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THE INFLUENCE OF ACCESS TO INFORMAL STEM LEARNING EXPERIENCES ON MIDDLE SCHOOL STUDENTS' SELF-EFFICACY AND INTEREST IN STEM

THESIS

A thesis submitted in partial fulfillment of the requirements for the degree of
Master of Science in Education in the College of Education
at the University of Kentucky

By

Soledad G. Yao

Lexington, Kentucky

Director: Dr. Margaret J. Mohr-Schroeder, Professor of STEM Education

Lexington, Kentucky

2019

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ABSTRACT OF THESIS

THE INFLUENCE OF ACCESS TO INFORMAL STEM LEARNING EXPERIENCES ON MIDDLE SCHOOL STUDENTS' SELF-EFFICACY AND INTEREST IN STEM

Informal learning experiences have become increasingly effective in enhancing self-efficacy and interest in the fields of science, technology, engineering, and mathematics (STEM). This study investigated the impact of access to informal STEM learning experiences on student self-efficacy and interest in STEM before and after participating in the 2018 See Blue See STEM Summer Experience. Pre-survey results indicated that middle school students who had previous access to informal STEM learning experiences are 3.21 times as likely to demonstrate high self-efficacy in STEM as those who had no previous access. After engaging in the 2018 summer experience, post-survey results showed a statistically significant increase in student self-efficacy in STEM and indicated that students who had previous access to informal STEM learning experiences are 4.13 times as likely to manifest interest in STEM as those who had no previous access. These results suggest that increasing exposure to informal STEM learning experiences enhances both self-efficacy and interest in STEM.

Key words/Key phrases: Informal learning, access, self-efficacy, interest, afterschool programs, STEM learning ecosystem

Soledad G. Yao

April 2, 2019

THE INFLUENCE OF ACCESS TO INFORMAL STEM LEARNING EXPERIENCES ON MIDDLE SCHOOL STUDENTS' SELF-EFFICACY AND INTEREST IN STEM

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April 2, 2019

To my beloved family:

Sio Len, Jr.

Shervin and Marie Angelet

Shermaigne and Mark Andrew

Sherlock, Dina May, Agatha Joy, and Liana Jasmin

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CHAPTER 1. INTRODUCTION

For as long as the burden of accountability remains to be in the hands of teachers and school administrators, research and studies in education will continue to flourish. Educators will continue to search for ways and means to improve instruction, on the part of teachers, and thus enhance student learning. One innovation that has received a lot of attention in the last three decades is the integration of science, technology, engineering, and mathematics that saw the birth of STEM in the early 1990s. This innovation opened lots of opportunities for learning about the four disciplines through more meaningful ways - by combining some, if not all of the four disciplines into one class, unit, or lesson, in designing solutions or finding answers to real-world problems. However, considering how classes and classrooms are typically structured in schools today, implementing a truly integrated STEM in the typical classroom presents a real challenge. This is where informal learning, and informal settings come in handy. Unlike the formal classroom which is pre-structured in terms of physical set-up, schedule, and resources according to some specific and pre-determined purpose and plan, informal setting, and consequently, informal learning, lend themselves to a much greater degree of flexibility.

Statement of the Problem

A strong STEM workforce drives a strong economy. Thus, building a strong STEM workforce should be one of the goals of education. STEM jobs are projected to grow 13% within the next ten years, between 2017 and 2027, compared to 9% for non-STEM jobs (Education Commission of the States, 2019). However, only 36% of all high school graduates are ready to take a college-level science course. (National Math and Science Initiative, 2014). How can the demand for the STEM workforce ever be met

if the students who are expected to fill those positions are not even ready to take a college-level science course? Another alarming finding was from a survey conducted in Europe which showed that girls gain interest in STEM at age 11, but then lose that interest at age 15 (Choney, 2017). What's disturbing about this finding is that lack of access, along with a combination of social factors were identified as possible causes. Compounding the negative impact of the findings above are data showing that in 2015, the US placed 38th of 71 countries in mathematics, and 24th in science in the International Student Assessment (Desilver, 2017) placing the US in the middle, instead of being on top of the pack.

Purpose of the Study

The overall purpose of this quantitative study was to take a closer look at the previous findings regarding middle school students losing interest in STEM due to lack of access. Does access really impact student interest in STEM? If it does, to what extent? Does access influence self-efficacy? How does STEM self-efficacy relate to STEM interest? Findings from this study will guide stakeholders in STEM education in making decisions on which direction to move into in helping students improve their chances of success in the STEM field.

The Research Questions

This study serves to examine some potential use, or advantage, of the learning experiences in STEM that are acquired in informal settings. Specifically, it aims to answer the following questions:

1. To what extent does access to informal learning experiences in STEM influence middle school students' self-efficacy in STEM?

2. How does access to informal learning experiences in STEM impact middle school students' interest in STEM?

Significance of the Study

Since its formulation more than two decades ago by Lent, Brown and Hackett (1994), the Social Cognitive Career Theory has provided the theoretical framework for a significant amount of research surrounding self-efficacy and interest. Much of the work that has been done along this line used the theory to evaluate the effectiveness of some specific learning or intervention programs or projects in terms of enhancement in the aforementioned constructs. While this study is likewise anchored on the same theory, it covers a broader perspective. Overall, it aims to determine how having access to any form of informal STEM learning experience impacts self-efficacy and interest in STEM. It stands to contribute to the ever-growing body of research that aims to find ways to enhance student self-efficacy and interest in STEM, with the ultimate goal of motivating more youth to join the STEM work force.

Theoretical Framework: Social Cognitive Career Theory

The Social Cognitive Career Theory (SCCT: Lent, Brown, & Hackett, 2002) posits that self-efficacy and outcome expectations on the activities that an individual participates in directly affect formation of that individual's career interests. Self-efficacy is related to individuals' belief regarding their competency in performing some particular behaviors or courses of action, while outcome expectations pertain to beliefs about the consequences or outcomes of performing those behaviors or courses of action (Lent, Brown, & Hackett,1994). Assumed to be contributing to self-efficacy beliefs are personal performance accomplishments (successes and failures performing some tasks), vicarious

experiences (from observing others perform a task), social persuasion (from family and friends), and physiological and emotional states (Lent, Brown, & Hackett, 1994). According to this theory, individuals form interest in an activity if they perceive themselves competent in doing the activity and if they expect a useful outcome out of doing it. Conversely, individuals' interest is not developed in activities that they perceive themselves to be weak in or if they expect no valuable outcome out of doing it. However, SCCT further holds that for interests to grow in areas in which individuals have talent and competencies, these individuals must be exposed by their environments to direct, vicarious, and persuasive experiences that will develop strong self-efficacy and outcome expectation beliefs.

SCCT within the STEM context is represented in Figure 1.1. It shows that STEM learning experiences, which derive from the STEM activities in which students participate, result from the combined influences of personal attributes (such as one's gender, age and race/ethnicity) and environment factors (including parental support, role models, and perceived barriers). These STEM learning experiences play critical roles in the development of self-efficacy and outcome expectations in STEM, both of which drive the motivation for the development of interests in STEM-related goals and careers.

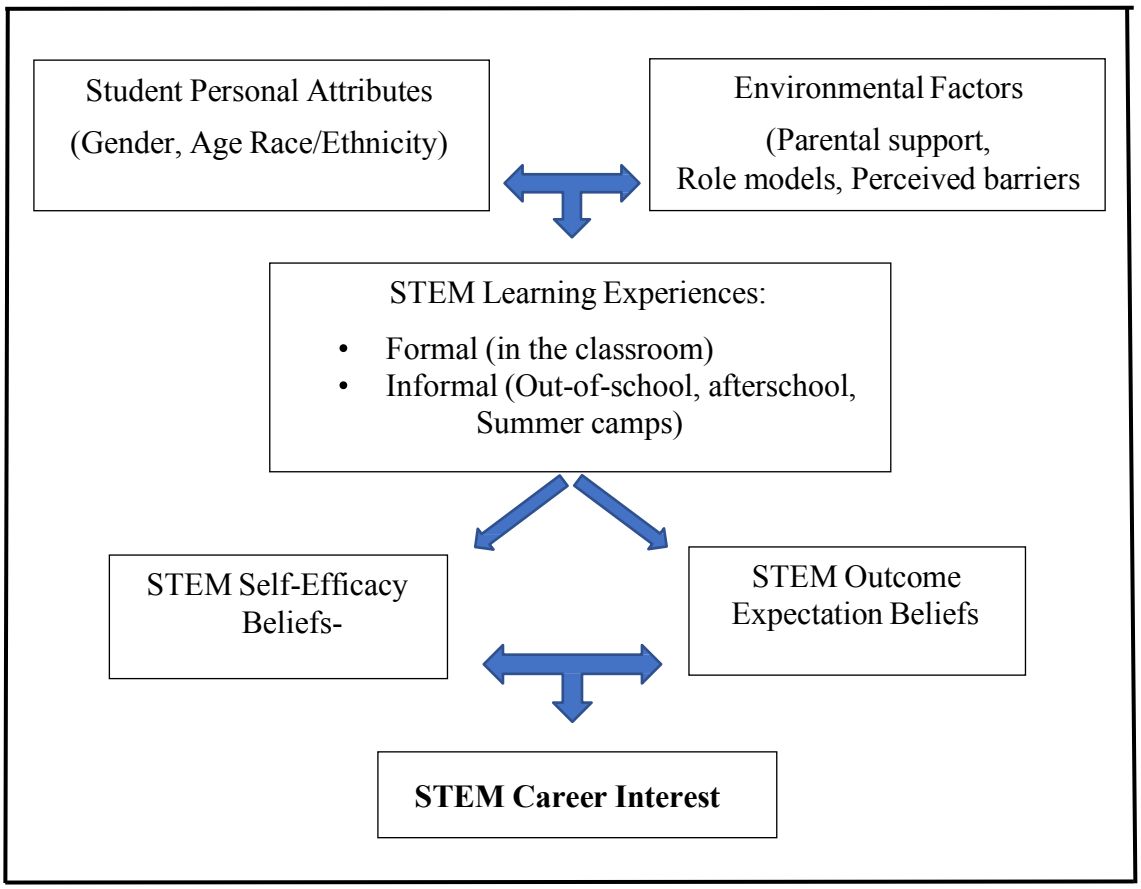

Figure 1.1. The Social Cognitive Career Theory Model. Adapted from Lent, Brown, & Hackett (2002).

Relevant Terminology

Formal learning

Formal learning, or structured learning, is a type of learning program where the goals and objectives are defined by the school – its administrators, instructional designers, and/or teachers. Examples of formal learning include classroom instruction, web-based training, remote labs, e-learning courses, workshops, seminars, webinars and others (Training Industry, 2019).

