2 = .346, F(11, 299) = 14.355
**p*<.05, ***p*<.001

Outcome Expectations

A regression model was also used to determine whether the eleven factors were predictors of mathematics, science, and engineering outcome expectations. Each model produced a significant result and explained 28%, 20%, and 32% of the variance, respectively. Multiple variables were significant predictors for outcome expectations in each subject, and the results can be found in Table 4. The factor *Innate Interest and Ability* contributed significantly to outcome expectations in all three subjects. *Direct Instruction* was a positive predictor of outcome expectations in mathematics and science, *Family Influence* and *Tinkering and Building* were positive predictors of outcome expectations in mathematics and engineering, and *Careers and Future Study* was a positive predictor of outcome expectations in science and engineering. *Nature and Community* was a negative predictor of outcome expectations in engineering only.

Table 4. Linear Model of Predictors for Outcome Expectations

Variables	Mathematics B	SE	β	Science B	SE	β	Engineering B	SE	β
Fixed	4.003	.043		4.152	.043		3.383	.053	
Classroom Instruction	-.016	.054	-.018	-.063	.053	-.075	-.014	.066	-.012
Nature and Community	-.083	.046	-.094	.012	.046	.014	-.194	.056	-.174*

Variables	Mathematics			Science			Engineering		
	B	SE	β	B	SE	β	B	SE	β
Tinkering and Building	.119	.048	.135*	-.068	.048	-.081	.427	.058	.384**
Innate Interest/Ability	.366	.053	.412**	.292	.053	.349**	.250	.064	.225**
Class Content	.008	.055	.009	-.002	.054	-.002	-.103	.067	-.092
Careers and Future	.018	.049	.020	.139	.049	.166*	.191	.060	.172*
STEM Extracurriculars	-.002	.050	-.003	-.049	.049	-.058	.022	.061	.020
Teacher Influence	.022	.048	.025	-.004	.048	-.004	.039	.059	.035
STEM Media	-.066	.048	-.074	.013	.048	.016	-.004	.059	-.003
Family Influence	.105	.049	.118*	.082	.049	.099	.117	.059	.105*
Direct Instruction	.142	.046	.160*	.124	.046	.148*	-.003	.056	-.003

Note: Mathematics Outcome Expectations – R = .527, R^2 = .278, F(11, 300) = 10.507; Science Outcome Expectations – R = .445, R^2 = .198, F(11, 300) = 6.720; Engineering Outcome Expectations – R = .567, R^2 = .322, F(11, 299) = 12.908

*p<.05, **p<.001

Interests

A final regression model was used to determine whether the eleven factors were predictors of mathematics, science, and engineering interests. Each model produced a significant result and explained 26%, 16%, and 33% of the variance, respectively. Multiple variables were significant predictors for interests in each subject, and the results can be found in Table 5. The factor *Innate Interest and Ability* contributed significantly to interest in all three subjects. *Careers and Future* was a positive predictor of interest in science and engineering, *Direct Instruction* was a positive predictor of interest in mathematics and science, and *Family Influence* and *Tinkering and Building* were positive predictors of interest in mathematics and engineering. *Nature and Community* was a negative predictor of interest in mathematics and engineering and *STEM Media* was a negative predictor of interest in mathematics.

Table 5. Linear Model of Predictors for Interests

Variables	Mathematics			Science			Engineering		
	B	SE	β	B	SE	β	B	SE	β
Fixed	3.488	.055		3.917	.063		2.989	.062	
Classroom	-.032	.068	-.028	-.112	.079	-.092	-.020	.077	-.015

	Mathematics			Science			Engineering		
Variables	B	SE	β	B	SE	β	B	SE	β
Instruction									
Nature and Community	-.167	.059	-.150*	.031	.067	.026	-.280	.066	-.212**
Tinkering and Building	.279	.061	.249**	-.097	.070	-.081	.533	.069	.405**
Innate Interest/Ability	.347	.067	.311**	.291	.077	.244**	.274	.075	.208**
Class Content	-.033	.070	-.030	.082	.079	.069	-.117	.078	-.089
Careers and Future	.096	.062	.086	.241	.071	.202*	.229	.070	.174*
STEM Extracurriculars	.026	.063	.024	-.072	.072	-.060	.039	.071	.030
Teacher Influence	.065	.062	.058	.030	.070	.025	.092	.069	.069
STEM Media	-.239	.062	-.214**	-.040	.070	-.033	-.094	.069	-.071
Family Influence	.155	.062	.138*	.102	.071	.085	.152	.070	.115*
Direct Instruction	.129	.059	.116*	.164	.067	.137*	-.027	.066	-.020

Note: Mathematics Interests – R = .512, R^2 = .262, F(11, 300) = 9.692; Science Interests – R = .405, R^2 = .164, F(11, 299) = 5.331; Engineering Interests – R = .578, R^2 = .334, F(11, 299) = 13.651
**p*<.05, ***p*<.001

