THE RELATIONSHIP BETWEEN SCIENTIFIC LITERACY AND SCIENCE SELF-EFFICACY OF UNDERGRADUATES ENROLLED IN SELECT BIOLOGY CLASSES

by

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Dedication

I would like to dedicate this work to my children, Ilyas, Isa, and Maria. I know that I was distracted or not completely present for each of you during this project and that you sacrificed that time with me for me to pursue my dream. I hope that the sacrifices that all of you have endured through this process are repaid with many opportunities in our future. I also hope that going on this journey with me has helped to harness a passion for learning in each of you that will lead to your success. Thank you for your patience and understanding throughout this process.

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ABSTRACT

THE RELATIONSHIP BETWEEN SCIENTIFIC LITERACY AND SCIENCE SELF-EFFICACY OF UNDERGRADUATES ENROLLED IN SELECT BIOLOGY CLASSES

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Scientific literacy and science self-efficacy have both been the focus of calls from educators and policymakers emphasizing the need to improve and reinforce them in order to improve science education. This study is aimed at examining the relationship between science self-efficacy and scientific literacy, two critical components of science education, to better understand specific correlations between the two. A correlation research design was employed to examine the relationship between undergraduate student science self-efficacy and scientific literacy. The researcher solicited a purposeful sample of students self-enrolled in various Biology courses from a large suburban public university to complete the SELDS and the TOSLS assessment in one sitting. Data were collected through online administration of the SELDS and TOSLS instruments through Qualtrics. Quantitative data were analyzed using descriptive statistics, Pearson's product-moment correlations, and Structural Equation Modeling (SEM). An analysis of the results of this study presented a statistically significant relationship between science self-efficacy and scientific literacy as well as between several specific components of science self-efficacy and scientific literacy. Another statistically significant relationship in this study was

between self-efficacy for learning and understanding science topics and students" ability to understand methods of inquiry to develop scientific knowledge. The results of the study can be beneficial to educators working with undergraduate students to help determine or develop their science literacy and science self-efficacy. Furthermore, they can be an important factor in the way that professors curate the learning experience for their students based on their science self-efficacy, self-efficacy to learning, and science literacy. The results of this study can be used to create a study on a larger scale to determine if the outcome was related to the narrow demographics of the participants. It is recommended to conduct this study on a larger scale, expanding to K-12 to develop a better understanding of the dynamics between components of science self-efficacy and scientific literacy.

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CHAPTER I:

INTRODUCTION

Science, Technology, Engineering and Mathematics (STEM) education is essential in education today to provide our students with the knowledge and skills they will need to become the innovators of tomorrow (Strimel, 2013). The importance of STEM education is evident in developing STEM educational program reforms to prepare students to pursue careers in the STEM fields, along with fostering inquiry, collaboration, and logical reasoning in developing learners (Jang, 2016). The current STEM workforce will hinder the ability of the US to compete in a global economy; the global economy is becoming more scientifically and technology based, and we lack domestic STEM talent (National Academy of Sciences, 2007). The US Department of Commerce (2017) reports that as the STEM employment pipeline continues to grow faster than ever, employers are in search of scientifically literate individuals to fill it. The National Academy of Sciences (1996) defines Scientific Literacy as “the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity” (p. 33). The National Science Board (NSB; 2018) and The White House (2017) have both stated that scientific literacy is essential to the youth of America. If the youth of today are to succeed as the workforce of tomorrow, it is essential for them to be scientifically literate (NSB, 2018; The White House, 2017).

Despite the need for STEM graduates, research suggests there is less interest in STEM fields among students (Holmes, 2017; PCAST, 2010). The President’s Council (2010) states that students become uninspired to continue in science and mathematics education because many determine early in their educational careers that STEM majors are either too difficult or uninteresting. Students declining interest in science or pursuing STEM majors has been attributed to students failing to “see” themselves in STEM, leading to an inability to engage in science (Carlone et al., 2014; Simpson & Bouhafa, 2020). Considering the significant role both science self-efficacy and scientific literacy play in shaping a competitive STEM force, this study is intended to examine the deeper underlying relationship between scientific literacy and student science self-efficacy in undergraduate students. This chapter will describe the research problem in the study, the significance of the study, the research purpose and questions, and give definitions of key terms.

Research Problem

There have been multiple calls for reform in science education based on growing concerns about the significantly poor performance seen on international science exams by United States students (Auerbach, 2017; Sparks, 2016), the lack of public understanding of science (Llorente, 2019), and the scientific educational background of our scientist pipeline (Aikenhead, 2005; Mcdonald, 2020). The Smithsonian Institute has also emphasized the poor performance of students in the United States and urged academic institutions to understand the need to promote scientific literacy by sharing findings from the Programme for International Student Assessment (PISA),

> "The United States placed 17th on the 2006 Programme for International Student Assessment test given to 15-year-olds in the World's 30th wealthiest nations to measure their ability to apply Math and science knowledge in real-life contexts" (Clough, 2011).

The NSB (2018) maintains that scientific literacy is essential for success in the 21st century. The National Academies of Sciences Engineering and Medicine (2018b) also highlight the benefits of promoting scientific literacy in their publication as a means to improve individual economic means, decision making, and the overall democratic society that is able to make educated and informed decisions. The importance of scientific literacy is also made apparent in its highlighted role among multiple standards-based educational reforms by the National Science Education Standards (NSES) and Next Generation Science Standards (NGSS; Auerbach, 2017; NGSS Lead States, 2013).

The National Center for Education Statistics (2011) reports that despite the numerous policies, funding, and programs aimed to improve STEM, science achievement remains low. A majority of the attention that has been paid to STEM has focused on improving the science and math test performance of students to retain a global position in these subjects. However, Farrington et al. (2012) suggest that more attention also needs to be paid to analyzing the relationship between student achievement and noncognitive factors such as student self-efficacy and their expectations of success in any particular subject area. Self-efficacy can be a strong predictor of academic achievement and persistence (Britner & Pajares, 2006; Chemers et al., 2011; Fouad & Smith, 1996; Graham et al., 2013; Mau, 2003; Pajares, 1997).

According to Britner and Pajares (2006), self-efficacy can also determine how hard a student will work and whether they will persevere to succeed academically. In an examination of factors that may influence a student's academic choices, science educators and researchers indicated science self-efficacy to be a major influence, not only on their science choices but also on their experiences and success in science (Britner & Pajares, 2006). Multiple research studies have been conducted focusing on student STEM coursework to determine student engagement (Britner, 2008; Eccles & Wang, 2016; Murphy & Alexander, 2000; Nolen, 2003; Simpkins et al., 2006; Velayutham et al., 2012). Despite the amount of emphasis and money being poured into STEM education and motivation, studies still show that middle and high school students continue to find science and math to be boring and unenjoyable (Ahmed et al., 2013; Gottfried et al., 2001; Hidi, 2000, Krapp, 2002).

Scientific literacy involves students being capable of processing information for application, pulling on their prior experiences, evaluating their understanding in order to make choices in determining relative importance and in making inferences (Sharma, 2017). It is evident science self-efficacy plays an important role in scientific literacy. Clinger (2014) highlights that scientific literacy goes beyond reading to practicing problem-solving, which truly encompasses the meaning of being a scientist. The practice of problem-solving and other skills believed to be critical components of scientific literacy all interconnect with academic choices and prior experiences; therefore, with science self-efficacy. While multiple studies have analyzed science self-efficacy and scientific literacy separately, there appears to be a gap in the research where analysis of the relationship between science self-efficacy and scientific literacy in students could yield unique results. This study will analyze the deeper interwoven relationship between scientific literacy and science self-efficacy to advance the literature on the relationship between these components in STEM.

Significance of the Study

One of the biggest issues faced by the United States in this decade is the lack of STEM innovators (Brown et al., 2016). Even though most of the innovations of the future are dependent on STEM majors, there is a significant shortage of graduates in these fields (Rice et al., 2013). The National Math and Science Initiative (NMSI; n.d.) states that due to our students falling significantly behind other countries, the United States is losing its competitiveness in the global economy.

Educating students to become more literate in the area of science is the best way to strengthen our nation in the global economy and advance our society, according to the President's Council (2010). However, science performance for students in the United States has declined considerably from where it was fifty years ago (NAEP, 2015a; OECD, 2019). Numerous attempts have been made to improve student performance in STEM through increased federal and state funding (Cornell Law School, 2020; NCLB, 2002, 2018), development and adoption of inquiry emphasized curriculum (AAAS, 1990; NRC, 2013), increasing the number of science classes in high school graduation requirements (Plunk et al., 2014). Yet, even with all of the interventions, there has been very little growth in student proficiency in science (NAEP, 2015a).

Increasing science literacy has the potential to significantly increase the number of STEM literate qualified science and engineering workers the United States needs to sustain our economy (National Academy of Science, 2007). This is evident in the recent renewal of interest in scientific literacy as seen in the increase of academic literature on defining scientific literacy (Aubrecht, 2020; Feinstein, 2011; Ristanto & Darmawan, 2020; Smith et al., 2015), measuring scientific literacy (Gormally et al., 2012; Nuhfer et al., 2016; OECD, 2016; Shaffer et al., 2019), and most importantly designing interventions that can improve scientific literacy (Auerbach & Schussler, 2017; Foster & Shiel-Rolle, 2011; Kleintjes Neff et al., 2017; Suwono et al., 2019).

The results of this study can be beneficial to curriculum developers and intervention specialists by clarifying the interwoven relationships between scientific literacy and science self-efficacy. A better understanding of the deeper significant relationships between science self-efficacy and scientific literacy skills can be beneficial in improving student success and closing achievement gaps by designing targeted interventions (ESSA, 2015). The results of this study can also benefit students by helping them develop a better understanding of their own self-efficacy factors and how those factors relate to their scientific literacy skills. According to George (2006), improving student scientific literacy has been linked to increased participation and success in science. Therefore, by helping to improve scientific literacy, this study can also help to increase student participation and success in science, thereby improving the STEM force in the United States (ESSA, 2015). The results of this study can also benefit students by helping them develop a better understanding of their own self-efficacy factors and how those factors relate to their scientific literacy skills. According to George (2006), improving student scientific literacy has been linked to increased participation and success in science. Therefore, by helping to improve scientific literacy, this study can also help to increase student participation and success in science, thereby improving the STEM force in the United States.

Research Purpose and Questions

The purpose of this study is to analyze the relationship between scientific literacy and science self-efficacy in undergraduate students enrolled in science courses, also shown in Figure 1.1 below. The research questions for this study are as follows:

1. Is there a statistically significant relationship between science self-efficacy and scientific literacy?
2. Is there a statistically significant relationship between self-efficacy for learning and understanding science topics and student ability to understand methods of inquiry?

3. Is there a statistically significant relationship between self-efficacy for learning and understanding science topics and student ability to organize, analyze, and interpret quantitative data and scientific information?
4. Is there a statistically significant relationship between self-efficacy for doing scientific activities and student ability to understand methods of inquiry?
5. Is there a statistically significant relationship between self-efficacy for doing scientific activities and student ability to organize, analyze, and interpret quantitative data and scientific information?