Informal learning

Informal learning is a collection of all the experiences acquired outside of the classroom. It is usually less structured and more spontaneous than formal learning (Training Industry, 2014). A more formal definition is offered by Crane (1994):

Informal learning refers to activities that occur outside the school setting, are not developed primarily for school use, are not developed to be part of an ongoing school curriculum, and are characterized by voluntary as opposed to mandatory participation as part of a credited school experience. Informal learning experiences may be structured to meet a stated set of objectives and may influence attitudes, convey information, and/or change behavior. Informal learning activities also may serve as a supplement to formal learning or even be used in schools, or by teachers, but their distinguishing characteristic is that they were developed for out-of-school learning in competition with other less challenging uses of time. (p. 3)

Informal STEM learning is a "lifelong, life-wide, and life-deep" learning of science, technology, engineering, and math that transcends beyond the four walls of the classroom and takes place across a multitude of "social dynamics and settings" (Sacco, Falk, & Bell, 2014).

Self-efficacy

Self-efficacy is one's belief in her/his ability to accomplish a task or to succeed un under some specified situations. It impacts one's interest as well as how s/he approaches goals, tasks, and challenges (Bandura, 1997).

Assumption

Respondents provided accurate information

Delimitations

This study was limited to the middle level participants (grades 5-8) of the 2018 See Blue See STEM Summer Experience. The survey data are self-reported, suggesting participant responses could be influenced by various biases.

Organization of the Thesis

Chapter 1 introduced the study. Chapter 2 presented a literature review of informal learning environments and their impact on K12 STEM education. Chapter 3 focused on the methodology of the study. Chapter 4 focused on the results. Chapter 5 presented the discussion, conclusion and recommendations.

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CHAPTER 2. REVIEW OF LITERATURE

This chapter reviews what the literature says about informal learning: how it compares with formal learning, why and how it has been adopted as a way to advance the teaching and learning of STEM, and how informal STEM learning programs have impacted the overall learning of STEM

Informal Learning versus Formal Learning

When understanding what informal learning is, it is helpful to compare it to formal learning. A very fitting, frequently used analogy for these two learning approaches is riding a bus versus riding a bike (Cross, 2007). When one is on a formal learning bus, the driver decides where to go and how to get there, while the passengers just passively ride along. When one is on an informal learning bike, the rider decides where to go, including how and at what pace to get there. Within the education context, this analogy can be gleaned in some characteristics that have been used to compare formal and informal approaches to learning (Table 2.1: Hofstein & Rosenfeld, 1996; Wellington, 1990;).

Table 2.1.
Differentiating Characteristics of Formal and Informal Learning

Formal vs Informal Learning
1) classroom vs out-of- school
2) structured/organized vs random/spontaneous
3) teacher-led vs learner-led
4) teacher-centered vs learner-centered
5) close-ended vs open-ended
6) curriculum-based vs non-curriculum-based
7) assessed/evaluated vs unassessed/unevaluated
8) solitary work vs social interaction
9) intentional/expected learning vs accidental/serendipitous learning

Formal learning is structured and organized according to specific goals and objectives. When on the formal training bus, options are limited. One can hop on and off when the bus stops, but the driver picks the route because it is pre-defined, and dictates the speed as there is a target time to get to the destination. When on the informal learning bike, one is free to make as many detours as desired, and can choose the speed and destination (Growth Engineering, 2019). Moreover, informal learning is social learning and does not have to be solitary. As an informal bike rider, one is like a part of a cycling club - with freedom to choose which bike rides to be a part of, can race people at one time then just hang out at another time, or make suggestions on some destinations to go and route to take (Growth Engineering, 2019).

There's some divide in perception regarding what constitutes the greatest difference between formal and informal. The European Center for the Development of Vocational Training, in its definition of informal learning states, "Informal learning is in most cases unintentional from the learner's perspective" (2011, p. 85), a definition which was adopted by the Professional Learning Board (2011). However, Jay Cross, who popularized the term "e-learning" and who is a stark believer of informal learning thinks differently. For him, it's not whether what happens is intentional or accidental, but rather who makes the choice of what to learn and how. If it's the learner that makes the choice, then it must be intentional and not accidental. The take home message from this is that it's not whether the learning that occurs is intentional/expected or accidental/serendipitous (item # 9 in Table 2.1) that makes the greatest difference between formal and informal learning. Rather it's more on whether the learning is in accordance with the learner's choice (learner-led) or someone else's (teacher-led) (item

#3 in Table 2.1). The implication with regard to item #9 is that while some accidental/serendipitous learning may unexpectedly come up during informal learning, it does not necessarily make learning informal. Informal learning is not accidental or unintentional learning.

Informal Learning Plus Formal Learning

Learning is like baking a cake in which the right ingredients are chosen, then mixed in the right proportion, for success. According to the 70-20-10 learning model (Training Industry, 2014), successful learning results from a combination of 70% experiential learning, 20% social learning, and 10% formal learning. Based on this formula, 90% of what an individual knows comes from informal learning (70% experiential learning + 20% social learning).

Research on the 70-20-10 Model (Training Industry, 2014) showed that 70% of what one learns is acquired through hands-on experience, daily tasks, and challenges. This reaffirms the well-known principle of learning by doing. What then is the role of the 10% formal learning? Formal learning is needed to reach one's potential by providing the theory and the facts, the figures and solid foundations upon which one builds the remaining 90% of one's development (Growth Engineering, 2019).

Informal Learning in STEM

Informal learning experiences in STEM can take numerous forms, from as simple as a casual walk in the park to a more planned visit to museums and science centers. Informal learning can also take place in the comfort of one's home, while watching *National Geographic* documentaries and other science television programs. In the United States where 95% of the average American student's lifetime is spent outside of the

classroom (Falk & Dierking, 2010), there's plenty of time and room for informal learning of STEM. An individual's total learning of STEM is a result of a continuous accumulation of learning experiences, motivated by one's needs and interests (Sacco, Falk, & Bell, 2014). Recognizing the role these out-of-school learning plays in sparking and sustaining interest in STEM, the National Research Council created a committee that was charged with outlining the criteria that can guide program developers in planning for effective out-of-school STEM settings and programs (National Research Council, 2015). Within the STEM context, the differences between formal and informal learning depends on the level of choice participants are afforded in terms of engagement in learning activities, with whom, and whether or not there is a formal curriculum and/or assessment process (Krishnamurthi & Rennie, 2013).

Informal science education is learning in informal, out-of-school contexts, including visiting science centers and engaging with the exhibits and programs there, researching either in a library or online, and participating in structured afterschool programs. In these programs, children engage in supervised and structured activities that are deliberately designed to promote learning and social development outside of the school day (Krishnamurthi & Rennie, 2013). These programs are typically implemented after school dismissal, but there are some that hold activities on weekends, over school break, and now, commonly during the summer. The Board of the National Association for Research in Science Teaching (NARST) concluded in a meeting that learning in out-of-school context means "learning that is self-motivated, voluntary, guided by the learner's needs and interests, learning that is engaged in throughout his or her life" (Dierking et al., 2003, p.109). It is noted that this definition reflects the attributes of

informal learning described in the previous section – learner-led or self-directed, which is thus expected to be interesting and of value to the learner. At times, the activities that children participate in result in "ah-ha" moments (Krishnamurthi & Rennie, 2013), which brings to mind the accidental, serendipitous attribute of informal learning discussed above.

Informal STEM Learning Outcomes and Goals

The diverse goals of informal learning have been organized in some frameworks: (a) *A Framework of the Dimensions of Scientific and Technological Literacy* (Rennie, 2007), (b) the National Science Foundation's *Framework for Evaluating Impacts of Informal Science Education Projects* (Friedman, 2008), and (c) the National Research Council's 2009 report, *Learning Science in Informal Environments* (Bell et al., 2009). The Rennie (2007) framework describes the behavior of scientifically and technologically literate persons in three dimensions: (a) knowledge, (b) capability, and (c) ways of thinking and acting. The Friedman (2008) framework delineates evaluation of science projects that involve (a) exhibitions, (b) mass media, (c) youth and community programs, (d) collaborations and other projects designed to impact ISE professionals, and (e) projects that combine different types of deliverables. The Bell et al. (2009) framework describes six science learning strands that help one understand how learners in informal environments: (a) Strand 1. Experience excitement, interest, and motivation to learn about phenomena in the natural and physical world; (b) Strand 2. Come to generate, understand, remember, and use concepts, explanations, arguments, models and facts related to science; (c) Strand 3. Manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world; (d) Strand 4. Reflect on science as a way of

knowing, on processes, concepts, and institutions of science, and on their own process of learning about phenomena; (e) Strand 5. Participate in scientific activities and learning practices with others, using scientific language and tools; and (f) Strand 6. Think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science. One can glean from these frameworks some variations in emphasis regarding informal learning. While the Rennie (2007) framework places emphasis on program participants, specifically the behaviors that they are expected to develop out of the programs, the Friedman (2008) framework is more focused on the projects that are featured in the program. The Bell et al. (2009) framework focuses more extensively on things program participants are expected to be able to do as a result of the program. One can see in this framework the incorporation of various aspects of cognitive and affective domains of learning.

Informal STEM Learning Roles

The important role that informal science learning plays in supporting the vision for K-12 science education has been recognized, particularly in attending to equity. Informal learning programs can provide youth from non-dominant communities support in their learning and broadening of "what counts" as STEM (Bell & Bevan, 2015) as well as in connecting their learning across formal and informal settings. Informal environments support not only "lifelong learning", but "life-wide" learning as well, which occurs as individuals socialize and circulate across a range of settings and activities (Bell & Bevan, 2015). These roles were recognized by the National Science Teachers Association in one of its declarations (NSTA, 2012).

Integration of Informal and Formal STEM Learning

Integrating formal and informal learning has recently become an increasing trend in STEM education. Driven by concerns about school accountability, the possibility of partnership or collaboration between school administrators and afterschool staff is now being considered as one possible way to help students reach academic goals. A potential benefit of this collaboration is student access to diverse and quality services that school may not be able to sustain within school hours, such as tutoring and academic enrichment activities (Little, Wimer, & Weiss, 2008). With an added advantage of pooled assets, resources, and perspectives, integration of formal and informal learning programs provides a complementary learning environment where there are more opportunities for development and reinforcement of skills (Afterschool Alliance, 2011). An essential feature of the integrated formal-informal learning program is alignment of learning that occurs in the two environments, guided by the school's curriculum. It has earlier been proposed that alignment between formal and informal learning can be achieved in the form of interpersonal, curricular and systemic links which serve to bridge the two learning environments as depicted in Figure 2.1 (Noam, 2003). Under this framework, interpersonal link is provided through interactions between school teachers and after- school staff, while systemic bridge takes the form of collaboration in decision making related to the school and after-school programs.