Learning Experiences and Intent to Pursue a STEM Career

A logistic regression analyzed the eleven learning experience factors as predictors of a student's intent to pursue a STEM career and found that two factors were significant: *Innate Interest and Ability* (expB = 2.630, *p*<.001) and *Careers and Future* (expB = 1.968, *p*<.001). However, STEM can be a broad umbrella for careers that are very different from each other and require different interests and skills. Evidence from the beliefs section of this study indicates differences in the types of learning experiences that affect beliefs in different STEM subjects. Therefore, the researcher decided to split the students who indicated interest in a STEM career into two groups according to their majors: those in mathematics and physical science focused disciplines such as engineering, computer science, physical sciences, and mathematics (named PS-STEM for this analysis) and those in life science focused disciplines such as biological sciences, health and nutrition, and agricultural sciences (named LS-STEM for this analysis). Then, a multinomial logistic regression was used to analyze how the eleven factors predicted intent to pursue a STEM career with an emphasis on one of these disciplines. The results are presented in Table 6.

Analysis of the multinomial logistic regression indicated that the same two factors that were significant predictors of students' intent to pursue a STEM career were also predictors of intent to pursue a STEM career in each of the LS-STEM and PS-STEM categories. This analysis did indicate that these factors were stronger predictors for PS-STEM than LS-STEM based on the higher odds ratios. However, this analysis also revealed additional factors as predictors of intent to pursue a STEM career that differed based on the fields of study. *Direct Instruction* was a significant positive predictor of intent to pursue a LS-STEM career, while *Tinkering and Building* and *STEM Extracurriculars* were negative predictors of intent to pursue a LS-STEM career. For those students intending to pursue a PS-STEM career, *Tinkering and Building* was a positive predictor while *Nature and Community* was a negative predictor.

Table 6. Logistic Model for Intent to Pursue a STEM Career

Variables	B	Std. Error	*p*	Odds Ratio
LS-STEM vs non-STEM				
Intercept	.231	.178	.194	
Classroom Instruction	-.215	.186	.248	.806
Nature and Community	.108	.164	.509	1.114
Tinkering and Building	-.623	.184	.001	.536*
Innate Interest and Ability	.646	.203	.001	1.907*
Class Content	.219	.194	.258	1.245
Careers and Future	.666	.191	.000	1.947**
STEM Extracurriculars	-.408	.199	.040	.665*
Teacher Influence	-.094	.160	.556	.910
STEM Media	-.178	.174	.304	.837
Family Influence	.306	.185	.097	1.358
Direct Instruction	.353	.163	.030	1.424*
PS-STEM vs non-STEM				
Intercept	-.457	.223	.041	
Classroom Instruction	-.274	.217	.207	.760
Nature and Community	-.716	.196	.000	.489**
Tinkering and Building	.606	.215	.005	1.833*
Innate Interest and Ability	1.549	.252	.000	4.705**
Class Content	-.116	.236	.622	.890
Careers and Future	.840	.219	.000	2.315**
STEM Extracurriculars	-.069	.202	.734	.934
Teacher Influence	.075	.209	.718	1.078
STEM Media	-.187	.208	.369	.829
Family Influence	.332	.203	.102	1.394
Direct Instruction	.190	.205	.352	1.210

Note: $R^2 = .524$ (Nagelkerke), Model $\chi^2(22) = 194.576$, $p < .001$

*p<.05, **p<.001

Discussion and Implications

The results suggest a number of learning experiences that are beneficial toward the development of students' STEM beliefs and intention to pursue a STEM career. While some experiences in this study demonstrated little lasting effect on these factors, such as general classroom instruction and content, those that were significant predictors provide insight into how those beliefs take shape. These results demonstrate the value of investigating learning experiences on beliefs and intentions in regards to different STEM subjects as the outcomes can be different. They can also help educators tailor interventions to their desired goals or improve interventions that are already available.

The experience that was a strong predictor across all STEM beliefs and disciplines was *Innate Interest and Ability*, which included high performance in STEM classes and having natural interest in STEM activities. This supports the results of several studies that indicate a long-held interest and ability as a key in the development of STEM beliefs and career intentions (Banerjee et al., 2018; Burt & Johnson, 2018; Dou et al., 2019; Maltese et al., 2014; Tai et al., 2006). However, these are not individual learning experiences and are likely the result of various influences early in life. Our prior research on these innate abilities suggests they likely form as the result of early experiences and family connections (Gossen & Ivey, 2023). The factors *Tinkering and Building* and *Family Influence* were key predictors of engineering and mathematics beliefs, particularly in how participants viewed their future and careers. This supports the development of perceived innate interest because many of these experiences happen as a result of a students' home and community environment and whether those situations included STEM influences. These findings also present opportunities for teachers to engage with students to improve engineering and mathematics beliefs. While there are some educators who have developed effective programs in robotics (Rocker Yoel et al., 2020; Zhang et al., 2021; Ziaeefard et al., 2017) and family engagement in STEM (Caspe et al., 2018; Kominsky et al., 2023), this study supports the need for educators to continue building on these early foundational supports that could lead to increasing STEM beliefs, particularly in engineering and mathematics.