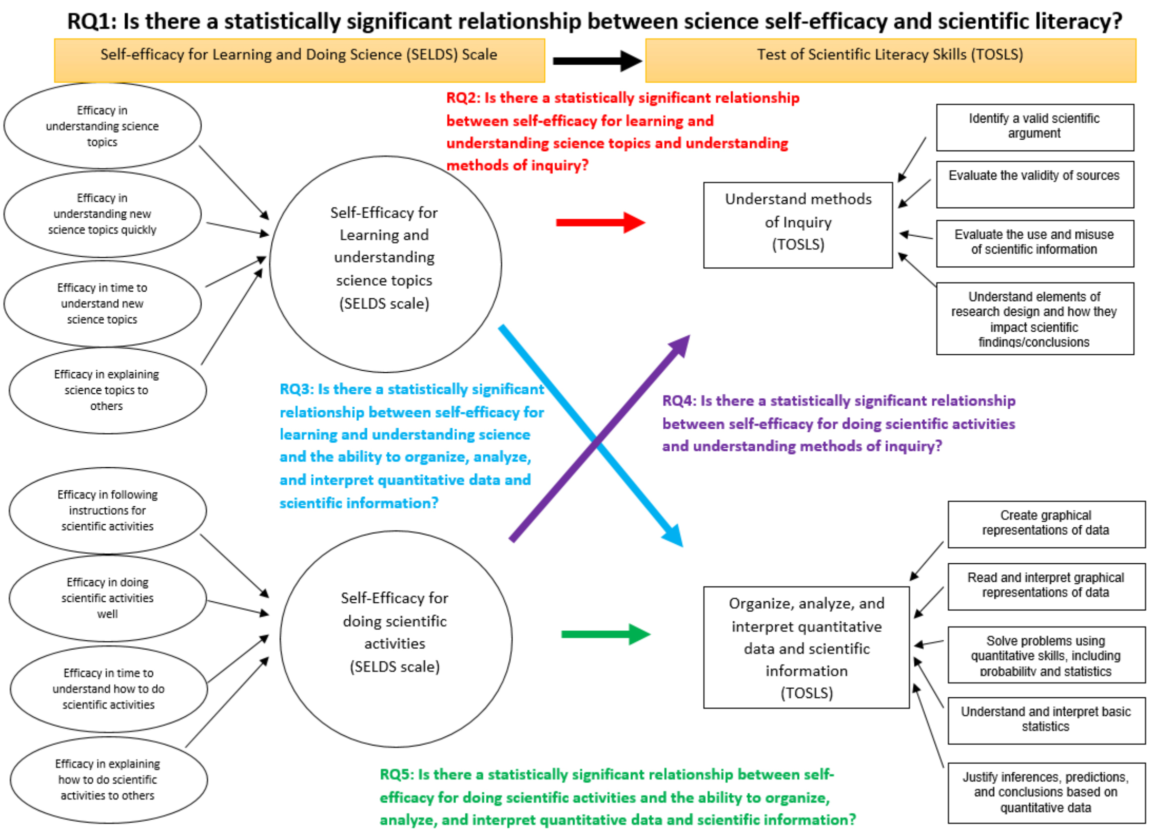

Figure 1.1 Overview of Research Questions

Definition of Key Terms

Methods of Inquiry: Methods of inquiry in science are the approaches and processes used to acquire new knowledge, reform, or incorporate previous knowledge (Prunckun, 2016).

Scientific Literacy: "…the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity" (National Academy of Sciences, 1996, p. 33).

STEM: The professional and academic disciplines of science, technology, engineering, and mathematics (The America Competes ACT of 2010, P.L. 111-358, Section 2).

Self-Efficacy: The beliefs one holds about their ability to accomplish a specific task (Bandura, 1986).

Science Self-Efficacy: The belief about one's ability to accomplish certain tasks related to science (Britner & Pajares, 2006).

Conclusion

There is a growing national concern about the lack of students pursuing or graduating with STEM degrees. Many organizations, researchers, and even former President Obama has addressed this national crisis. A lack of a qualified STEM workforce will mean that the US will fall further behind in the global economy than it already has (Teitelbaum, 2014). Without STEM innovators, our economy will falter, and we will face economic hardships (NMSI, n.d.). Despite the need for a more scientific literate STEM workforce, student performance in scientific literacy has continued to remain low (NAEP, 2015a). Since scientific literacy, similar to scientific methods of inquiry, heavily involves prior experience, student choice, and the ability to make decisions, science self-efficacy plays an important role in scientific literacy (Sharma, 2017). This study will analyze the deeper interwoven relationships between scientific literacy and science self-efficacy in undergraduate students to determine the significant role one plays in the other. Chapter two will provide a discussion of the literature relevant to this topic, including academic self-efficacy, science self-efficacy, and general and scientific literacy.

CHAPTER II:

LITERATURE REVIEW

Chapter one of this dissertation presented a synopsis of the current challenge of low scientific literacy and science self-efficacy and the roles they play in STEM education and how they ultimately contribute to a shortage of qualified STEM workers. In order to gain a better understanding of why some students develop an interest and persistence in science while others do not, there is a need for research that looks beyond measurements such as test scores, which can be superficial. There is a need for research that looks more closely at non-cognitive factors that can lead students to achieve persistence or resilience in science, such as their self-efficacy in science (Farrington et al., 2012). Research provides evidence that self-efficacy can be a strong predictor of achievement and persistence in STEM subject areas such as math and science (Hackett & Betz, 1989; Lent et al., 1984). Due to stronger motivation and greater ambitions that come with a higher self-efficacy, higher ambition will also be demonstrated (Nicolaidou & Philippou, 2003).

This study focuses on the relationship between undergraduate student science self-efficacy and scientific literacy to develop a better understanding of the underlying relationships between the two and highlight the impact that different areas of science self-efficacy can have on specific scientific literacy skills in students. Therefore, this chapter will establish the theoretical framework for the study and examine some of the existing literature and research on self-efficacy, science self-efficacy, self-efficacy for learning and doing science, general literacy, scientific literacy, and measurements of scientific literacy.

Theoretical Framework

The Test of Scientific Literacy Skills (TOSLS), developed by Gormally et al. (2012), provides a significant part of the framework for this study. Through an extensive literature search, surveying of faculty, and pinpointing of common challenges for students related to scientific literacy, Gormally et al. established a total of nine key skills to be necessary for students' development of scientific literacy in their tool. The TOSLS provides the framework for the scientific literacy component of this study. As this study focuses on the relationships between scientific literacy and student science self-efficacy, this study is also theoretically framed by the social cognitive theory.

Bandura (1986) defines self-efficacy as how a person judges themselves on their ability to organize or execute what is needed to achieve a goal. Bandura (1997) further developed his concept of self-efficacy from the social cognitive theory to elaborate that self-efficacy can be defined as the perception one holds of their capability for performing or learning actions at designated levels. Since this study is analyzing scientific literacy through an assessment (TOSLS) and analyzing its relationships with self-efficacy, it is also important to consider motivation, achievement, and persistence within the scope of the social cognitive theory.

According to both Bandura (1997) and Schunk (1995), self-efficacy affects students' efforts, achievement, and persistence. Pajares (1997) further states that self-efficacy can also increase student interest in the material, which is known to increase their persistence and achievement. Achievement is directly related to self-efficacy as self-efficacy influences a person's behavior (Dibenedetto, 2015). While positive progress and results will lead to increased self-efficacy, negative responses will lower their self-efficacy (Schunk, 2012). Motivation is also directly controlled by self-efficacy (Dibenedetto, 2015). One's aspirations for their goals as well as what they achieve can be influenced positively if they are faced with positive expectations (Bandura, 1997). Graham et al. (2013) elaborate on the importance of self-efficacy in STEM persistence by describing self-efficacy as the powerful influence which can be a predictor of college persistence in STEM college aspirations for students.

Self-Efficacy

Self-efficacy can be described as the beliefs an individual or group holds about their ability or capacity in a particular task (Bandura, 2001; Hoy et al., 2006). Many researchers have established a positive relationship between self-efficacy and higher achievement (Britner, 2008; Chen et al., 2012; Dibenedetto & Bembenutty, 2013; Pajares, 1996; Zientek & Thompson, 2010), which, in turn, also establishes a positive relationship with career intent or selection of academic major (Bandura et al., 2001). According to Bandura (1997), these self-efficacy beliefs are created from a complex self-persuasion process that relies on the individual's ability to process the information they are getting directly, socially, and physiologically about their efficacy. While in early life, Pastorelli et al. (2001) explain that an individual relies on external control and environmental influences, and they shift to personal control as they develop a better understanding of their sense of control and their ability to guide their actions as well as their personal motivators. Pastorelli et al. (2001) further elaborate these guides, and personal motivators then become a sense of academic attainment for students as they move into the academic environment in the classroom.

Banks (2020) notes that interest in self-efficacy and academic performance in literature can be found beginning in the early 1990s, referred to as academic self-regulation. According to Banks (2020), early literature defines academic self-regulation as proactively regulating the self-learning process motivationally, behaviorally, and meta-cognitively. Zimmerman et al. (1992) described students with academic self-regulation to be those that have a proactive mindset, do well in learning, and have the capability to self-motivate. According to Zimmerman (1990), students that were self-regulated learners had a higher self-efficacy that helped them to reach their goals and overcome academic challenges.

Self-efficacy plays a role in influencing student performance in various ways, including their efforts in setting goals (Zimmerman et al., 1992). Pastorelli et al. (2001) elaborate that perceived self-efficacy will affect how much effort an individual will put in and their persistence when facing difficulties. The level an individual is willing to challenge themselves and how they perceive their goal acquisition is also influenced by their self-efficacy (Pastorelli et al., 2001). Therefore, according to Pastorelli et al. (2001), individuals with higher self-efficacy tend to set goals more challenging for them, and they are able to better regulate their personals efforts to reach those goals while overcoming any obstacles which may come in their way. Schunk (1995) also elaborates that students who show higher academic self-efficacy demonstrate better persistence and effort in academic performance and learning.

When students have a high self-efficacy in their academic abilities, they use self-regulatory behaviors to make conscious decisions (Zimmerman & Kitsantas, 2005). Further, Zimmerman and Kitsantas (2005) maintain that these conscious decisions stemming from their high self-efficacy help define student identities and reinforce their self-efficacy, thereby creating a self-empowerment cycle. On the other hand, students with a lower academic self-efficacy tend to disengage from learning, cope poorly with stress, and do not regulate their learning (Bandura et al., 1996; Caprara et al., 2008). Maintaining self-efficacy is already a difficult task for many students, and when external factors such as low teacher expectations are factored in, this can further damage student self-efficacy (Lynn et al., 2010). Therefore, there is a need to develop ways to help increase student self-efficacy and self-resilience (Lynn et al., 2010). Pajares (1996, 2002, 2003) states that student self-efficacy influences their attitudes and perceptions of the subject, which directly impacts their decision for further study in the subject or career goals within said subject. A strong self-efficacy in science makes students more likely to develop a positive attitude towards science, leading to higher achievement and probability for a career consideration (Britner & Pajares, 2006).