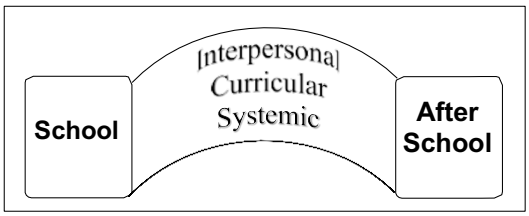

Figure 2.1. Aligning formal and informal learning (Adapted from Noam et al., 2003).

There has been a growing consensus among researchers that there is a need to develop more collaborations between public schools and informal science institutions such as museums, and various youth programs (National Science Foundation, 2012). Such informal institutions have been making strides to create more opportunity and access to serve K-12 students. For example, almost 75% of science-rich cultural institutions in the United States have programs specifically designed for school audiences in the form of half-day workshops, one-day field trips, and even year-long programs (Bevan et al., 2010).

The STEM Learning Ecosystem

In STEM, there have been efforts to combine formal and informal resources to enhance STEM learning. Termed STEM learning ecosystem, the concept involves a broad collection of various material resources, such as institutions and organizations, as well as social resources like social networks, peers, educators (both in and outside school), friends, family, and community (Falk et al., 2016). In essence the STEM ecosystem is a collection of the environment, people, and events that permit individual learners to interact in diverse settings and culture (NRC, 2015).

Informal STEM Learning Experiences

Informal STEM Learning in a Contextual Setting

Based on *The Nation's Report Card* students who reported more frequent experiences outside of school scored higher than students who had little to no experiences in informal learning settings (Rodriguez, 2016). Research shows that informal sites such as libraries and museums offer contextual learning experiences often not accessible in the classroom. For example, the Makerspaces (Open Education Database, 2019), which are now increasingly common across the United States, serve to spark interest in STEM by

providing collaborative spaces where people can gather and display their creativity by engaging in DIY projects and learning from each other by sharing ideas. In these settings, students get opportunities to cultivate foundational STEM skills by prototyping solutions to problems and at the same time gain access to tools like 3D printers (Open Education Database, 2019).

Science museums have been found to provide a contextual site for integrating mathematics with science (Popovic & Lederman, 2015), at the same time connecting mathematics to real-world problems. Making connections between STEM and solving real-world problems is one capability that K-12 students should be able to develop (Popovic & Lederman, 2015).

Informal STEM Learning Experiences, Self-Efficacy, and Interest in STEM

The Social Cognitive Career Theory (SCCT) has inspired dozens of studies in STEM that revolve around such constructs as self-efficacy, interest, and literacy/knowledge in STEM. Many of these studies serve to evaluate impacts of informal learning programs in STEM in terms of how said constructs change among the participants, as a result of the program (e.g., Blotnicky et al., 2018; Bong et al., 2015; Burwell-Woo et al., 2015; Jackson et al., 2015; Jackson & Mohr-Schroeder, 2018; Lin et al., 2018; Minnigerode, 2013; Mohr-Schroeder et al., 2014; Sublett & Plasman, 2018), perception of STEM (Baran et al., 2016; Hammack et al., 2015; Roberts et al., 2018), and attitudes toward STEM (Wiebe et al., 2018). Other studies also include impact of informal learning programs on students' goals, aspirations, and career options (Dabney et al., 2012; Grigg et al., 2018; Halim et al., 2018; Kitchen et al., 2018; Wong, 2010), as well as gaining valuable field experience from the program (Mohr-Schroeder et al.,

2018). There are also programs intended for diverse learners (Burgin et al., 2015; Mohr-Schroeder et al., 2014; Roberts et al., 2018) as well as on integrated STEM with focus on community collaboration (Burrows et al., 2018). These programs share, as a common feature, incorporation of a broad spectrum of interesting activities that aim to elicit positive outcomes from the participants around STEM content.

Due to the gender gap that has persisted in science, mathematics, and engineering education for years, studies involving efficacy commonly delineate the impact on male and female individuals. While it may not come as a total surprise for males to manifest higher academic self-efficacy in engineering compared to females (Burger et al., 2010), it is somewhat unexpected for males to also exhibit higher self-efficacy in biology (Mohammed, Atagana, & Edawoke, 2014). When it comes to young boys and girls, however, one should exercise care when comparing self-efficacy. It is possible that these two groups use different standards in determining the degree of their ability. For example, a girl may consider a B grade in a science exam to be a poor grade and thus reflects her lack of science ability, while a boy who receives a C grade on the same exam may view the grade as passing and therefore indicative of his strong science ability (Rittmayer & Beier, 2008). Indeed, by virtue of it being a self-judgment and a self-belief, a measure of self-efficacy is subjective and depends on one's bar of standard of what is high and what is low.

Informal STEM Learning Experiences for Girls

Due to the observed underrepresentation of women in STEM fields, there is often a deliberate effort to put emphasis on the recruitment of as many females as possible, as program participants. In some cases, studies are limited to girls. In one such study, it was

shown that students' self-efficacy in mathematics and science played an important role in women's college major choice, and that these self-efficacy perceptions were fostered by support from parents, families and teacher (Hong, 2009). This is consistent with SCCT (Lent, Brown, & Hackett, 2002). A related study found self-efficacy, teacher influence, and peer influence to be primary predictors of middle school girls' confidence and interest in mathematics and science (Rabenberg, 2013). A study involving secondary school students investigated how the students' level of self-efficacy related to their enrollment in advanced STEM coursework (Bernasconi, 2017). In this case, students' level of self-efficacy did not correlate to their enrollment in advanced STEM coursework. Rather, an increase in enrollment was observed due to student participation in a community of practice that was meant to increase student enrollment in said coursework. Some investigations incorporate interventions designed to increase STEM self-efficacy of middle school girls. For example, a four-week workshop was created and implemented that featured sewing electrical circuits using the LilyPad Arduino circuits. Results showed that girls who completed the workshop were more likely to have increases in STEM self-efficacy than girls who did not participate in the workshop (Kaiser, 2016). By comparison, the boy counterparts did not show a significant increase nor decrease in STEM self-efficacy upon completion of the workshop. This study reflects how girls' and boys' interests can vary. Other programs introduce innovations to ignite interest, like one where STEM was integrated with fashion in a program called Fashion FUNdamentals, (Ogle et al., 2017). At program end, participants had higher measures of self-efficacy in mathematics and science as well as higher achievement scores in mathematics. In

addition, the girls' self-efficacy in mathematics and science positively predicted their interest in STEM.

Informal STEM Learning Experiences for Underrepresented Groups

Informal learning can be an effective agency for recruiting underrepresented students into STEM careers (Denson et al., 2015). For example, the Mathematics, Engineering, Science Achievement (MESA) program provided educationally disadvantaged students opportunities to succeed in the STEM disciplines by offering trainings in SAT/ACT preparation and study skills, experiences in hands-on activities and competitions, and career exploration through field trips and invited guest speakers. Eight themes emerged from the participants' description of the benefits they were able to derive from the program: informal mentoring, fun learning, efficient time management, application of math and science, feeling of accomplishments, confidence building, camaraderie, and exposure to new opportunities. Good performance in terms of entrance examinations scores and improved grades in mathematics and physics courses reflected the benefits the participants acquired from the program (Kotys-Schwartz, Besterfield-Sacre, & Shuman, 2011). STEM-based co-curricular programs conducted in informal settings can offer activities and learning experiences that complement those provided by a traditional STEM classroom.

Chapter Summary

This chapter reflects the breadth and depth of studies that have been undertaken on informal learning of STEM. Those studies have looked into various impacts that informal learning experiences can have on STEM-related attributes and future goals of individuals. One thing that can be noted from those studies is that a majority of those

serve to evaluate the impact of specific informal STEM learning programs, either immediately after the program is implemented, or after longer periods of time, as in the case of longitudinal studies. The present study is different in that its main purpose is not to evaluate the impact of the program. Rather, this study uses the program as an avenue to determine the impact of having access versus having no access to informal STEM learning experiences on such constructs as self-efficacy and interest in STEM. The emphasis here is not on the informal learning experience itself, but on having access to such learning experiences in general. What the study is trying to investigate is how self-efficacy and interest in STEM vary between students who have and have no prior access to informal learning experiences – either through home, school, and others like after school and summer camp, or any combination of these.

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CHAPTER 3. METHODOLOGY

This chapter describes the salient features of the methodology used to conduct this study: the participants, the data collection, and the design of the study.

The Study Participants

The participants in this study were incoming K-12 students for grades 5-8 who were a subset of the overall participants in the 2018 See Blue See STEM Summer Experience (Mohr-Schroeder et al., 2014; Roberts et al., 2018). They were recruited through various recruiting avenues including, school identification, informational flyer, website, social media, summer program recruiting events, and word of mouth in the region where the camp was held. The recruitment process encouraged participation by underrepresented populations in STEM fields by providing incentives in the form of guaranteed slots in the camp, as well as scholarship and provision for transportation to and from camp, if needed. In this study, underrepresented populations in STEM fields refer to females, Black, Latino/a, Mixed, Native Americans or Alaska Natives, and Native Hawaiians or Other Pacific Islanders (National Science Foundation, 2017). The distribution of the participants by gender and race is shown in Table 3.1 and represented in Figure 3.1. There were 75 females (37%) and 127 (63%) males; 123 (61%) Whites and a total of 79 (31%) students of color distributed as follow: 30 (15%) Black, 18 (9%) each of the Latino(a) and Asian, 12 (6%) Mixed (2 or more races), and 1 (.5%) Native Hawaiian/Pacific Islander.

Table 3.1.
Distribution of Respondents by Gender and Race.