Examination of the more concrete experiences that occur in the school setting revealed two that seem to have an influence on students in STEM: *Careers and Future* and *Direct Instruction*. The former activities were positive predictors of all three beliefs in science and engineering and the likelihood of choosing a STEM major in both physical science and life sciences. Mohd Shahali et al. (2019) and Gamse et al. (2017) indicate career-focused interventions are valuable because students gain awareness of STEM professions and what they entail, learn about particular fields, and work on projects or activities that mimic the work of STEM professionals. These results strongly suggest the need to infuse STEM career-focused activities in the school curriculum to improve science and engineering beliefs and STEM career aspirations.

That *Direct Instruction* acted as a predictor of STEM beliefs and actions was somewhat surprising given the emphasis on inquiry learning in science and mathematics teaching initiatives and its demonstrated effectiveness (Firman et al., 2019; Furtak et al., 2012). However, the data indicates that direct instruction is a positive predictor of all three belief constructs in mathematics and science, as well as intent to pursue an LS-STEM career. While there is not a direct explanation in the data for why students with high science and mathematics beliefs indicated a preference for these learning experiences, it is possible those students appreciate structured, teacher-driven lessons. In contrast, engineering beliefs were not significantly predicted by direct instruction likely because engineering tasks often happen in less structured classroom environments. A study of high school students by Oliver et al. (2021) also suggests the development of scientific literacy is highest when inquiry is in some or most but not all lessons, supporting the need for diverse instructional strategies for learning and development of STEM beliefs.

Types of Learning Experiences for Different STEM Disciplines

A growing community of STEM educators has approached the need for development of a competent STEM workforce by delivering experiences in and out of the school environment to increase interest and self-efficacy in STEM subjects and careers (van den Hurk et al., 2019). Many of these learning experiences follow the recommendations of prior research and are also in line with the some of this study's findings. However, it is important to ensure these experiences meet the needs of the students who participate and the goals of those presenting them. Studies that support STEM interventions often include activities such as robotics and engineering or nature and outdoor experiences. The results from this study show that *Tinkering and Building* was a positive predictor of STEM career intention in physical science disciplines and *Nature and Community* was a positive predictor of career intention in life science disciplines, but each was a negative predictor of the alternate discipline. The data also shows the *Nature and Community* factor as a significantly negative predictor of engineering interest, outcome expectations, and self-efficacy along with mathematics interest. This suggests that targeting students in the broadest definition of STEM with a learning experience centered on nature and the outdoors may not be beneficial for those who are interested in engineering or mathematics-heavy science fields. Furthermore, those experiences centered on tinkering, building, robotics, and other engineering- or construction-focused activities may not be useful for students who are interested in pursuing a life science career. While both approaches can be helpful, educators should clearly understand their goals, who their target audience is, and the likely approaches that will benefit those students. It also may prove valuable when working with a wide range of students to ensure both types of opportunities are available so that students with an array of interests are served appropriately.

The results also indicated that STEM extracurricular activities such as camps and clubs were negative predictors of students majoring in life science-focused STEM disciplines compared to non-STEM majors. This may be the result of many of these extracurricular activities being focused on robotics, engineering, and technology. These results suggest there may be a need for a focus on more extracurricular activities that are centered on life sciences, including the outdoors, wildlife, and health.

Limitations and Future Research

This study examined the views of undergraduates by asking them to reflect on their experiences in early life and K-12 schools, while examining their beliefs and majors as they currently stand. The results of this study are reliant on the idea that students' accounts of their experiences accurately reflect how they learned and what they did. It's also likely that students see the benefit or detriment of these experiences through the lens of where they currently are, even if their feelings at the time of the experience were different. These limitations suggest the need to examine how experiences affect students in real time and the eventual results from those experiences.

Participants also had the option to indicate that they had "always had an interest in STEM" during the survey. While this option was consistent with prior literature which led to its inclusion on the questionnaire, it does not constitute a single learning experience and in fact may be the confluence of multiple experiences. Since this factor had a large impact on the results, it's important not to discard it, but rather we should seek to understand and unpack the types of influences that might cause someone to believe they have always had an interest in STEM disciplines.

Conclusion

There is a need to cultivate students' beliefs about STEM and ultimately encourage more students to pursue a STEM career, but the methods for accomplishing this development are still being explored. This study supports the literature in a call for early intervention and exposure to STEM experiences, especially if they can be connected to family activities. It also encourages the use of career- and future-focused experiences and a diverse range of instructional strategies in the school curriculum. As we in the education community continually seek to advance STEM education and the initiatives that foster positive beliefs and potentially career choices, we should consider the approaches that are most effective for students. This means we can't take a one-size-fits-all approach to STEM activity and intervention development. Teachers, researchers, and educators can consider how some experiences are more likely to improve certain science beliefs, while other experiences might improve engineering or mathematics beliefs. When possible, educators should seek to provide a range of options for students to encourage interest, self-efficacy, and participation across the STEM disciplines and meet the needs of a variety of students.

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