Science Self-efficacy

Academic self-efficacy can be further categorized into different academic domains. Science self-efficacy is considered to be one of those domains (Hallak et al., 2018). According to research by Gwilliam and Betz (2001), science self-efficacy at the college level is a means to predict student achievement and their persistence in pursuing science as a major or career. The current research on science self-efficacy is mostly organized into the different sub-disciplines within science, where researchers have developed content-specific assessment tools to examine self-efficacy utilizing knowledge and skillsets within their defined discipline (Dalgety & Coll, 2006; Ferrell & Barbera, 2015; Hiller & Kitsantas, 2016).

However, all of the findings from these studies in specific subcategories within science have conformed to the literature from the varied academic self-efficacy literature - they mirror the positive relationship between students specific science content efficacy beliefs and their success in those subjects (Dorfman & Fortus, 2019; Trujillo & Tanner, 2014; Ucar & Sungur, 2017; Villafañe & Lewis, 2016; Zusho et al., 2003). As a whole, science self-efficacy and its relationship with various other learning elements in science such as the epistemic beliefs and conceptions of learning science has been at the center of attention in the field of science (e.g., Britner & Pajares, 2006; Chen & Pajares, 2010; Chiou & Liang, 2012; Dorfman & Fortus, 2019; Tsai et al., 2011; White et al., 2019), making science self-efficacy its own domain within academic self-efficacy (Koballa & Glynn, 2007).

Student self-efficacy in learning science has often been conceptualized at a singular scale in previous studies (e.g., Glynn et al., 2009; Pintrich & De Groot, 1990; Tuan et al., 2005); however, using a singular scale may hinder the ability to fully realize student science self-efficacy. This is also evident in the attempts to develop a more multi-dimensional instrument by several researchers to better evaluate student science self-efficacy at various levels (Baldwin et al., 1999; Capa Aydin & Uzuntiryaki, 2009; Uzuntiryaki & Capa Aydin, 2009). Through the development of these multidimensional instruments, four unique dimensions which better represent student science self-efficacy have surfaced in the literature: self-efficacy for science knowledge and comprehension skills, self-efficacy for science-related analytical or problem-solving skills, self-efficacy for science practical work such as laboratory activities, and self-efficacy for the applications of science concepts and skills to daily situations (Baldwin et al., 1999; Capa Aydin & Uzuntiryaki, 2009; Uzuntiryaki & Capa Aydin, 2009). The instrument selected to measure science self-efficacy in this study, Self-Efficacy for Learning and Doing Science Scale (SELDS), incorporates both learning and doing within their scale, aligning with the four dimensions mentioned above. The SELDS inclusion of each of the dimensions is concurrent with indications from researchers that general self-efficacy items are not sufficient in exploring student self-efficacy and should be better developed to be adapted to various contexts (Multon et al., 1991; Pajares, 1996).

Self-Efficacy for Learning and Doing Science Scale (SELDS).

The Self-Efficacy for Learning and Doing Science (SELDS) is an 8-item scale with a (1-5 range) Likert scale for each item. The SELDS scale has undergone a series of validity tests, shown a high internal consistency (0.92), concurrent validity, and good reliability (Porticella et al., 2017). The scale can be divided into two subscales, each containing four items, self-efficacy for learning science and self-efficacy for doing science.

Self-Efficacy for Learning Science. The first subscale on the SELDS, Self-Efficacy for learning science, consists of statements to which participants indicate their level of agreement or disagreement on a five-point Likert scale. The statements included in this section are: “I think I’m pretty good at understanding science topics,” “Compared to other people my age, I think I can quickly understand new science topics,” “It takes me a long time to understand new science topics,” and “I feel confident in my ability to explain science topics to others” (Porticella et al., 2017). The development of this subscale incorporates several features to support data quality. “It takes me a long time to understand new science topics” is included as a reverse coded question. By posing the question again with a negative root, the instrument ensures consistent responses from participants, and this item also acts as an attention filter to ensure participants are indeed reading and responding to each question validly (Porticella et al., 2017).

Understanding science topics and quickly understanding science topics. Duschl (2008) indicates conceptual understanding of scientific knowledge, as well as reasoning and critical thinking, are important aspects to include within science learning in science education research. This highlights the importance of including an item that measures a student’s efficacy in understanding science topics within this study. Another component which is unique within this scale is that it includes the statement indicative of a student’s approach to learning by including the statement about understanding science topics quickly. A learner’s self-efficacy and their approach to learning have been linked positively in the literature (Chiou & Liang, 2012; Phan, 2007, 2011).

According to Chin and Brown (2000), approaches to learning specify the methods a student utilizes to refine their academic tasks, and this is also associated strongly with their motivation related to that task. So, identification with learning science topics quickly can give a better insight into the approach to learning by that student. Learning has been categorized broadly into deep and surface approaches by researchers (Entwistle & Ramsden, 1983; Liang et al., 2010). Overall, deep approaches to learning have shown to have a positive relationship with learner's self-efficacy, and surface approaches to learning have a negative association (Diseth, 2011; Moneta et al., 2007; Prat-Sala & Redford, 2010). Therefore, according to Phan (2007), learners that take a deep approach to learning will be more likely to have a higher self-efficacy than those who take a surface approach. Research on a learner's science self-efficacy and their approaches to learning (e.g., Ellis et al., 2008; Kember et al., 2004; Tsai et al., 2011) is still in an early phase and therefore needs to be further investigated. Analyzing the relationship between a student's efficacy for understanding science topics and their specific scientific literacy skills can further clarify how these variables contribute to other self-efficacy theories.

Explaining science topics to others. The ability to explain science topics to others not only demonstrates a whole different level of understanding by the student but also brings communication into the classroom. Multiple studies have established that the communication component of scientific literacy should also be applied within classrooms to further science learning (Chang et al., 2011; Yore et al., 2003). Communication skills can be defined as the ability to use reading, writing, listening, speaking, or a combination of the four skills to collaborate or convey messages (Rodriguez et al., 2017). Jenkins (1999) also emphasized the importance of a student's ability to communicate on science topics as a central goal for science education reforms. Therefore, including a dimension of science communication self-efficacy within the study can help to further explore the relationships between science self-efficacy and scientific literacy while including a sociocultural feature of science learning that should not be excluded.

Self-Efficacy for Doing Science. The second subscale on the SELDS, Self-Efficacy for doing science, consists of statements to which participants indicate their level of agreement or disagreement on a five-point Likert scale. The statements included in this section are: "I think I'm pretty good at following instructions for scientific activities," "Compared to other people my age, I think I can do scientific activities pretty well," "It takes me a long time to understand how to do scientific activities," and "I feel confident in my ability to explain how to do scientific activities to others" (Porticella et al., 2017). The development of this subscale also incorporates the same features as the first subscale to support data quality. A reverse coded question is included in this subscale as well; it poses the question a second time with a negative root ensuring consistent responses from participants and also acts as an attention filter question (Porticella et al., 2017).

Following instructions for and doing scientific activities. Science learning activities wherein students are able to manipulate and observe materials and objects are an essential component of science learning (Millar et al., 1999). Tsai (2003) explains that science learning activities are essential in helping students learn science, and it allows them to do science. Not only do science activities allow students to better learn science, but they give them an opportunity to apply the scientific concepts they have learned, and being able to do so is an essential ability to become scientifically literate (Millar & Osborne, 1998; Roberts, 2007). Campbell and Lubben (2000) also argue that everyday science applications are critical to reaching mastery of science learning. Since doing science activities is a critical component of science learning, studying the relationships involved in its self-efficacy can further the literature on science learning.

Explaining how to do scientific activities to others. Similar to the connection to communication in the section above on explaining science topics to others, the ability to explain how to do scientific activities to others also ties in the communication component. The importance of interpersonal communication in knowing science has been suggested in the literature based on the significance of language being characterized as a pertinent feature in the science learning process for students (Carlsen, 2007; Chang et al., 2011; Yore et al., 2003). With scientific activities, this takes on a whole new light, as they need to be able to communicate scientifically, discuss their inquiries, procedures, and understandings to develop a deeper understanding of the science learning involved.

The two subscales on the SELDS are uniquely crafted to include self-efficacy for science knowledge and comprehension skills, science-related analytical or problem-solving skills, science practical work, and the application of science concepts and skills to daily situations. These four dimensions within science self-efficacy, also mentioned earlier in the literature review, have been highlighted by researchers (Baldwin et al., 1999; Capa Aydin & Uzuntiryaki, 2009; Uzuntiryaki & Capa Aydin, 2009). These dimensions also integrate seamlessly into the features of scientific literacy (Roberts, 2007). Before exploring the literature on scientific literacy, it is important to first examine general literacy.

General Literacy

The historical origin of the concept of literacy has been described by the United Nations as being "familiar with literature" or generally "well-educated" (United Nations Education Scientific and Cultural Organization, 2006). The historical definition of the term illiterate has been adjusted over the years. Starting with the 1930s Census, illiterate has been defined as any individual over the age of ten that is unable to read and write in any language to an individual with fewer than five years of formal education (U.S. Department of Commerce, 1979; United Nations Education Scientific and Cultural Organization, 2006). According to the United Nations Education Scientific and Cultural Organization (2006), the term literacy was first defined in 1947 as the basic ability to read and write, and this definition was used to define literacy for almost seventy years. The definition of literacy was then expanded by The National Assessment of Adult Literacy as an individual's capability to use "printed and written information to function in society, to achieve one's goals, and to develop one's knowledge and potential" (White &

McCloskey, 2003). This definition further evolved, going beyond basic reading and writing to encompass the acquisition of knowledge as well as critical thinking (National Research Council, 2014).

According to the Organization for Economic Co-operation and Development OECD (2016), generalized literacy skills have been one of the main curricula focuses in early education, with the educational goals then shifting from generalized literacy over to the acquisition of content knowledge in upper-grade levels. Vacca et al. (2014) maintain that integration of reading into content area curriculum may help students be successful in their content literacy as well as with their general literacy. Vacca and Vacca (2002) define content literacy as "the ability to use reading and writing to learn subject matter in a given discipline" (p. 15). Vacca et al. (2014) maintain that content area teachers play an integral role in developing literacy by helping students to think critically and learn effectively while communicating with content area text. Generalized literacy skills have been shown to influence the development of scientific literacy skills directly (Aberšek & Aberšek, 2013). Even the OECD (2016) has reported that the insufficient development of student's generalized literacy skills can be linked to their inadequate performance in scientific literacy assessments.

Scientific Literacy

Scientific literacy has been theorized in science education for over 60 years (Holbrook & Rannikmae, 2012; National Academies of Sciences, Engineering, and Medicine, Snow, & Dibner, 2016). The National Research Council (NRC; 1996) defines scientific literacy as the ability to "use evidence and data to evaluate the quality of science information and arguments put forth by scientists and in the media." More recently, scientific literacy has been defined by The Organization for Economic Co-operation and Development (OECD) in collaboration with Programme for International Student Assessment (PISA) as "the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and changes made to it through human activity" (OECD, 2004, p.133). PISA's definition of scientific literacy has been used to design their assessment of scientific literacy, which is used on an international test to measure scientific literacy in students. PISA assesses students on their scientific literacy skills in four categories: scientific knowledge and use of that knowledge, the use of science as a form of human knowledge, student awareness of the importance of science and technology, and student engagement in scientific issues as a citizen (OECD, 2006).