Ethnicity	Male Count/**% by Gender /% by Race**	Female Count/**% by Gender /% by Race**	**Total by Race**
White	84/(66.1)/(68.3)	39/(52.0)/(31.7)	**123(60.9)**
Black	17/(13.4)/(56.7)	13/(17.3)/(43.3)	**30(14.9)**
Latino/a	9/(7.1)/(50.0)	9/(12.0)/(50.0)	**18/(8.9)**
Asian	9/(7.1)/(50.0)	9/(12.0)/(50.0)	**18/(8.9)**
Mixed (2 or more)	8/(6.3)/(66.7)	4/(5.3)/(33.3)	**12/(5.9)**
Native Hawaiian/ Pacific Islander	0/(0)/(0)	1/(1.3)/(100)	**1/(0.5)**
Total by Gender	**127/(62.9)**	**75/(37.1)**	**202**

[a] Value in %

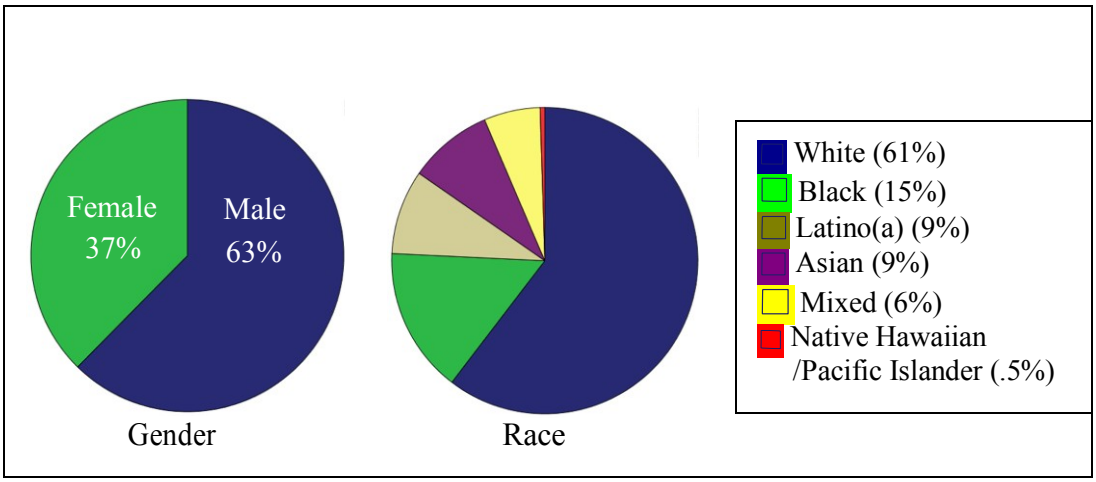

Figure 3.1. Distribution of the respondents by gender and race.

Data Collection

The data used in this study was obtained from the results of the pre- and post-survey conducted with the participants of the 2018 See Blue See STEM Summer Experience (Mohr-Schroeder et al. 2014; Roberts et al. 2018), a week-long summer

STEM camp for elementary and middle level students. The camp, which began in 2010, provides students in the region opportunities to enhance their knowledge on STEM content and skills through authentic hands-on activities that are led by STEM faculty at the university. For the 2018 summer camp, students participated in robotics (e.g., LEGO Mindstorm EV3) for 3 hours and in a variety of other STEM content sessions (e.g., DNA extraction, solar cells, 3D printing) for another 3 hours each day. In these activities, students worked as a community of practice as they explored, investigated, and collaborated in an authentic, contextual setting, applying integrated STEM to develop their critical thinking and problem-solving skills.

The original survey instrument consisted of 46 items which were a mixture of Likert and open-ended questions. The pre- and post-survey aimed to measure the STEM literacy of the students, which included opportunity and access to STEM, attitude toward STEM, utility of STEM, personal contributions to STEM, interest in STEM, academic confidence in STEM, career interest in STEM, and self-efficacy in STEM. The STEM literacy inventory was in its final year of pilot, and the final unidimensional instrument, which included the questions below, yielded a Cronbach's alpha greater than .90, indicating the survey had high internal consistency. The questions that are of specific relevance to the purpose of this study are those that pertain to the participants' access to STEM, their confidence level in STEM, and their particular interests in STEM. These questions are shown in Table 3.2.

Table 3.2.
The Questions Used to Collect Data

STEM Literacy Inventory Questions Used in the Study				
• Where have you had the chance to go to a museum, science center, or other place with STEM activities? (Check all that apply) ☐ At school ☐ At home ☐ Other (camp, after school club) ☐ Nowhere				
• How confident are you that you can solve hard problems in STEM?	Not at all confident ☐	A little bit confident ☐	Very confident ☐	Completely confident ☐
	Strongly Disagree	Disagree	Agree	Strongly Agree
• I want to participate in new STEM experiences	☐	☐	☐	☐
• STEM interests me.	☐	☐	☐	☐
• I am interested in taking STEM courses.	☐	☐	☐	☐
• I am interested in careers that use STEM.	☐	☐	☐	☐

The Study Design

This study used a correlational observational design to determine if there was a possible correlation between self-efficacy and interest in STEM on one hand, and access to informal STEM learning experiences on the other hand. To test possible correlation between self-efficacy and access, responses to the first two questions were analyzed. For the possible relationship between interest and access, responses on the first question were analyzed with the last four questions separately, affording four possible correlations involving four different aspects of interest in STEM.

There were originally 240 respondents, from which 202 were left after checking for entries with missing data, which were subsequently excluded. The data were analyzed using SPSS software (Version 24), with logistic regression as the main analytical

technique. Multinomial regression analysis was dismissed as a possible technique option due to the noticeable skewness of the data distribution, arising from uneven distribution of responses. The uneven distribution was most prominent in the responses to efficacy and interest questions where most of the responses converged toward the high values (Scales 2 & 3) while the responses corresponding to the lowest value (Scale 0) was often absent. The distribution of the data on Access was likewise uneven, as will be discussed in the following chapter. The choice of which variables to investigate was made based on the SCCT framework. Other variables included in the analysis were Gender and Race to control for demographic effects.

Chapter Summary

This chapter describes the overall approach in the conduct of this study. It included a total of 202 participants which were recruited with a deliberate effort to increase the number of the underrepresented population. The data used were from the participant responses to some items related to this study on the STEM literacy inventory pre- and post-survey instrument. The variables of particular relevance in this study pertain to access to informal learning experiences in STEM, self-efficacy in STEM, and interest in STEM. The study employed a correlational observational design, and relied on logistic regression analysis using SPSS (Version 24) as the main analytical tool. Demographic information about the respondents, such as gender and ethnicity/race, were also analyzed to serve as control variables.

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CHAPTER 4. RESULTS AND ANALYSIS

This chapter presents a summary of the data on the various variables that were used in this study, the corresponding results obtained after statistical treatment, and the interpretation of findings. Data analysis were performed using SPSS software (Version 24) for categorical data and employed correlation and logistic regression analyses.

The Variables

Described below are the different variables included in this study, both dependent and independent variables. For Efficacy and Interest, the Likert scales have been defined for the survey items where the responses were gathered.

Dependent variables

Efficacy = self-efficacy in STEM
0 = Not at all confident
1 = A little bit confident
2 = Very confident
3 = Completely confident
Interest1 = interest in participating in new STEM experiences
Interest2 = interest in STEM in general
Interest3 = interest in taking STEM courses
Interest4 = interest in careers that use STEM
0 = Strongly Disagree
1 = Disagree
2 = Agree
3 = Strongly Agree

Independent variables

Gender
Ethnicity/Race
Access = access to informal STEM learning experiences
0 = No access 1 = With access
Access was facilitated:
a) Through school c) Through others means (camps, afterschool)
b) Through home d) Nowhere (No access)

The frequencies of responses on Access are shown in Table 4.1 and represented in Figure 4.1. The distribution by gender and race are shown in Table 4.2.

Table 4. 1.
Frequency of the Responses on Access

Access	Through school	Through home	Others (Camp, Afterschool)	Nowhere
No	58(29) [a]	104(52)	111(55)	179(89) (with access)
Yes	144(71)	98(48)	91(45)	23(11) (no access)
Total				202

[a] Value in %

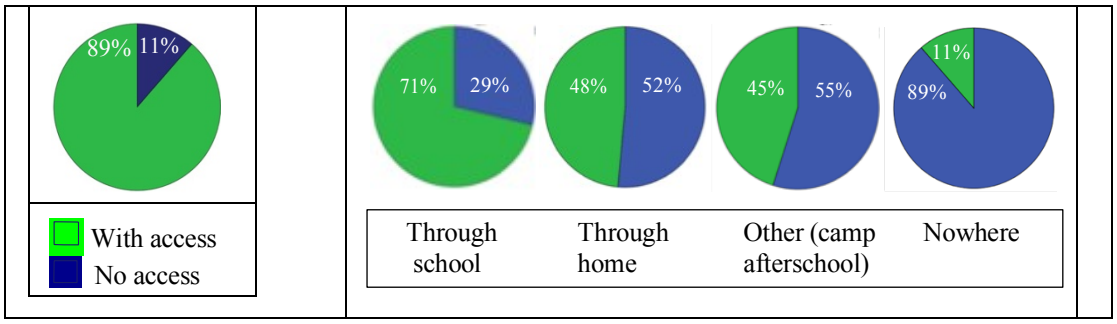

Figure 4.1. Representation of Access responses.

Table 4.2.
Distribution of Access Data by Gender and Race

Distribution of Responses to Access by Gender and Race			
	No Access (0)	With Access (1)	Total
By Gender			
Female (0)	7 (30%)	68 (38%)	75
Male (1)	16 (70%)	111 (62%)	127
Total	23 (11%)	179 (89%)	202
By Race			
Students of Color (0)	8 (35%)	71 (39%)	79
White (1)	15 (65%)	108 (61%)	123
Total	23 (11%)	179 (89%)	202

Out of 202 respondents, 11% reported having had no access to informal STEM learning experiences anywhere, while 89% have had access - either through school, home, and other means like summer camp and afterschool. There were several cases involving multiple means of gaining access like any combination of school, home, and others. Hence, 71% respondents reported having had access through school, while about the same proportion had access through both home (48%) and through other means, like camp and afterschool (45%). There were 23 (11%) participants who had no access anywhere.

With or without access, the predominance of male over female (61% vs 39% when there is access; 70% vs 30% when there is no access) and of White over students of color (60% vs 40% when there is access; 65% vs 35% when there is no access) participants is notable in Table 4.2.

Frequencies of the responses for Efficacy and Interest are shown in Table 4.3. With the exception of that for Interest2, the frequency of the highest scale response (Scale = 3) all increased, up to as much as 12% (Interest4). These increases are also reflected in the corresponding graphic representations shown in Figures 4.2 to 4.6.