Multiple sources state that the skill of scientific literacy has been underdeveloped across all educational levels (Bensaude-Vincent, 2001; Peters, 2013; Robertson, 2012). More alarmingly, according to Impey et al. (2011), despite having taken college-level science courses, college graduates still have the same level of science literacy as high school graduates. Reforms to educational standards have made it a point to drive the curriculum to incorporate scientific literacy skills into the curriculum through K-16 education (NGSS, 2013; NRC, 2014). Researchers have argued that there is a critical need to improve scientific literacy for all students, not just the developing scientists (Scheufele, 2014; Stilgoe et al., 2014; vanderLinden et al., 2014).

Scientific literacy is often perceived synonymously as science literacy; however, Roberts and Bybee (2014) clarify that while both science literacy and scientific literacy include the mastery of scientific knowledge and processes, scientific literacy expands to include the use of that scientific knowledge to make knowledgeable decisions. Keefe and Copeland (2011) state that the term literacy has often been defined differently depending on the context of its application. Like the term literacy, science literacy is a term that embraces a broad range of definitions; science literacy is used by researchers to highlight whether a student has a particular skill set needed to be successful in science (Jusino, 2020). However, there is general agreement among researchers that scientific literacy involves the ability to understand science-related articles and the ability to interpret and communicate socially about their validity and conclusions (Pelger & Nilsson, 2016). According to Pelger and Nilsson (2016), scientific literacy implies that a person is capable of both evaluating and posing evidence-based arguments, and they can then apply conclusions from these arguments to scientific issues. Another component of scientific literacy that scientists agree on is that the measurable skills that are critical to scientific literacy need to include both conceptual understanding along with views of science and society (Bauer et al., 2007). While the definition and components of scientific literacy have matured significantly in the last 50 years or so, Showalter (1974) was the first to depict them in an aspect that could be adapted into the science curriculum as objectives.

Components of Scientific Literacy

Showalter (1974) established a framework for scientific literacy with the following components: nature of science, concepts in science, processes of science, values, science society, interest, and skills. According to Lederman (2019), the nature of Science and science processes, also referred to as scientific inquiry, were distinctly highlighted in Showalter's work as closely related constructs of scientific literacy. Lederman and Lederman (2014) explain that existing literature often confuses the relationship and distinctions between the nature of scientific knowledge (NOSK) and scientific inquiry (SI).

Nature of Science

The Nature of Science (NOS) generally indicates "the epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development" (Lederman, 2007). The NOS and nature of scientific knowledge (NOSK) are both terms used synonymously in literature and are indicative of the characteristics of scientific knowledge (Lederman, 2019). According to Lederman (2007), the characteristics of scientific knowledge were originally described using the phrase nature of scientific knowledge; however, the phrase was later reduced to nature of science. Not only was NOS one of the components identified by Showalter, but the understanding of NOS was also later defended as a critical component of scientific literacy in the reiterated framework for scientific literacy by the National Science Teachers Association (NSTA, 1982). In a review of the literature on NOS, Lederman (2007) lists six aspects of NOS that relate to what students should know:

- The difference between observation and inference, observations are descriptive statements that several observers can agree on, whereas inferences are the developed explanations for observations.
- The difference between scientific laws and theories.
- Scientific knowledge comprises human imagination and creativity along with empirical observations.
- Scientific knowledge is laden with theory and is therefore subjective.
- Society, politics, socioeconomic factors, philosophy, and religion are all elements that affect science.
- Scientific knowledge is tentative and therefore is not considered absolute.

NOS is often mixed with science processes of scientific inquiry (SI) as these aspects often overlap and interact, and Lederman (2007) notes that it is essential to differentiate between the two.

Scientific Inquiry

SI, also often referred to as scientific processes, are more specific activities associated with collecting and analyzing data and drawing conclusions (AAAS, 1990, 1993; NRC, 1996). The National Research Council defines scientific inquiry as to the "diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work" (1996, p.23). Some of the scientific processes within SI also overlap and interact with components of NOS (Lederman, 2007). The scientific processes of observing falls within SI as an individual process used in a cyclical manner, whereas the understanding of the distinction between observations and inferences and observations are theory-laden falls within NOS (Lederman, 2007).

Since SI is inherently the way the knowledge that falls within NOS is developed, SI was often considered a component of NOS (Lederman, 2019). However, in the National Science Education Standards (NSES) developed in 1996, NOS was situated as its own standard separate from scientific inquiry, which was treated as a closely related independent standard (NRC, 1996). The NSES were the first to recognize and establish the distinction of scientific inquiry as to the doing of science, such as observing, inferring, or concluding from the knowledge of science (Lederman, 2019). While both NOS and SI are established to be separate, both are integral components of scientific literacy (Lederman, 2019). The intricate and complicated components of scientific literacy can be seen in the various measurement tools that have been created to measure scientific literacy in students.

Measurements of Scientific Literacy

There have been various instruments developed with the intention to measure scientific literacy, with a focus; however, only on the assessment of content knowledge specifically. With the focus on scientific literacy and the need to develop it, many measurement forms have been created, including surveys for the general public, assessments for K-12 students, or even open-ended questionnaires. Since this study requires contextual independence from the scientific literacy assessment, measurements that have a longitudinal nature were not utilized. There have been several assessments developed in recent years that have more specific targets being measured, including the Science Literacy Concept Inventory (SLCI), the Test of Science Literacy Skills (TOSLS), and many others. Data will be collected using the TOSLS.

Test of Science Literacy Skills (TOSLS)

Gormally et al. (2012) developed the TOSLS to measure science literacy in undergraduate biology students. While Science literacy concept inventory (SLCI) is a more recently developed instrument to measure the science literacy for undergraduate students (Nuhfer et al., 2016), it was precluded from this study due to its inclusion of questions that require discipline-specific knowledge which may not be familiar to the selected population of this study. Unlike other scientific literacy assessments, the TOSLS is a 28-question selected response assessment that measures both scientific and quantitative literacy while eliminating any influence of content-specific knowledge. Gormally et al. designed the TOSLS to measure science literacy within nine subscales divided into two domains. The first domain is understanding methods of inquiry that develop scientific knowledge, and the second domain in the organization, analysis, and interpretation of data (Gormally et al., 2012). In the design on the TOSLS, Gormally and colleagues aligned their operational definition for scientific literacy with the definition by the National Research Council (NRC, 1996), which includes the ability to "use evidence and data to evaluate the quality of science information and arguments" (p. 145). Their design also incorporated the definition for quantitative literacy by the National Assessment of Adult Literacy (NAAL) as "the knowledge and skills required to perform quantitative tasks" (Kutner et al., 2007, p.2). This includes the ability to "use evidence and data to evaluate the quality of science information and arguments" (NRC, 1996, p. 145). Their design also incorporated the definition for quantitative literacy by the NAAL as "the knowledge and skills required to perform quantitative tasks" (Kutner et al., 2007, p.2).

Similar to this study, Gormally and colleagues surveyed undergraduate biology students. The researchers began the development of the TOSLS by surveying undergraduate biology instructors that were active participants of an undergraduate biology teaching association (Gormally et al., 2012). Responses from a diverse sample of undergraduate biology instructors were used to formulate the two domains with a focus on the common misconceptions encompassing scientific literacy, which were then broken down further into nine categories of skills (Gormally et al., 2012). Approximately 86 faculty members across multiple institutions were involved in the process of identifying the nine science literacy skills in the instrument, which helps to provide the assessment with additional content validity. After multiple rounds of piloting and making adjustments to the instrument, Gormally et al. (2012) report that the TOSLS is a valid instrument to measure science literacy. This is also evident in its usage in a high school setting (Chandler, 2017) as well as in various undergraduate institutions (Coke, 2014; Segarra et al., 2018; Waldo, 2015). While the TOSLS is designed to measure science literacy in undergraduate students, the domains and skills measured significantly overlap with both the PISA Science framework and the NAEP Science assessments (Neidorf et al., 2015; OECD, 2017).

The TOSLS goes beyond just science literacy and incorporates multiple dimensions of literacy within its domains. The first domain on the instrument includes components of informational literacy, and the second domain incorporated quantitative literacy. The following sections of this literature review will delve further into the incorporation of information literacy and quantitative literacy in each of the domains on the TOSLS as well as the domains themselves.

Informational Literacy

According to the Association of College and Research Libraries, informational literacy is defined as the ability to recognize the need for information, accessing that information, evaluating that information, and being able to then effectively utilize that information (American Library Association, 2000). With a stronger focus on non-fiction text, informational literacy differs greatly from generalized literacy, and this focus also connects this branch of literacy directly to scientific literacy. Since scientific literacy includes the ability to interact with the informational text as well as evaluate the validity of its source, this area of scientific literacy, therefore overlaps with informational literacy. This area of literacy is an essential component of scientific literacy in which students tend to struggle. According to a survey of Australian high school students with lower scores on the scientific literacy skills assessment, it was found that they struggled to identify, evaluate, and utilize academic research (Salisbury & Karamanis, 2011). Among the skills that are assessed on the TOSLS, most of the skills assessed in domain one are components of informational literacy (Gormally et al., 2012).

Domain One. The first domain on the TOSLS has been designed to measure the understanding of the Nature of Science, which Gormally et al. (2012) describe as the understanding of the methods of inquiry that lead students to develop scientific knowledge. The term “Inquiry” is a contested term in the literature, and there are multiple ideas on what constitutes inquiry. While there are some who associate the term inquiry with a curriculum that is hands-on or activity-based (Tamir, 1998; Willden et al., 2002), Gormally’s application of it in their instrument, on the other hand, treats it as a process skill. Gormally’s use of the term methods of inquiry is better aligned with literature that argues inquiry focuses on the reasoning practices that students can use to both understand and construct scientific ideas (Hammer et al., 2008; Lehrer & Schauble, 2006; Warren et al., 2001). Referring to methods of inquiry in this study is going to align with the application of it in Gormally's instrument, which matched the definition of scientific methods of inquiry by Prunckun (2016), the approach and processes used to acquire new knowledge, reform, or incorporate previous knowledge.

This domain includes four categories of skills: identifying a valid argument, evaluating sources, evaluating the use of information, and understanding research design (Gormally et al., 2012). These skills can all be found as cross-cutting concepts in the Next Generation Science Standards (NGSS) and scientific and investigation reasoning skills, also known as process skills, in Texas Essential Knowledge and Skills (TEKS) standards (National Research Council, 2013; TEC, 2018).

Identify a valid scientific argument. The first skill in domain one on the TOSLS is to "identify a valid scientific argument" and is assessed through 3 of the 25 items on the instrument (Gormally et al., 2012). Gormally et al. (2012) report that the common misconceptions and student challenges related to this skill, according to the consensus by the surveyed faculty, are an "inability to link claims correctly with evidence and lack of scrutiny about evidence" and that "unrelated evidence considered to be support for scientific arguments." According to Gormally et al. (2012), this skill is explained as the ability to "recognize what qualifies as scientific evidence and when scientific evidence supports a hypothesis." Gormally et al. (2012) measurement of the students' ability to identify a valid scientific argument is true to the NGSS learning objectives based on the presumptions that "science disciplines share common rules of obtaining and evaluating empirical evidence" and "science knowledge is based upon logical and conceptual connections between evidence and expectations" (National Research Council, 2012). While Texas has not adopted NGSS standards, the definition for scientific literacy in the TEKS for Science (2018) is similar to that of NGSS as "know[ing] that scientific hypotheses are tentative and testable statements that must be capable of being supported or not supported by observational evidence."

Evaluate the validity of sources. The second skill in the first domain on the TOSLS is to "evaluate the validity of sources" and is assessed through five of the 25 items on the instrument (Gormally et al., 2012). Gormally et al. (2012) report that a common misconception or student challenge with this skill is the "inability to identify accuracy and credibility issues." Gormally et al. (2012) also state that students are unable to "distinguish between types of sources; identify bias, authority, and reliability." While this is a critical skill for the general population, it is not generally included in the curriculum. However, this skill is consistent with the Common Core State Standards linked to the NGSS, including the ability to "delineate and evaluate argument[s] and specific claims in a text, including the validity of reasoning as well as relevance and sufficiency of evidence" (NGSS Lead States, 2013, p. 8).

Evaluate the use and misuse of scientific information. The third skill in the first domain on the TOSLS is to "evaluate the use and misuse of scientific information" and is assessed through three of the 25 items on the instrument (Gormally et al., 2012). The common misconception or student challenge associated with this skill by surveyed faculty is that "prevailing political beliefs can dictate how scientific findings are used. All sides of a controversy should be given equal weight regardless of their validity" (Gormally et al., 2012). This skill is further explained by Gormally et al. (2012) as the ability to "recognize a valid and ethical scientific course of action and identify appropriate use of science by government, industry, and media that is free of bias and economic, and political pressure to make societal decisions." This is another skill that greatly overlaps with both State and National standards. The definition of science literacy by the NGSS comparably includes the awareness that there are limitations to science and that "science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions" (NGSS Lead States, 2013, p. 127). Similarly, the curriculum in Texas states that students should "know that scientific hypotheses are tentative and testable statements that can be supported or not supported by observational evidence" (TEC, 2018, p. 2).

Understand elements of research design and how they impact scientific findings/conclusions. The last skill within the first domain is that the student should "understand elements of research design and how they impact scientific findings/conclusions" and is assessed on three of the 25 items on the instrument (Gormally et al., 2012). According to surveyed faculty, the common misconception or student challenge with this skill is the "misunderstanding randomization contextualized in a particular study design. General lack of understanding of elements of good research design" (Gormally et al., 2012). This skill is further explained by Gormally et al. (2012) as the ability to "identify strengths and weaknesses in research design related to bias, sample size, randomization, and experimental control." This skill also overlaps with the Science and Engineering practices outlined by the NGSS as well as the crosscutting concept of cause and effect (NGSS Lead States, 2013). This skill is also true to student expectations aligned with the TEKS that "The student analyzes published research and is expected to identify the scientific methodology used by a researcher; examine a prescribed research design and identify dependent and independent variables; evaluate a prescribed research design to determine the purpose for each of the procedures performed; and compare the relationship of the hypothesis to the conclusion" (TEKS for Career and Technical Education, 2014).

Quantitative Literacy

Since a lot of the academic research in science is reported in a quantitative manner, such as numerical and graphical data, this intertwines quantitative literacy with informational and scientific literacy. Quantitative literacy is defined as the knowledge and skills that are required to complete calculations that are related to everyday activities by the National Center for Education and Statistics (Kirsch et al., 2007; Kunter et al., 2007). With a similar focus on student ability to interpret, analyze, and communicate information, there is significant overlap amongst the definitions of both scientific literacy and quantitative literacy. An overlap in definition also suggests there will be a correlation in performance on scientific literacy with quantitative literacy performance. According to Kunter et al. (2007), there was a slight gain in quantitative literacy between 1992 and 2003, similar to the gains in science reported by the NAEP. Gormally et al. (2012) connect quantitative literacy into domain two of their TOSLS assessment by requiring students to understand statistics and perform calculations.

Domain Two. The second domain on the TOSLS was designed to focus on the ability to "organize, analyze, and interpret quantitative data and scientific information" (Gormally et al., 2012, p. 367). This domain establishes a connection between scientific literacy and quantitative literacy, which is also evident in state and national standards as well. The incorporation of quantitative literacy within the TOSLS also aligns with the general expectation that an individual that is scientifically literate should be able to organize and interpret data. This domain includes five categories of skills: create a graphical representation of data; read and interpret graphical representations of data; solve problems using quantitative skills (including probability and statistics); understand and interpret basic statistics; and justify inferences, predictions, and conclusions based on quantitative data (Gormally et al., 2012). Subsequent sections of this literature review will further explore these skills and their overlap with state and national standards.

Create graphical representation of data. The first skill on the second domain of the TOSLS, "create graphical representations of data," is assessed on one of the 25 items in the instrument, and Gormally et al. (2012) further explain this skill as the ability to "identify the appropriate format for the graphical representation of data given a particular type of date." The expectation for students to pick the right way to represent data is consistent with the crosscutting concept of recognizing patterns by the NGSS (NGSS Lead States, 2013). This skill is also a general component of multiple course expectations in the state of Texas. An example of common student challenges and misconceptions shared by surveyed faculty that Gormally et al. reported is that "scatter plots show differences between groups. Scatter plots are best for representing means, because the graph shows the entire range of data." Not only do students need to be able to create graphical representations of data, but they should also be able to read and interpret graphical representations of data.

Read and interpret graphical representations of data. The second skill within domain two is to "read and interpret graphical representation of data," which is assessed on four of the 25 items. This skill is explained by Gormally et al. (2012) as the ability to "interpret data presented graphically to make a conclusion about study findings" and report that the common student challenge with this skill is "difficulty in interpreting graphs, inability to match patterns of growth, (e.g., linear or exponential) with graph shape." The explanation for this skill substantially overlaps with the NGSS standards for data analysis, "mathematical representations . . . needed to identify some patterns" and "graphs, chart, and images can be used to identify patterns in data" (NGSS Lead States, 2013, p. 92). This overlap is also seen in the curriculum in Texas, within the Science TEKs, which require students to use a variety of methods to communicate valid conclusions (2018).

Solve problems using quantitative skills (including probability and statistics). The third skill in domain two, "solve problems using quantitative skills, including probability and statistics," is assessed on three of the 25 items on the instrument. Gormally et al. (2012) further explain this skill as the ability to "calculate probabilities, percentages, and frequencies to draw a conclusion." The examples of common student challenges from faculty surveys were that students tend to "[guess] the correct answer without being able to explain basic math calculations" and often provide "statements indicative of low self-efficacy." Problem-solving skills, similar to those measured on the TOSLS, have been incorporated into specific student performance expectations, including the ability of the student to "use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction" (NGSS Lead States, 2013, p. 91). Not only are these a part of National standards, but this expectation is also established in state standards that require students to use mathematical procedures to perform calculations and express quantities (Georgia Department of Education, 2016; Texas Essential Knowledge and Skills for Science, 2018).

Understand and interpret basic statistics. The fourth skill in this domain is to "understand and interpret basic statistics," which is assessed on three out of the 25 items in the instrument and explained by Gormally et al. (2012) as the ability to "understand the need for statistics to quantify uncertainty in data." The most common challenges with this skill reported by faculty are the "lack of familiarity with function of statistics and with scientific uncertainty" and that "statistics prove data is correct or true" (Gormally et al., 2012). The overlap of this skill, understanding and interpreting basic statistics within national and state standards, falls in with the overlap for the previous skill, solving problems using quantitative skills, as most national and state standards include this skill within the ability of the student to problem-solve using quantitative skills.

Justify inferences, predictions, and conclusions based on quantitative data. The last skill measured in domain two of the TOSLS is to "justify inferences, predictions, and conclusions based on quantitative data"; these actions are assessed on the remaining three items on the instrument. Gormally et al. (2012) further explain this skill as the ability of the student to "interpret data and critique experimental designs to evaluate hypotheses and recognize flaws in arguments," and they identify the common student challenge with this skill to be the "tendency to misinterpret or ignore graphical data when developing a hypothesis or evaluating an argument" as reported by the surveyed faculty. This skill is an integral component of the scientific competencies of the OECD (2007), and they state it as the ability to "interpret data from related datasets presented in various formats" (p. 101). Similar to most of the other skills on the TOSLS, this skill is also in the NGSS crosscutting concepts for and within the process skills outlined in Texas curriculum that require students to "plan investigations, interpret data, and draw conclusions" (Texas Essential Knowledge and Skills for Science, 2018).

Chapter Summary

This literature review provides a framework for the ideas involved in this study regarding the relationship between student science self-efficacy and scientific literacy. There is a positive relationship between academic self-efficacy and student achievement, and students with higher self-efficacy will continue to make decisions that further empower their efficacy. Science self-efficacy is one of the academic domains that fall within academic self-efficacy and is further organized within each of the scientific domains as well. Similar to academic self-efficacy, higher science self-efficacy correlates to higher achievement in science for students. This study examines the relationship between science self-efficacy and scientific literacy and therefore explores general literacy in the literature as well. While there are various definitions of scientific literacy and what it means to be scientifically literate, there is an agreement that there is a critical need to develop scientific literacy skills among all students. The following chapter will describe the methodology to be used by the researcher during the current study. This chapter will include an overview of the research problem, research purpose and questions, research design, population and sample, instrumentation, data collection procedures, data analysis, privacy and ethical considerations, and limitations for this study.

CHAPTER III:

METHODOLOGY

The purpose of this study was to examine the relationship between science self-efficacy and scientific literacy in undergraduate students. This correlational study collected survey and assessment data from a purposeful sample of undergraduate students self-enrolled in Biology courses at a large suburban Hispanic Serving Institution (HIS) located in southeast Texas. Data were collected from the *Self-Efficacy for Learning and Doing Science Scale* (SELDS) and the *Test of Scientific Literacy Skills* (TOSLS). Quantitative data were analyzed using descriptive statistics, Pearson's product-moment correlations, and Structural Equation Modeling (SEM). This paper presents an overview of the research problem, operational definitions of the theoretical constructs, the purpose of the research and the corresponding research questions, the research design, the population and sampling of the participants, instrumentation, how the data was collected and analyzed, ethical considerations, and the limitations of the study.

Overview of the Research Problem

According to the National Research Council (2012), the number of students currently studying in STEM areas is not nearly enough to meet the demands for a skillful STEM workforce. Low self-efficacy in math and science has been linked to fewer students seeking out an education in science and mathematics. Both scientific literacy and science self-efficacy have been the focus of calls from educators and policymakers emphasizing the need to improve and reinforce them in order to improve science education (National Assessment Governing Board [NAGB], 2010; NRC, 1996, 2012). Despite the focus on scientific literacy and its incorporation into national standards as the goal of science education, there has not been a significant change in the scientific literacy of U.S. students (Impey et al., 2017; NRC, 2013; OECD, 2016). Both scientific literacy and science self-efficacy have been the focus of calls from educators and policymakers emphasizing the need to improve and reinforce them in order to improve science education (NAGB, 2010; NRC, 1996, 2012). There is a gap in the literature examining factors that influence both science self-efficacy and scientific literacy, whereas both science self-efficacy and scientific literacy have been linked to improving science education. This study examined the relationship between science self-efficacy and scientific literacy, two critical components of science education, to better understand specific correlations between the two.