Table 4.3.
Frequency of the Responses on Efficacy and Interest

Frequency and Distribution of Responses to Efficacy and Interest Items				
	Scale	Pre-Survey	Post Survey	Change
Efficacy	0	1(.5) [a]	3(1.5) [a]	2(1)
	1	72(35.6)	52(25.9)	-20(-26.1)
	2	99(49.0)	96(47.8)	-3(-1.2)
	3	30(14.8)	50(24.9)	20(**10.1**)
Interest1	0	0(0)	0(0)	0(0)
	1	13(6.4)	18(8.9)	5(2.5)
	2	119(58.9)	100(49.5)	-19(-9.4)
	3	70(34.7)	84(41.6)	14(**6.9**)
Interest2	0	2(1.0)	2(1.0)	0(0)
	1	15(7.4)	15(7.4)	0(0)
	2	83(40.9)	85(42.1)	2(1.2)
	3	102(50.2)	100(49.5)	-2(-0.7)
Interest3	0	1(.5)	1(.5)	0(0)
	1	15(7.4)	18(8.9)	3(1.5)
	2	122(60.4)	99(49.0)	-23(11.4)
	3	64(31.7)	84(41.6)	20(**9.9**)
Interest4	0	2(1.0)	3(1.5)	1(.5)
	1	19(9.4)	18(8.9)	-1(.5)
	2	107(53.0)	83(41.1)	-24(-11.9)
	3	74(36.6)	98(48.5)	24(**11.9**)

[a] Value in %

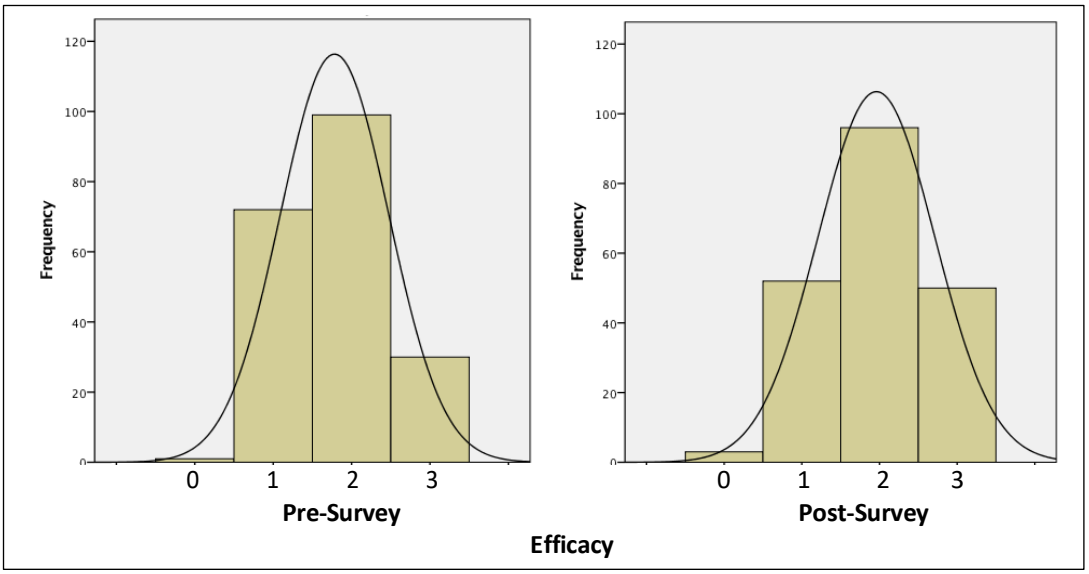

Figure 4.2. Representation of Efficacy responses.
The frequency of the "3" responses increased by about 10%.

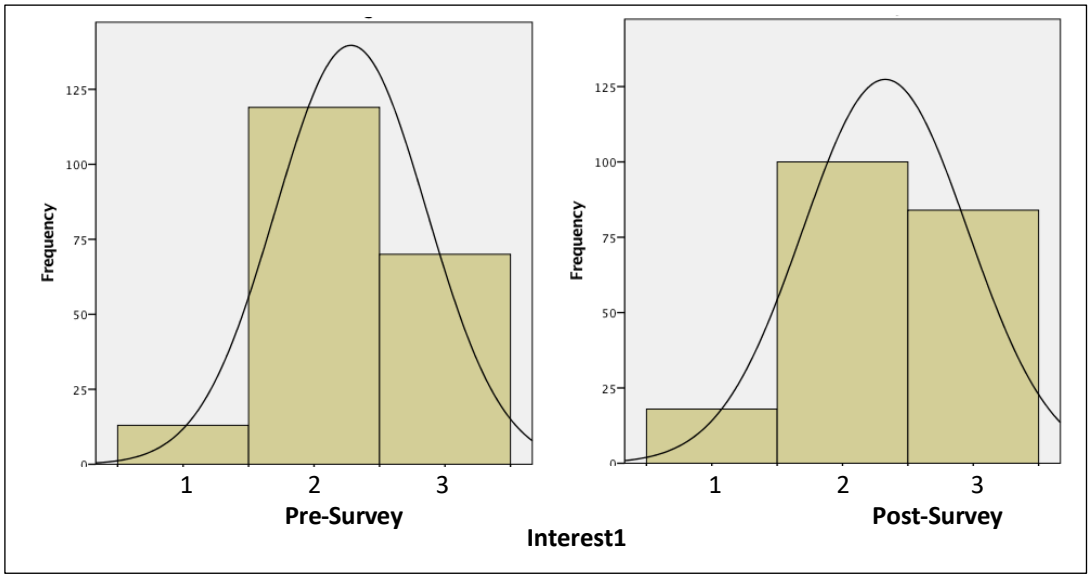

Figure 4.3. Representation of Interest1 responses. (Interest in participation in new STEM experiences). The frequency of the "3" responses increased by about 7%.

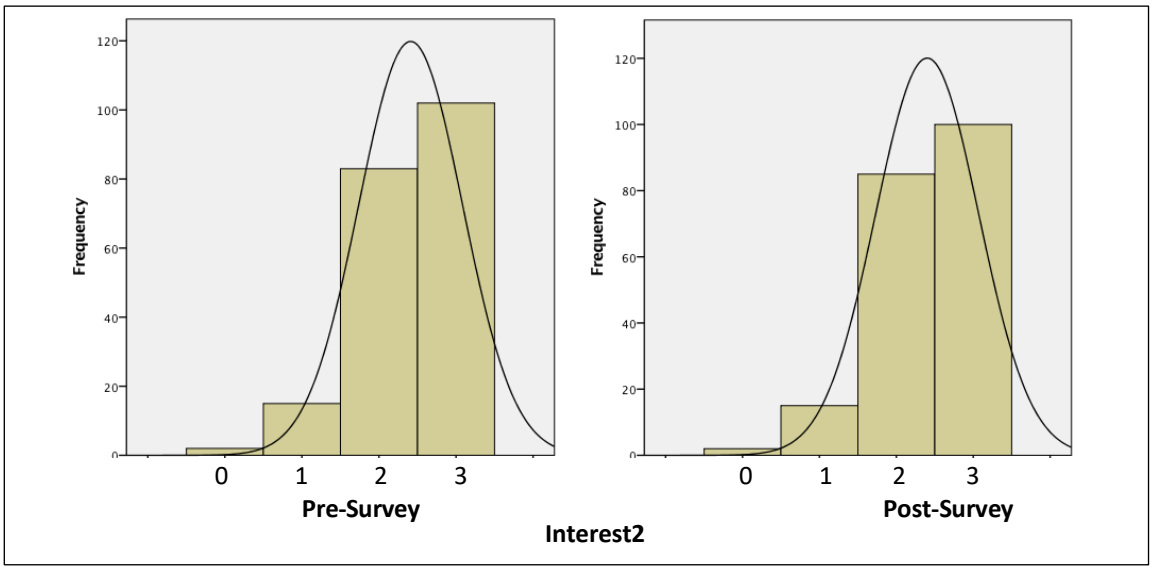

Figure 4.4. Representation of Interest2 responses. (Interest in STEM, in general). The frequency of the "3" responses remained more or less the same.

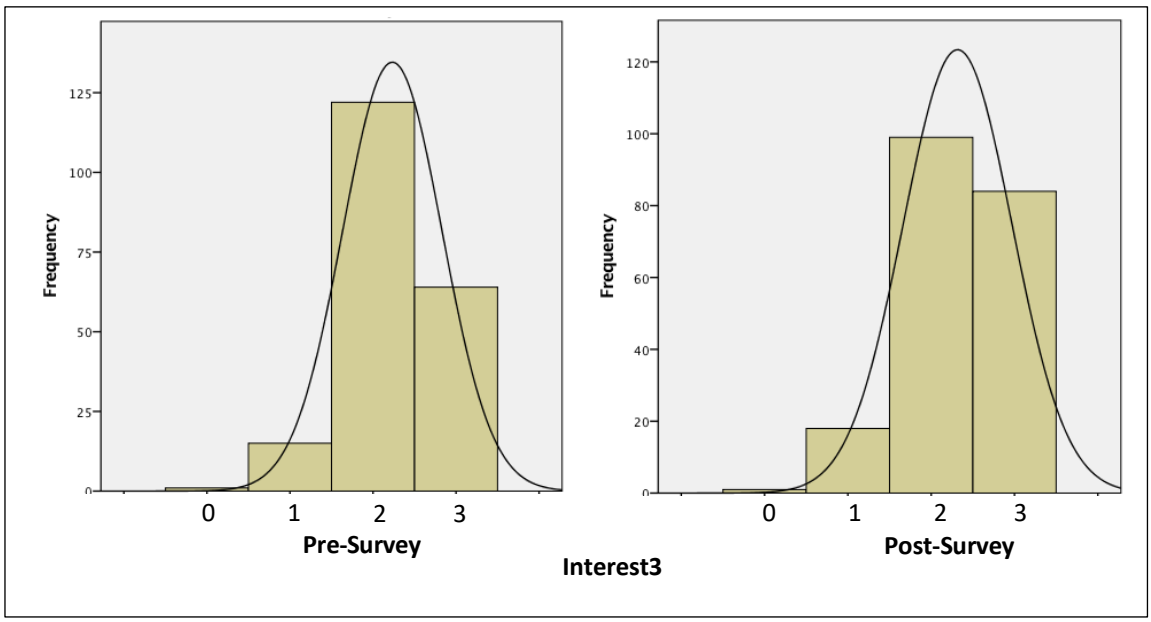

Figure 4.5. Representation of Interest3 responses. (Interest in taking STEM courses). The frequency of the "3" responses increased by about 10%.