Operationalization of Theoretical Constructs

This study consisted of two constructs: (a) science self-efficacy and (b) scientific literacy. According to Bandura (1997), self-efficacy is a person's beliefs about his or her personal capability to learn specific content. Britner and Pajares (2006) build on Bandura's definition by defining science self-efficacy as the learner's belief in their ability to complete science tasks, activities, or courses successfully. Science self-efficacy was measured in the study using student scores from the *Self-Efficacy for Learning and Doing Science Scale* (SELDS). According to the National Research Council (1996), scientific literacy is defined as the general knowledge and understanding that a student should have of scientific concepts and processes that he or she would need for effective decision making and participation in society productively. Scientific literacy was measured in the study through participants' scores on the *Test of Scientific Literacy Skills*.

Research Purpose, Questions, and Hypotheses

The purpose of this study was to examine the relationship between science self-efficacy and scientific literacy in undergraduate students. The research questions for this study were as follows:

R1: Is there a statistically significant relationship between science self-efficacy and scientific literacy?

H_0: A statistically significant relationship does not exist between science self-efficacy and scientific literacy.

H_a: A statistically significant relationship does exist between science self-efficacy and scientific literacy.

R2: Is there a statistically significant relationship between self-efficacy for learning and understanding science topics and student ability to understand methods of inquiry to develop scientific knowledge?

H_0: A statistically significant relationship does not exist between self-efficacy for learning and understanding science topics and student ability to understand methods of inquiry to develop scientific knowledge.

H_a: A statistically significant relationship does exist between self-efficacy for learning and understanding science topics and student ability to understand methods of inquiry to develop scientific knowledge.

R3: Is there a statistically significant relationship between self-efficacy for learning and understanding science and student ability to organize, analyze, and interpret quantitative data and scientific information?

H_0: A statistically significant relationship does not exist between self-efficacy for learning and understanding science and student ability to organize, analyze, and interpret quantitative data and scientific information as measured by the TOSLS.

H_a: A statistically significant relationship does exist between self-efficacy for learning and understanding science and student ability to organize, analyze, and interpret quantitative data and scientific information as measured by the TOSLS.

R4: Is there a statistically significant relationship between self-efficacy for doing scientific activities and student ability to understand methods of inquiry to develop scientific knowledge?

H_0: A statistically significant relationship does not exist between self-efficacy for doing scientific activities and student ability to understand methods of inquiry to develop scientific knowledge.

H_a: A statistically significant relationship does exist between self-efficacy for doing scientific activities and student ability to understand methods of inquiry to develop scientific knowledge.

R5: Is there a statistically significant relationship between self-efficacy for doing scientific activities and student ability to organize, analyze, and interpret quantitative data and scientific information?

H_0: A statistically significant relationship does not exist between self-efficacy for doing scientific activities and student ability to organize, analyze, and interpret quantitative data and scientific information.

H_a: A statistically significant relationship does exist between self-efficacy for doing scientific activities and student ability to organize, analyze, and interpret quantitative data and scientific information.

Research Design

For this study, a correlational research design was used to examine the relationship between undergraduate student science self-efficacy and scientific literacy. The advantage of implementing this design will be that it allowed the study to determine both the strength and the direction of relationships between science self-efficacy and scientific literacy. The researcher solicited a purposeful sample of students self-enrolled in various Biology courses from a large suburban public university to complete the SELDS and the TOSLS assessment in one sitting. Data were collected through online administration of the SELDS and TOSLS instruments through Qualtrics. Quantitative data were analyzed using descriptive statistics, Pearson's product-moment correlations, and Structural Equation Modeling (SEM).

Population and Sample

The population of the study consisted of a suburban public university located in Texas. The participating university serves approximately 9,000 students (undergraduate and graduate) and has two campuses. Of the university population, approximately 62% are female, and 38% are male. Of the population, 38% self-identify as White, 35% as Hispanic/Latino, 10% as African American, 8% as Asian, 6% as international, and 3% as other races.

Table 3.1

Undergraduate Enrollment by Race/Ethnicity and Gender

	Male (n)	Female (n)
White	1,009	1,480
Black	161	329
Asian	253	239
American Indian	4	9
Native Hawaiian	2	2
Multi-racial	89	120
Unknown	40	45
International	48	46
Hispanic	958	1,864

Table 3.2

Hispanic and Non-Hispanic Enrollment

	Frequency (n)
Hispanic only	949
Hispanic, American Indian, or Alaska Native	216
Hispanic, Asian	19
Hispanic, Black or African American	49
Hispanic, Multi-Racial	189
Hispanic, Native Hawaiian or Other Pacific Islander	12
Hispanic, White	1,924
Total Hispanic	3,358
Total Non-Hispanic	5,724
Total Enrollment	9,082

Instrumentation

Self-Efficacy for Learning and Doing Science Scale (SELDS)

The DEVISE project by Cornell University is working on developing scales that can be used specifically for citizen science participants (Porticella et al., 2017). The Self-Efficacy for learning and doing science (SELDS) scale utilized in this study was created to measure the participant's confidence in learning science topics and performing science activities in 2017 (Porticella et al., 2017). SELDS is an 8-item scale split into two components, one measuring the confidence in learning science and the other measuring confidence in doing science. Each component is 4-questions with a 5-point Likert scale ranging from *Strongly Disagree* to *Strongly Agree*. The results can be used either as an overall instrument level or at the subscale level. The scale has undergone a series of validity tests by the Cornell Lab of Ornithology. Through the pilot tests conducted to assess Cronbach's alpha coefficients, the alpha coefficient of the generic SELDS was 0.92, which is indicative of high internal consistency. The reliability of the scale was measured to be r = .82 and .89, which indicates that the SELDS scale could acquire stable responses from a single sample over time.

The total item correlations within the scale were measured by Pearson's correlation between each of the items on the scale and the total scale overall, and it ranged from .54 to .83, which indicates that all of the items within the scale measure consistently with the total scale, and it also suggests a positive item discrimination power within the scale. The SELDS scale also showed positive correlations with a different scale measuring interest in science and motivation for learning and doing science, suggesting concurrent validity. Lastly, an exploratory factor analysis was conducted and showed a unidimensional scale with all factor loadings above 0.70 (Porticella et al., 2017).

Test of Scientific Literacy Skills (TOSLS)

The Test of Scientific Literacy Skills (TOSLS) was developed by Gormally et al. (2012). Traditional tests designed to measure student scientific literacy skills are designed to focus specifically on one skill and are limited to instructors as they require instruments that may not be readily available (Gormally et al., 2012). Therefore, Gormally et al. (2012) designed this test to measure and assess student proficiency across all of the skills they need to be scientifically literate in an undergraduate introductory science course while freely available and quick to score and administer. The Test of Scientific Literacy Skills was administered to students through the Qualtrics software system on the students' personal computers. The TOSLS assessment has a time limit of 35 minutes, and it contains 28 multiple choice questions. Multiple rounds of pilot testing, interviews, and expert reviews were conducted to create the TOSLS assessment and explored the internal consistency of the test to determine its reliability. The Kuder-Richardson 20 formula was utilized to measure the internal consistency, and TOSLS scored 0.731 as a pretest and 0.748 as a post-test, which is considered to reflect good test reliability (Gormally et al., 2012).

Data Collection Procedures

The researcher obtained permission to conduct the study from the University of Houston-Clear Lake (UHCL) Committee for the Protection of Human Subjects (CPHS) and the participating University's Institutional Review Board (IRB) before collecting data. After permission was gathered, the researcher solicited undergraduate students enrolled in selected Biology courses at the participating university by contacting the Biology professors via email with information regarding the purpose of the study and the process for collecting the surveys. The researcher disseminated an electronic link containing access to the SELDS and TOSLS assessment through the use of Qualtrics. The purpose of the study, voluntary participation, the timeframe for completing the survey, as well as ethical and confidentiality considerations were communicated to participants through a cover letter in Qualtrics. A letter of consent outlining the details of the study was also given to students through Qualtrics. Appendix A contains the cover letter presented through Qualtrics, and Appendix B contains the letter of consent presented through Qualtrics.

Once participants gave consent, demographic information was collected, and the survey was administered. Once survey responses were collected, the data was entered into quantitative research software Statistical Package for the Social Sciences (SPSS) for further analysis. All data were secured in a password protected folder on the researcher's computer. At the culmination of the study, the data will be maintained by the researcher for five years, which is the time required by CPHS guidelines. The researcher will destroy the contents of the file once the deadline expires.

Data Analysis

Quantitative Analysis

All data were imported into IBM SPSS for analysis. To answer research question one, *Is there a statistically significant relationship between science self-efficacy and scientific literacy*, a Pearson's product moment correlation (r) was conducted to determine if there is a significant relationship between science self-efficacy and scientific literacy skills.

To answer research question two, *Is there a statistically significant relationship between self-efficacy for learning and understanding science topics and student ability to understand methods of inquiry to develop scientific knowledge?*, a Pearson's product moment correlation (r) was conducted to determine if there is a significant relationship between science self-efficacy and scientific literacy skills.

To answer research question three, *Is there a statistically significant relationship between self-efficacy for learning and understanding science and student ability to organize, analyze, and interpret quantitative data and scientific information?*, a Pearson's product moment correlation (r) was conducted to determine if there is a significant relationship between science self-efficacy and scientific literacy skills. The data from Qualtrics was also be imported into AMOS in order to utilize structural equation modeling (SEM). Structural equation modeling was utilized to determine if there is a statistically significant relationship between the independent variables of science self-efficacy and scientific literacy. According to Mueller (1997), SEM can expand simpler regression and correlation models as it allows for hypothesizing, analyzing, and representing the relationships between variables. In this study, SEM was used to conduct a path analysis of the direct and indirect relationships between factors as well as the strength of those relationships.

To answer research question four, Is there a statistically significant relationship between self-efficacy for doing scientific activities and student ability to understand methods of inquiry to develop scientific knowledge?, a Pearson's product moment correlation (r) was conducted to determine if there is a significant relationship between science self-efficacy and scientific literacy skills.

To answer research question five, Is there a statistically significant relationship between self-efficacy for doing scientific activities and student ability to organize, analyze, and interpret quantitative data and scientific information? a Pearson's product moment correlation (r) was conducted to determine if there is a significant relationship between science self-efficacy and scientific literacy skills.

Privacy and Ethical Considerations

The researcher obtained permission to conduct the study from the UHCL's CPHS and the participating University's IRB before collecting data. The name of the university in which the study will be conducted will not be mentioned in the study, nor will the individual names of the participants who take the survey. A survey cover letter was attached at the start of the Qualtrics survey, which stated the purpose of the study, ensuring that the participants were aware that their participation was voluntary and that their responses and identities will remain completely confidential. Each participant who completed the survey was assigned a random participant number, and all data taken from the survey each participant completes is reflected with the assigned participant number. The data collected in the study was stored on a password protected computer hard drive, and the researcher's cloud drive. The computer was kept in a locked office. The data in the cloud will be stored safely for five years, after which time the data will be destroyed.

Limitations of the Study

This study has several limitations. First, is the focus on undergraduate students in selected Biology courses. It is possible that the dynamics between student science self-efficacy and scientific literacy varies from one course to another or in different universities. One might expect that the level of scientific literacy will be higher for students who are enrolled in the courses because they already plan to pursue science in their careers. Second, is that it is assumed that all students with varying levels of self-efficacy will participate in the study and take the survey. This is almost certainly not the case. Students enrolled in undergraduate courses in Biology may have varying levels of science self-efficacy and scientific literacy, and some may choose not to participate in the study due to their level of self-efficacy or scientific literacy.

Third, is the honesty of the participants in the survey conducted online. Some of the participants may not give honest responses to the self-efficacy scale, therefore misrepresenting their science self-efficacy in the study. Some students may use external resources in the scientific literacy component making their scores on the scientific literacy component inflated or inaccurate. Fourth, the study was conducted in only one university in selected courses and is, therefore, generalizing the results to the population and may not be an accurate representation of the university or undergraduate students enrolled in science courses.

Conclusion

The purpose of this study was to examine the relationship between science self-efficacy and scientific literacy in undergraduate students. This chapter was intended to describe the methodology of this correlational study in detail. The quantitative portion of this study used a purposeful sample of undergraduate students enrolled in selected Biology courses at a public University in Texas. Data were collected from the sample using Qualtrics to administer the SELDS scale and TOSLS. The quantitative data collected was analyzed using a Pearson's product-moment correlation and structural equation model (SEM), which examines the relationship between student science self-efficacy and scientific literacy in undergraduate students. The information collected from the survey was analyzed and coded to produce a descriptive overall response. The results from this methodology are reported in chapter four of this study.

CHAPTER IV:

RESULTS

The purpose of this study was to examine the relationship between science self-efficacy and scientific literacy in undergraduate students. This chapter presents the results of the quantitative data analysis of the study. First, an explanation of the participant's demographics of the study is presented, followed by the results of the data analysis. This chapter presents the data analysis for each of the five research questions and concludes with a summary.

Participant Demographics

Biology professors at the participating university agreed to administer the survey in their courses, which as a department consisted of approximately 481 students; of that, 225 students completed the survey (46.8% response rate). Table 4.1 provides specific response data for all participants in the survey. One hundred and seventy students indicated female (75.6%), while 55 students indicated male. Participants were prompted to select all races that apply, 115 students (51.1%) were White/Caucasian, 45 students (20.0%) were Asian, 24 students (10.7) were other, and 14 students (6.2%) were Black/African American. Table 4.1 provides specific participating student demographics.

Table 4.1

Demographics of Participating Students

	All (%)
Total Students	100.0 (n = 225)
Female	75.6 (n = 170)
Male	24.4 (n = 55)
White/Caucasian	51.1 (n = 115)
White/Caucasian and Black/African American	1.8 (n = 4)
White/Caucasian and American Indian/Alaska Native	0.9 (n = 2)
White/Caucasian and Asian	0.4 (n = 1)
White/Caucasian and Native Hawaiian or Pacific Islander	0.4 (n = 1)
White/Caucasian and Other	6.7 (n = 15)
Black/African American	6.2 (n = 14)
Black/African American and Other	0.9 (n = 2)
American Indian/Alaska Native and other	0.4 (n = 1)
Asian	20.0 (n = 45)
Native Hawaiian or Pacific Islander	0.4 (n = 1)
Native Hawaiian or Pacific Islander and Other	0.0 (n = 0)
Other	10.7 (n = 24)

Research Question One

Research question one, Is there a statistically significant relationship between science self-efficacy and scientific literacy?, was measured using frequencies, percentages, and a Pearson's Product-Moment correlation (r). Results of the Pearson's Product Moment correlation

(r) indicated there was a statistically significant positive relationship between a student's science self-efficacy and his or her scientific literacy TOSLS scores, $r(225) = 0.190$, $p = .004$, $r2 = 0.04$. As student's science self-efficacy increased, so did the scientific literacy TOSLS scores. The proportion of variation in TOSLS scores attributed to science self-efficacy was 4.0%. The average scientific literacy score on the TOSLS assessment was 55.5% out of 100.0% (SD = 22.1).

The Self-Efficacy for Learning and Doing Science (SELDS) scale measured student science self-efficacy (8-items) using a 5-point Likert scale (1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree). Tables 4.2 and 4.3 display the responses from the SELDS scale from all participants. Students (80.0%) Agreed/Strongly Agreed about thinking that they were pretty good at understanding science topics and that they could quickly understand new science topics compared to other people their age (58.7%). Most students (40.4%) Disagreed/Strongly Disagreed about taking a long time to understand new science topics but were Neutral (28.4%) about taking a long time to understand how to do scientific activities. Students also Agreed/Strongly Agreed about feeling confident in their ability to explain science topics to others (58.7%) and in their ability to explain how to do scientific activities to others (47.1%). Majority of students (87.6%) Agreed/Strongly Agreed that they were pretty good at following instructions for scientific activities and that they could do scientific activities well compared to other people their age (74.2%).

Table 4.2

Expanded Responses from the SELDS Scale (%)

Survey Item	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. I think I'm pretty good at understanding science topics.	1.3 (n = 3)	6.2 (n = 14)	15.6 (n = 35)	64.4 (n = 145)	15.6 (n = 35)
2. Compared to other people my age, I think I can quickly understand new science topics.	0.9 (n = 2)	4.4 (n = 10)	36.0 (n = 81)	45.8 (n = 103)	12.9 (n = 29)
3. It takes me a long time to understand new science topics.	5.3 (n = 12)	35.1 (n = 79)	32.4 (n = 73)	21.3 (n = 48)	5.8 (n = 13)
4. I feel confident in my ability to explain science topics to others.	2.2 (n = 5)	9.8 (n = 22)	29.3 (n = 66)	46.2 (n = 104)	12.4 (n = 28)
5. I think I'm pretty good at following instructions for scientific activities.	0.4 (n = 1)	2.7 (n = 6)	9.3 (n = 21)	52.9 (n = 119)	34.7 (n = 78)
6. Compared to other people my age, I think I can do scientific activities pretty well.	0.4 (n = 1)	4.4 (n = 10)	20.9 (n = 47)	49.8 (n = 112)	24.4 (n = 55)
7. It takes me a long time to understand how to do scientific activities.	10.7 (n = 24)	40.9 (n = 92)	28.4 (n = 64)	15.1 (n = 34)	4.9 (n = 11)
8. I feel confident about my ability to explain how to do scientific activities to others.	0.0 (n = 0)	5.8 (n = 13)	31.6 (n = 71)	47.1 (n = 106)	15.6 (n = 35)

Table 4.3

Collapsed Responses from the SELDS Scale (%)

Survey Item	Strongly Disagree/Disagree	Neutral	Agree/Strongly Agree
1. I think I'm pretty good at understanding science topics.	7.6 (n = 17)	15.6 (n = 35)	80.0 (n = 180)
2. Compared to other people my age, I think I can quickly understand new science topics.	5.3 (n = 12)	36.0 (n = 81)	58.7 (n = 132)
3. It takes me a long time to understand new science topics.	40.4 (n = 91)	32.4 (n = 73)	27.1 (n = 61)
4. I feel confident in my ability to explain science topics to others.	12.0 (n = 27)	29.3 (n = 66)	58.7 (n = 132)
5. I think I'm pretty good at following instructions for scientific activities.	3.1 (n = 7)	9.3 (n = 21)	87.6 (n = 197)
6. Compared to other people my age, I think I can do scientific activities pretty well.	4.9 (n = 11)	20.9 (n = 47)	74.2 (n = 167)
7. It takes me a long time to understand how to do scientific activities.	10.7 (n = 24)	28.4 (n = 64)	15.1 (n = 34)
8. I feel confident about my ability to explain how to do scientific activities to others.	0.0 (n = 0)	31.6 (n = 71)	47.1 (n = 106)

Research Question Two

Research question two, Is there a statistically significant relationship between self-efficacy for learning and understanding science topics and student ability to understand methods of inquiry to develop scientific knowledge?, was measured using Pearson's Product-Moment correlation (r). Results from the Pearson's Product Moment correlation (r) indicated that there was a statistically significant positive relationship between a student's self-efficacy for learning and understanding science topics and student ability to understand methods of inquiry to develop scientific knowledge, $r = .16$, $r2 = 0.03$, $p = .015$.

As student's self-efficacy for learning and understanding science topics increased, so did their ability to understand methods of inquiry to develop scientific knowledge on the TOSLS assessment. The proportion of variation in TOSLS scores on questions that assessed student ability to understand methods of inquiry to develop scientific knowledge attributed to their self-efficacy for learning and understanding science topics was 3.0%. Pearson's Product Moment correlations (r) were also assessed on the items within the self-efficacy for learning and understanding science topics component of the SELDS scale were also individually measured with the skills in the understanding methods of inquiry to develop scientific knowledge component of the TOSLS assessment as shown in Figure 4.1.

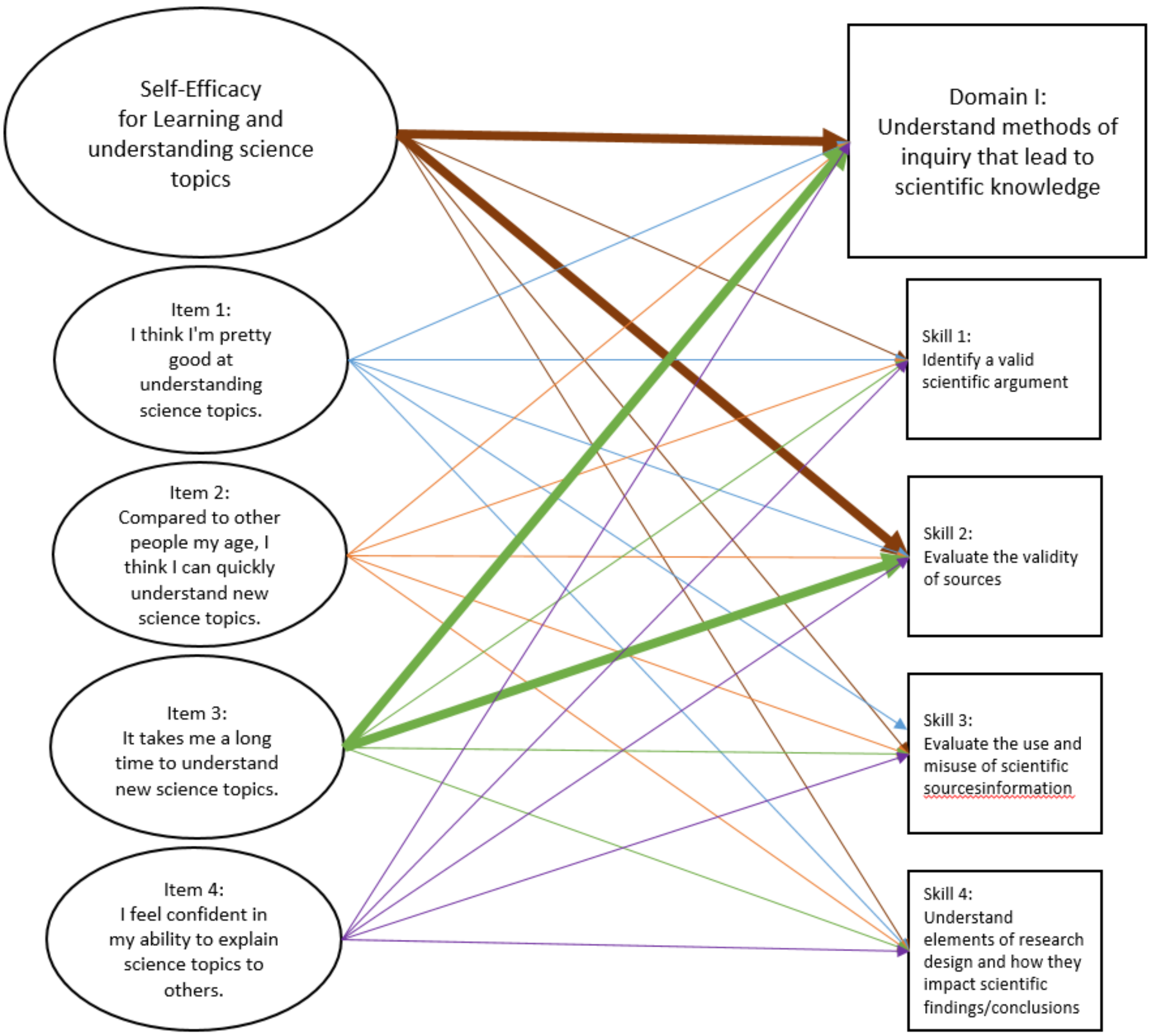

Figure 4.1 Pearson's Product Moment Correlations: SELDS Learning Component and TOSLS Domain I