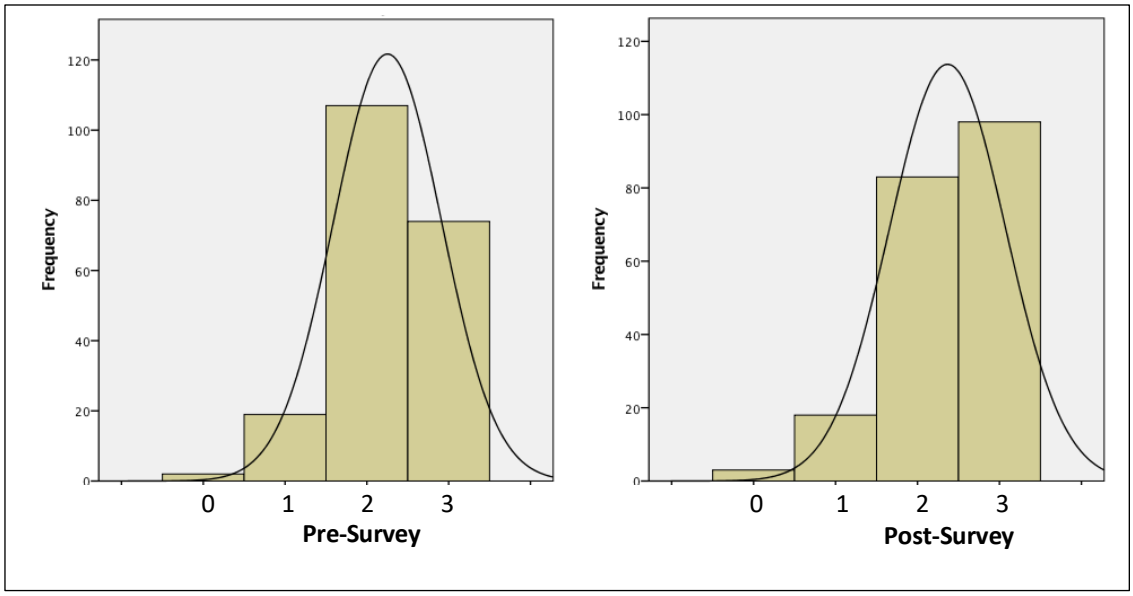

Figure 4.6. Representation of Interest4 responses. (Interest in careers that use STEM). The frequency of the "3" responses increased by about 12%.

Correlation Analysis

Analysis of results was initiated by looking at any possible association among dependent and independent variables. The Spearman's rho association values were determined for this purpose, values of which are shown in Table 4.4 (pre- and post-survey responses). From the pre-survey responses, a statistically significant correlation ($p < .05$) was observed between Access and Efficacy. Efficacy has also been found to be statistically significantly correlated with Gender and Interest1 ($p < .05$) and with Race and Interest2 ($p < .01$). From the post-survey results, a statistically significant correlation ($p < .05$) was observed between Access and Interest2, Efficacy and Race ($p < .05$), and between Efficacy and Interest1, Interest2, Interest3, and Interest4 ($p < .01$). It is quite evident in these results that student interests in STEM was enhanced statistically significantly after they participated in the week-long summer experience.

Table 4.4
Spearman's Rho Correlation Coefficients Between Access and Efficacy/Interest

Spearman's Rho Correlation Coefficients between Access and Efficacy/Interest							
	Gender	Race	Efficacy	Interest 1	Interest 2	Interest 3	Interest 4
Pre-Survey							
Access	-.053	-.035	**.152***	.097	.116	.126	.031
Efficacy	**.160***	**.276****		**.181***	**.217****	.123	.081
Post- Survey							
Access	-.050	-.032	.095	.098	**.172***	.082	.107
Efficacy	.110	**.169***		**.316****	**.335****	**.298****	**.301****

* p < .05;**p < 01

Logistic Regression Analysis.

The first step in logistic regression is the identification of the appropriate model to use in the analysis. Five variable pairs (A-E) were investigated, all involving Access as the primary predictor variable. The respective outcome variables are Efficacy (A), Interest1 (B), Interest2 (C), Interest3,(D), and Interest4 (E). The following section describes how the regression model for each of the five variable pairs was selected.

Logistic Regression Models.

Six models involving different combinations of variables were tried for each of the variable pairs 1-5. In Model 1, only the Access variable was used as a predictor. Then in Models 2 to 6, other predictor variables were added to Access, in the following sequence: addition of Gender in Model 2, of Race in Model 3, of both Gender and Race in Model 4, of the Access_Gender interaction term in Model 5, and of the Access_Race interaction term in Model 6.

Table 4.5.
Model Summary for A: Efficacy vs Access

Model Summary for 1: Efficacy vs. Access						
	Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*
Pre-Survey						
Model Coefficient	4.478 **(.034)**[c] *	10.321 **(.006)** **	20.852 **(< .001)** ***	24.261 **(< .001)** ***	26.126 **(< .001)** ***	25.210 **(< .001)** ***
Nagelkerke R Square	.030	.068	.134	.155	.166	.161
Access	.947 **(.035)***	1.037 **(.024)***	1.105 **(.019)***	1.166 **(.015)***	2.353 **(.038)***	.530 (.494)
Gender		.738 **(.016)***		.590 (.065)	2.031 (.095)	.587 (.067)
Race			1.240 **(< .001)** ***	1.165 **(< .001)** ***	1.182 **(< .001)** ***	.321 (.722)
Access_ Gender					-1.585 (.210)	
Access_ Race						.954 (.322)
Post-Survey						
Model Coefficient	1.699 (.192)[c]	4.328 (.115)	7.621 **(.022)***	9.306 **(.025)***	12.165 **(.016)***	10.422 **(.034)***
Nagelkerke R Square	.012	.031	.054	.065	.085	.073
Access	.612 (.183)	.661 (.115)	.675 (.151)	.710 (.133)	1.877 **(.036)***	.077 (.921)
Gender		.529 (.104)		.432 (.193)	1.987 (.054)	.430 (.197)
Race			.786 **(.015)***	.730 **(.026)***	.750 **(.023)***	-.154 (.865)
Access_ Gender					-1.765 (.105)	
Access_ Race						1.019 (.294)

[c] *p ; *p < .05; **p < .01; ***p < .001*

Table 4.6.
Model Summary for B: Interest1 vs Access

Model Summary for 2: Interest1 vs. Access						
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Pre-Survey						
Model Coefficient	1.533 (.216) [c]	1.749 (.417)	2.806 (.246)	3.232 (.357)	5.359 (.252)	3.817 (.431)
Nagelkerke R Square	.020	.023	.036	.042	.069	.049
Access	.930 (.184)	.909 (.195)	.976 (.166)	.948 (.180)	-18.350 (.999)	1.460 (.121)
Gender		-.286 (.647)		-.406 (.522)	-19.832 (.999)	-.397 (.533)
Race			.654 (.260)	.716 (.224)	.714 (.230)	1.587 (.230)
Access_Gender					19.772 (.999)	
Access_Race						-1.102 (.455)
Post-Survey						
Model Coefficient	1.908 (.167) [c]	2.562 (.278)	2.984 (.225)	3.907 (.272)	6.034 (.197)	13.089 **(.011)**
Nagelkerke R Square	.021	.028	.032	.042	.065	.139
Access	.909 (.140)	.881 (.154)	.942 (.129)	.912 (.143)	2.216 **(.032)**	2.562 **(.003)****
Gender		-.435 (.430)		-.521 (.350)	.971 (.393)	-.540 (.352)
Race			.520 (.298)	.588 (.245)	.602 (.236)	21.280 (.998)
Access_Gender					-1.933 (.591)	
Access_Race						-21.392 (.998)

[c] *p ; *p < .05; **p < .01*

Table 4.7.
Model Summary for C: Interest2 vs Access

Model Summary for 3: Interest2 vs. Access						
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Pre-Survey						
Model Coefficient	2.210 (.137)[c]	2.225 (.329)	3.725 (.155)	3.828 (.281)	7.363 (.118)	3.846 (.427)
Nagelkerke R Square	.025	.025	.042	.043	.082	.043
Access	.989 (.111)	.984 (.114)	1.035 (.099)	1.023 (.104)	-18.795 (.999)	1.112 (.222)
Gender		-.065 (.904)		-.174 (.749)	-20.198 (.999)	-.172 (.752)
Race			.633 (.218)	.660 (.206)	.660 (.213)	.792 (.478)
Access_Gender					20.422 (.999)	
Access_Race						-.168 (.893)
Post-Survey						
Model Coefficient	4.558 **(033)***[c]	4.798 (.091)	6.266 **(.044)***	6.366 (.095)	6.478 (.166)	10.351 **(.035)***
Nagelkerke R Square	.051	.053	.070	.071	.072	.114
Access	1.352 **(.021)***	1.375 **(.020)***	1.405 **(.018)***	1.418 **(.017)***	1.678 (.083)	2.602 **(.002)***
Gender		.259 (.622)		.169 (.751)	.480 (.652)	-.195 (.722)
Race			.679 (.192)	.656 (.211)	.659 (.209)	2.621 **(.037)***
Access_Gender					-.411 (.737)	
Access_Race						-2.560 (.066)

[c] *p; *p* < .05

Table 4.8.
Model Summary for D: Interest3 vs Access

Model Summary for 4: Interest3 vs. Access						
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Pre-Survey						
Model Coefficient	2.549 (.110)[c]	2.557 (.278)	2.725 (.256)	2.725 (.436)	2.834 (.586)	3.038 (.552)
Nagelkerke R Square	.029	.030	.032	.032	.033	.035
Access	1.075 (.086)	1.079 (.086)	1.089 (.083)	1.089 (.083)	.776 (.510)	1.499 (.111)
Gender		.047 (.932)		.011 (.984)	-.352 (.780)	.019 (.973)
Race			.223 (.674)	.222 (.680)	.218 (.685)	.771 (.490)
Access_Gender					.453 (.745)	
Access_Race						-.710 (.576)
Post-Survey						
Model Coefficient	1.639 (.200)[c]	1.641 (.440)	3.346 (.188)	3.365 (.339)	4.378 (.357)	11.815 **(.019)***
Nagelkerke R Square	.017	.017	.035	.036	.046	.122
Access	.834 (.174)	.835 (.174)	.876 (.157)	.871 (.160)	1.678 (.083)	2.378 **(.004)****
Gender		.021 (.966)		-.071 (.890)	.967 (.396)	-.057 (.914)
Race			.638 (.191)	.647 (.189)	.657 (.184)	21.209 (.998)
Access_Gender					-1.286 (.313)	
Access_Race						-21.186 (.998)

[c]*p;* *$p < .05$; **$p < .01$

Table 4.9.
Model summary for E: Interest4 vs Access

Model summary for 5: Interest4 vs. Access						
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Pre-Survey						
Model Coefficient	.184 (.668)[c]	1.210 (.546)	.297 (.862)	1.241 (.743)	1.308 (.860)	2.665 (.615)
Nagelkerke R Square	.002	.012	.003	013	.013	027
Access	.294 (.616)	.336 (.660)	.303 (.650)	.340 (.613)	.112 (.922)	1.192 (.193)
Gender		.474 (.308)		.460 (.329)	.145 (.913)	.475 (.315)
Race			.158 (.735)	.083 (.862)	.080 (.866)	1.496 (.258)
Access_Gender					.362 (.797)	
Access_Race						-1.641 (.247)
Post-Survey						
Model Coefficient	1.187 (.276)[c]	1.211 (.546)	1.191 (.551)	1.219 (.749)	2.073 (.722)	5.400 (.249)
Nagelkerke R Square	.012	.012	.012	012	.021	054
Access	.696 (.251)	.702 (.248)	.695 (.252)	.700 (.249)	1.417 (.132)	2.079 **(.016)***
Gender		.075 (.876)		.080 (.868)	1.034 (.360)	.095 (.845)
Race			-.030 (.949)	-.041 (.932)	-.037 (.939)	2.118 (.095)
Access_Gender					-1.157 (.354)	
Access_Race						-2.633 (.057)

[c]*p;* **p* < .05

The six models were compared with respect to model coefficient Chi-square and pseudo R-square values. The model coefficient determines whether the addition of a

predictor variable significantly improves the predictive power of a model in describing the relationship between outcome and predictor variables. It tells whether the model as a whole, with all the predictors in it, is significant. The pseudo R-square (like the Nagelkerke R-square), on the other hand, is used to estimate the percentage of the total variance accounted for by a model. Actually, there is no R-square in logistic regression, but in its absence, a pseudo R-square, like the Nagelkerke, is employed as an estimate of the real one. Summaries of the six models tested for A-E are given in Tables 4.5 to 4.9 (pre- and post-survey results).

To facilitate comparison, the overall significance (see Model coefficient in the tables) of Models 1-6, along with corresponding pseudo R-square (Nagelkerke value in the tables) have been tabulated in Table 4.10 for the pre-and post-survey results. These results reveal statistically significant regression models overall for Efficacy vs Access, both during pre- (Models 1-6) and post- (Models 3-6) survey.

It is noted that none of the interaction terms turned out to be statistically significant (Tables 4.5 – 4.9), consistent with the correlation results in Table 4.4 which shows neither Gender nor Race to be statistically significantly correlated with Access. This indicates that inclusion of the interaction terms in Model 4, which contains both demographic variables Gender and Race, does not statistically significantly increase the predictive power of the model. Hence, model choices were just limited to Models 1-4 which did not incorporate any of the interaction terms.

Table 4.10.
Summary of Models with R-Square Values

Summary of Models with R-Square Values							
		Models					
	Pre-Survey						
A	Efficacy	1*	2**	3**	4**	5**	6**
	vs Access	.030[b]	.068	.134	.155	.166	.161
B	Interest1	1	2	3	4	5	6
	vs Access	.020	.023	.036	.042	.069	.049
C	Interest2	1	2	3	4	5	6
	vs Access	.025	.025	.042	.043	.082	.043
D	Interst3	1	2	3	4	5	6
	vs Access	.029	.030	032	.032	.033	.035
E	Interest 4	1	2	3	4	5	6
	vs Access	.002	.012	.003	.013	013	027
	Post-Survey						
A	Efficacy	1	2	3*	4*	5*	6*
	vs Access	.012[b]	.031	.054	.065	.085	.073
B	Interest1	1	2	3	4	5	6*
	vs Access	.021	.028	.032	.042	.065	.139
C	Interest2	1*	2	3*	4	5	6*
	vs Access	.051	.053	.070	.071	.072	.114
D	Interst3	1	2	3	4	5	6*
	vs Access	.017	.017	035	.036	.046	.122
E	Interest 4	1	2	3	4	5	6
	vs Access	.012	.012	.012	.012	.021	.054

[b] Nagelkerke Pseudo R-square value

In choosing the model to use in data analysis, overall significance, as measured by the Model coefficient, was given first consideration. In cases where either two or more models were statistically significant, or where none of the models were statistically significant, the one with the highest pseudo R-square value was chosen. Based on these criteria, Model 4 was chosen in the analysis of all the variable pairs, including D (pre-

survey) and E (post-survey), in which Models 3 and 4 share the same R-square value. Using the same model allows for a better comparison of results.

Exponentiated Logistic Regression Coefficients, Exp(B): The Odds Ratio.

Considering the evidences discussed in the previous section regarding the goodness-of-fit of Model 4, the results for this model were the ones used in the logistic regression analysis. In carrying out the statistical treatment, some response values had to be recoded to reduce categories to two so that the technique may be applicable. Following are the recoded categories:

Efficacy
0 = Not at all confident
1 = A little bit confident
2 = Very confident
3 = Completely confident
→ 0, 1 = 0 (Low Efficacy, reference category)
2, 3 = 1 (High Efficacy, indicator category)

Interest:
Interest1 = Interest in participating in new STEM experiences
Interest2 = Interest in STEM in general
Interest3 = Interest in taking STEM courses
Interest4 = Interest in careers that use STEM.
0 = Strongly Disagree
1 = Disagree
2 = Agree
3 = Strongly Agree
→ 0, 1 = 0 (Low Interest, reference category)
2, 3 = 1 (High Interest, indicator category)

Gender → 0 = Female (reference category)
1 = Male (indicator category)

Ethnicity/Race → 0 = Students of Color (reference category)
1 = White (indicator category)

Unlike linear regression, and as the name indicates, logistic regression is expressed in terms of a logit function, so that the B coefficients (the values recorded in Tables 4.5 to 4.9) do not really reflect a similar relevance as that in linear regression. In the logit model, the outcome is expressed as the log odds, and is modeled as a linear

combination of the predictor variables (UCLA Institute for Digital Research and Education, 2019). In running logistic regression, the log odds are automatically exponentiated and included in the table of results under the heading Exp (B), which represents the odds ratio, a measure of the likelihood of an event occurring for the indicator category (1) compared to the reference (0). Exp (B)/Odds ratio values for A-E, pre- and post-survey, are shown in Table 4.11.

Table 4.11.
Odds Ratio (OR) Values

		Odds Ratio (OR) Values				
		A Efficacy	B Interest1	C Interest2	D Interest3	E Interest4
	Pre-Survey					
Access	With Access vs No Access	**3.209*** **(.015)**	2.579 (.180)	2.780 (.104)	2.973 (.083)	1.405 (.613)
Gender	Male vs Female	1.805 (.065)[c]	.667 (.522)	.840 (.749)	1.011 (.984)	1.584 (.329)
Race	White vs Students of Color	**3.206**** **(<.001)**	2.047 (.224)	1.934 (.206)	1.248 (.680)	1.086 (.862)
	Post-Survey					
Access	With Access vs No Access	2.035 (.133)	2.489 (.143)	4.130 **(.017)***	2.389 (.160)	2.015 (.249)
Gender	Male vs Female	1.541 (.193)	.594 (.350)	1.184 (.751)	.932 (.890)	1.084 (.868)
Race	White vs Students of Color	2.076 **(.026)***	1.801 (.245)	1.928 (.211)	1.910 (.189)	.960 (.932)

[c] *p; * p* < .05; ; ****p* < .001

Table 4.11 reveals three statistically significant odds ratio values – (a) pre-survey Efficacy vs Access ($p < .05$), (b) pre-survey Efficacy vs Race ($p < .001$), and (c) post-survey Interest2 vs Access ($p < .05$). The interpretation and relevance of these values are discussed in the following section.

The McNemar Test

Finally, the McNemar test was conducted to determine differences in the pre- and post-survey results (Table 4.12). It will be noted that a statistically significant increase in self-efficacy in STEM ($p < .05$) was observed after students participated in the week-long summer experience.

Table 4.12.
The McNemar Test

Pre- and Post-Survey McNemar Test					
	Efficacy	Interest1	Interest2	Interest3	Interest4
p	**.014***	.359	1.000	.607	1.000

p < .05

Analysis of Results

The tables in the previous section show some interesting results, notably on the values of the odds ratio in Table 4.11. Central to these findings is the statistical significance of the value for the Efficacy vs Access relationship (pre-survey) and for Interest2 vs Access (post-survey), which, by no coincidence, is consistent with the results of the correlation analysis. The Spearman's rho correlation coefficient (Table 4.4) for said relationships are significant ($p < .05$), establishing a significant degree of association between the variables involved.

Before interpreting the findings, a brief note regarding interaction terms is in order. The Access_Gender and Access_Race terms were included in Models 5 and 6, respectively, in order to determine if the impact of Access on Efficacy/Interest differs by gender or by race. It will be noted in Table 4.10 that inclusion of the Access_Gender interaction term substantially increased the R-square value, especially for Interest1 (64%) and Interest2 (91%) from pre-survey results and for Efficacy (31%) and Interest1 (55%) from post-survey results, suggesting possible interactive effect between Access and Gender. However, notable as they appear to be, none of the interaction terms in Tables 4.5 to 4.9 are statistically significant. Hence, interactive effects will not be taken onto account in the interpretation of results.

The odds ratio (OR) values in Table 4.11 reveal some findings that are relevant to this study. Specifically, statistically significant impacts of Access were detected on Efficacy (OR =3.21, $p < .05$) as per pre-survey results and on Interest2 (OR = 4.13, $p < .05$) as per post-survey results. These results indicate that at the outset, respondents who had prior access to informal STEM learning experiences are 3.21 times as likely to manifest high self-efficacy in STEM as those that had no previous access, controlling for Gender and Race. After participating in the See Blue See STEM Summer Experience, those who had prior access emerged 4.13 times as likely to exhibit high Interest2 (interest in STEM in general) as those who had no prior access.

Overall, some notable impacts of Access were observed. In the pre-survey, for example, a statistically significant impact was detected on self-efficacy (OR = 3.209, $p < .05$). In addition, substantial (although not statistically significant) impacts were discerned on the various interest components, with OR values all higher than 2.5, i. e.,

2.579, 2.780, and 2.973 for Interest1 (interest in participating in new STEM experiences), Interest2 (interest in STEM in general), and Interest3 (interest in taking STEM courses), respectively. Then after the summer experience, a statistically significant OR value of 4.130 ($p < .05$) was recorded for Interest2 (interest in STEM in general) and a statistically significant increase in self-efficacy was detected based on the McNemar test ($p < .05$, Table 4.12). Additionally, impacts on the other aspects of STEM Interest remained high with OR values ranging from 2.015 to 2.489.

Chapter Summary

This chapter describes the variables used in this study, the statistical treatment involved, and the analysis and interpretation of the findings. The statistical treatment employed SPSS (Version 24) software and relied principally on logistic regression technique. Analysis of results revealed a statistically significant impact of access to informal STEM learning experiences on both self-efficacy and interest in STEM.

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CHAPTER 5. DISCUSSION, CONCLUSIONS, AND IMPLICATIONS

This concluding chapter discusses the findings and the corresponding implications, particularly for major stakeholders; formalizes the answers to the research questions; and explores other aspects of informal STEM learning that may be investigated to help promote student learning of STEM, and consequently, drive the motivation to consider a career in the STEM field.

By way of revisiting, this study aimed to answer the following research questions:

1. To what extent does access to informal learning experiences in STEM influence middle school students' self-efficacy in STEM?
2. How does access to informal learning experiences in STEM impact middle school students' interest in STEM?

Discussion of Results

Access to informal STEM learning experiences had a statistically significant impact on student self-efficacy in STEM. Results of this study showed that at the outset, the participants who had prior access to informal STEM learning experiences were 3.2 times as likely to exhibit high self-efficacy in STEM as those who had no previous access, controlling for Gender and Race. Access likewise impacted student interest in STEM to a comparable, although relatively lesser degree than it did self-efficacy. The odds for middle school students who had prior access ranged from 1.405 to 2.973.

That Access did not initially impact interest in STEM to the same extent as it did self-efficacy is consistent with SCCT. This theory holds that self-efficacy is not the only determinant of interest. Interest is also driven by outcome expectation belief which comes into play with self-efficacy in influencing interest. Applying this to this study's findings,

one can either say that as a result of access to informal STEM learning experiences, student self-efficacy belief in STEM was enhanced but not enough to drive interest, or that self-efficacy was enhanced but the corresponding outcome expectation belief was not. The latter could be due to a variety of reasons. For example, one may be confident in one's capability to perform STEM-related tasks but thinks that those capabilities do not align with her/his outcome expectation beliefs. It could also be attributed to environmental factors, like a perceived lack of support, or worse, anticipated barriers that dampen the motivation to cultivate an interest in STEM (Lent et. al., 2002). In this study, the high self-efficacy of the participants who had prior access did not immediately translate to a corresponding, equally high interest in STEM, which is possible at times. In math, for example, it was found that math competence beliefs are not significantly predictive of future math interests (Ganley & Lubienski, 2016). It has also been found from a longitudinal study (Grigg et al., 2018) that prior math interest positively predicted subsequent math self-efficacy whereas the opposite was not true. These findings suggest that believing in one's capability in performing domain-specific tasks may not necessarily be equated to liking the domain. In fact, it is actually conceivable that individuals may be interested in a domain and its attendant activities despite their lack of confidence in the ability to perform well in the accompanying tasks (Denissen, et. al., 2007). One may also think that individuals who perceive themselves as capable of performing tasks may just not be interested in those tasks (Renninger et al. 2002).

Although previous access did not significantly impact interest in STEM initially, further access enhanced both self-efficacy and interest in STEM. After attending the week-long See Blue See STEM summer experience, a statistically significant increase in

self-efficacy ($p < .05$) was detected and an overall enhancement of interest in STEM was observed. Most notable of these results were the odds on Interest2 (Interest in STEM in general) for the participants who had prior access. The odds increased from 2.78 to a statistically significant value of 4.13 ($p < .05$).

The influence of Gender was generally less pronounced than that of Access, but the results were interesting. Prior to the summer experience, the odds for males were 1.805 on Efficacy. After the summer experience, the odds went down to 1.541. This is noteworthy as it indicates a narrowed down gender gap in self-efficacy after attending the summer experience. Additionally, equally notable are the results showing odds ratio values that are less than 1: .667 on Interest1 and .840 on Interest2 (pre-survey); .594 on Interest1 and .932 on Interest3 (post-survey). These values place males lower than females in the likelihood of demonstrating high interest in STEM. Other values are close to 1: 1.011 on Interest3 (pre-survey); 1.184 on Interest2 and 1.084 on Interest4 (post-survey). These values place males and females in more or less equal footing in regard to the likelihood of manifesting high interest in STEM. In addition, the observed overall decreasing trend in the odds ratio values after the students participated in the summer experience suggests that further access can possibly narrow down the gender gap on both Efficacy and Interest in STEM. Research shows that self-efficacy is an important factor why more boys are attracted to STEM subjects at university and more girls are attracted to subjects that has more of their own gender like Health care, Elementary Education and the Domestic sphere (Tellhed et al., 2017). There are indications that one's self-efficacy level undergoes a decreasing pattern as one grows up. For example, it has been shown that five-year-old girls can readily say that girls can be

“really, really smart” (Bian et al., 2017) but from six years up, they start believing that brilliance is much more likely in boys (Davis, 2017). It is suggested that in order to bridge the gender gap in STEM, there is a need to tackle the stereotypes that girls are exposed to early on in their life (Gjersoe, 2018). In view of this, it is critical that female students be afforded sufficient access to informal STEM learning experiences, specifically, since the opportunities for formal learning experiences are fixed and just the same for boys and girls.

Race had a statistically significant impact on Efficacy in both pre- and post-survey, controlling for Access and Gender. The odds for Whites on Efficacy were 3.206 ($p < .001$) in the pre-survey but was lowered to 2.076 ($p < .05$) in the post-survey. Again, this is an interesting observation as it indicates that the summer experience had the effect of narrowing down the race gap in STEM self-efficacy among the participants. Also, an overall trend of decreasing odds ratio values was observed on the various aspects of STEM interest after the students engaged in the summer experience. Overall the range in the odds ratio values shifted from 1.086 to 2.047 in the pre-survey to 0.96 to 1.928 in the post-survey. As in Gender effect, these suggest that increasing access to STEM learning opportunities has the potential of narrowing down the race gap in STEM interest.

As a whole, the results described in the previous section nicely fit the social cognitive career theory, SCCT. This model explains how personal factors (such as gender and race) interact with environmental factors (like parental support and role model) to influence learning experiences which play a crucial role in the development of self-efficacy and interest (Lent, Brown, & Hackett, 1994). This study has demonstrated that

access to informal STEM learning experiences influences both self-efficacy and interest in STEM and that further access enhances the same.

Research indicates that informal learning environments provide support for significant science learning for all ages and that informal learning experiences are just as crucial as STEM academic achievement in school (Bell, 2009). Informal STEM learning experiences supplement learning acquired in the classroom as they oftentimes involve experiences that are typically not encountered in the traditional classroom (Mohr-Schroeder et al., 2014) owing to structural and organizational constraints imposed by such classroom.

SCCT underscores the critical importance of individuals' environment not only in motivating, but more importantly, in sustaining their interests, based on their self-efficacy and outcome expectation beliefs. SCCT emphasizes that these interests are bound to wane or even disappear if individuals are not exposed to learning experiences in their environment that tend to enhance their self-efficacy and outcome expectation beliefs. Due to the structured nature of formal learning which typically features a "fits-all" style of instruction, informal learning can fill the gap by offering experiences that are more flexible and more tunable to students' interests and needs. That the respondents in this study are middle school students has some significance, too, for it is at middle school age that students are considered mature enough to seriously think about preparing for their future career. Care must be taken that these students are provided access to environments that will tend to reinforce the interest and self-efficacy that they have acquired earlier on in life, otherwise, as mentioned, whatever self-efficacy and interest in STEM students

may have acquired may just fade away if not sufficiently sustained through appropriate learning experiences and learning environments (Lent, Brown, & Hackett, 1994).

Conclusions

Access to informal STEM learning experiences statistically significantly influences middle school students' self-efficacy in STEM. The odds are 3.21 times as high for a student with prior access as they are for one without prior access. Participation in summer learning experiences which affords students sufficient time and opportunities to engage in extended, authentic, content-rich and skills-developing hands-on activities enhances both self-efficacy and interest in STEM. At the end of the 2018 See Blue See STEM summer experience, a statistically significant increase in self -efficacy was observed overall, and a statistically significant odds of having high interest in STEM was noted for the participants who had previous access. The odds are 4.13 as high for those who had previous access as for those who had no previous access. These results suggest that increasing exposure to informal STEM learning experiences enhances both self-efficacy and interest in STEM. These findings corroborate those from previous studies which showed that informal learning experiences/environment increase motivation and interest in STEM fields (e.g., Mohr-Schroeder et al., 2014; Roberts et al., 2018) and may actually be effective in supporting learning of non-dominant groups (Bell, 2009).

Implications

The SCCT holds that learning experiences, which are crucially affected by the interplay between personal and environmental factors, critically influence one's self-efficacy and outcome expectations, both of which contribute to the development of interest. While awareness on personal interests normally starts early on in life, an

environment that helps sustain said interests should be accessible to individuals. This brings to the forefront the essential role played by informal environments and informal learning experiences in helping individuals develop and sustain a robust self-efficacy and interest in whatever they have set their mind on. This is particularly true within the STEM context where informal environments provide contextual and situated learning experiences that are commonly not available in a formal environment. The formal and informal aspects of an individual's learning experiences have drawn great attention recently as more studies (Hofstein & Rosenfeld, 1996; National Science Foundation, 2012) have shown the complementary nature of these two forms of experiences. No longer is learning in science, technology, engineering and math a monopoly of the traditional classroom. Informal environments and settings such as museums, science centers, zoos, summer camps, afterschool, and the home, to mention a few, have taken more active roles in students' overall learning of STEM. This study, together with the increasing number of other studies out there involving informal learning experiences/environment, serve to guide parents, teachers, school administrators and other stakeholders in making decisions that help make learning of STEM more meaningful and fun for students. More importantly, this study calls for efforts to help build and sustain a rich STEM Learning ecosystem.

Future Research Directions

With the increasing awareness on the crucial role played by informal learning experiences in the overall student learning of STEM, more studies around this topic are expected to emerge. So far, majority of research on this area are focused on students (e.g., Blotnicky et al., 2018; Bong et al., 2015; Burwell-Woo et al., 2015; Dabney et al., 2012;

Grigg et al., 2018; Halim et al., 2018; Hammack et al., 2015; Jackson et al., 2015; Kitchen et al., 2018; Lin et al., 2018; Minnigerode, 2013; Mohr-Schroeder et al., 2014; Roberts et al., 2018; Sublett & Plasman, 2018; Wiebe et al., 2018; Wong, 2010), which is not surprising, students being the primary stakeholder in education. There have also been studies involving other stakeholders, such as teachers (Dellinger, 2008; Jackson & Mohr-Schroeder, 2018; Klassen, 2010; Mohr-Schroeder et al., 2018; Nadelson, 2013; Powell-Moman, 2011) and parents (Halim et al., 2018; Jacobs et al., 2017; Lloyd et al., 2018; Mikulak, 2012; Simunovic et al., 2018). A stakeholder that may relatively be more challenging to reach out to is the administrator. Nonetheless, it would be interesting, as a follow up on this study, to shift the focus to administrators, such as school principals and heads of departments. Some relevant questions to consider for future studies involving this group of stakeholders would be: (a) What is the school administration's view on the possible role of informal learning in the learning of STEM?; (b) To what extent are schools supporting informal learning in STEM?; and (c) What is the likelihood of schools integrating formal and informal approaches for a more effective learning of STEM?

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