The results of the Pearson's Product Moment correlations (r) are included in Table 4.4. The Pearson's Product Moment correlations (r) indicated that there was also a statistically significant positive relationship between a student's self-efficacy for learning and understanding science topics and their ability to evaluate the validity of sources, r = .15, r2 = .02, p = .02. As self-efficacy for learning and understanding science topics increased, so did the ability to evaluate the validity of sources on the TOSLS assessment. The proportion of variation in scores on questions that assessed their ability to evaluate the validity of sources attributed to their self-efficacy for learning and understanding science topics was 2.0%.

Item three, “It takes me a long time to understand new science topics” on the SELDS scale, had a statistically significant positive relationship with the ability to understand methods of inquiry that lead to scientific knowledge, $r = .17$, $r2 = .03$, $p = .009$, and the ability to evaluate the validity of sources, $r = .19$, $r2 = .04$, $p = .003$ on the TOSLS assessment. As self-efficacy on item three on the SELDS scale increased, so did the ability to organize, analyze, and interpret quantitative data and scientific information. The proportion of variation in the scores for the ability to organize, analyze, and interpret quantitative data and scientific information on the TOSLS assessment attributed to self-efficacy reported on item three on the SELDS scale was 3.0%. As self-efficacy on item three on the SELDS scale increased, so did the scores on questions that assessed student ability to evaluate the validity of sources on the TOSLS assessment. The proportion of variation in the scores on questions that assessed student ability to evaluate the validity of sources attributed to self-efficacy reported on item three on the SELDS scale was 4.0%.

Table 4.4

Correlations: SELDS Learning Component and TOSLS Domain I

	Domain I: Understand methods of inquiry that lead to scientific knowledge	Skill 1: Identify a valid scientific argument	Skill 2: Evaluate the validity of sources	Skill 3: Evaluate the use and misuse of scientific information sources	Skill 4: Understand elements of research design and how they impact scientific findings/conclusions
Self-Efficacy for Learning and understanding science topics	r = .162*	r = .128	r = .153*	r = .108	r = .059
Item 1: I think I'm pretty good at understanding science topics.	r = .127	r = .100	r = .090	r = .100	r = .097
Item 2: Compared to other people my age, I think I can quickly understand new science topics.	r = .042	r = .040	r = .050	r = .032	r = -.002
Item 3: It takes me a long time to understand new science topics.	r = .173*	r = .100	r = .194*	r = .088	r = .056
Item 4: I feel confident in my ability to explain science topics to others.	r = .123	r =.130	r = .100	r =.098	r = .024

*Statistically Significant ($p < .05$)

Research Question Three

Research question three, Is there a statistically significant relationship between self-efficacy for learning and understanding science and student ability to organize, analyze, and interpret quantitative data and scientific information?, was answered using a Pearson's Product-

Moment correlation (r). Results from the Pearson's Product Moment correlation (r) indicated that there was a statistically significant positive relationship between a student's self-efficacy for learning and understanding science topics and student ability to organize, analyze, and interpret quantitative data and scientific information, $r = .228$, $r2 = 0.05$, $p = .001$. As self-efficacy for learning and understanding science topics increased, so did the ability to organize, analyze, and interpret quantitative data and scientific information on the TOSLS assessment.

The proportion of variation in TOSLS scores on questions that assessed student ability to organize, analyze, and interpret quantitative data and scientific information attributed to self-efficacy for learning and understanding science topics was 5.0%. The items within the self-efficacy for learning and understanding science topics component of the SELDS scale were also individually measured with the skills in the organize, analyze, and interpret quantitative data and scientific information component of the TOSLS assessment as shown in Figure 4.2 using Pearson's Product Moment correlations (r). The results of the Pearson's Product Moment correlation (r) are included in Table 4.5.

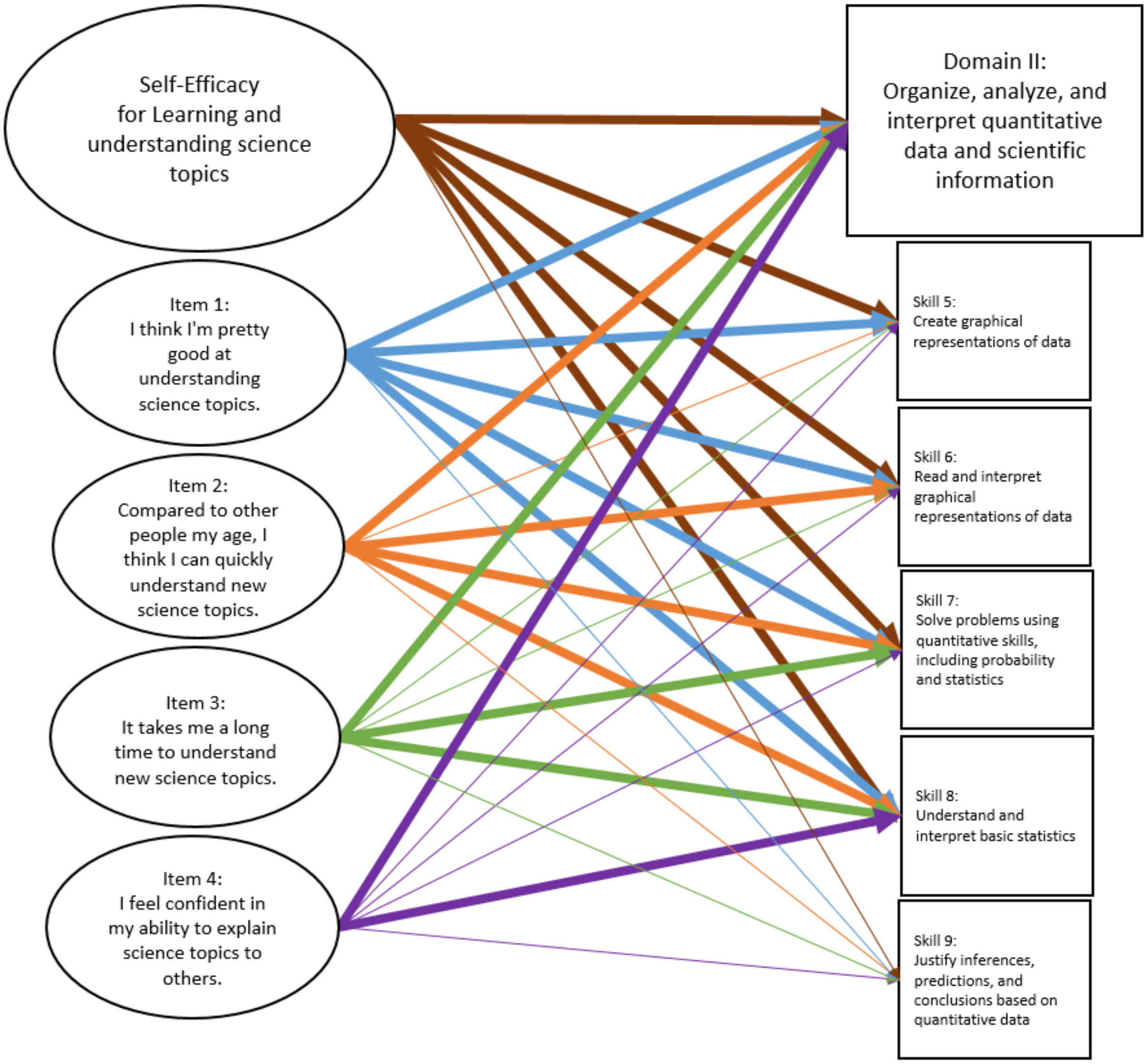

Figure 4.2 Pearson's Product Moment Correlations: SELDS Learning Component and TOSLS Domain II

Table 4.5

Correlations: SELDS Learning Component and TOSLS Domain II

	Domain II: Organize, analyze, and interpret quantitative data and scientific information	Skill 5: Create graphical representations of data	Skill 6: Read and interpret graphical representations of data	Skill 7: Solve problems using quantitative skills, including probability and statistics	Skill 8: Understand and interpret basic statistics	Skill 9: Justify inferences, predictions, and conclusions based on quantitative data
Self-Efficacy for Learning and understanding science topics	r = .228*	r = .139*	r = .144*	r = .208*	r = .236*	r = .079
Item 1: I think I'm pretty good at understanding science topics.	r = .235*	r = .172*	r = .158*	r = .186*	r = .204*	r = .123
Item 2: Compared to other people my age, I think I can quickly understand new science topics.	r = .171*	r = .090	r = .148*	r = .212*	r = .154*	r = -.022
Item 3: It takes me a long time to understand new science topics.	r = .139*	r = .079	r = .031	r = .135*	r = .154*	r = .104
Item 4: I feel confident in my ability to explain science topics to others.	r = .144*	r = .080	r = .112	r =.094	r = .188*	r = .024

*Statistically Significant ($p < .05$)

The Pearson's Product Moment correlations (r) indicated a statistically significant positive relationship between a student's self-efficacy for learning and understanding science topics and the ability to create graphical representations of data ($r = .139$, $r2 = .019$, $p = .038$) and read and interpret graphical representations of data ($r = .144$, $r2 = .02$, $p = .031$). Student's self-efficacy for learning and understanding science topics also produced a statistically significant positive relationship with the ability to solve problems using quantitative skills ($r = .208$, $r2 = .043$, $p = .002$), and understand and interpret basic statistics ($r = .236$, $r2 = .056$, $p < .001$) on the TOSLS assessment. As self-efficacy for learning and understanding science topics increased, so did the ability to create graphical representations of data, read and interpret graphical representations of data, solve problems using quantitative skills, and understand and interpret basic statistics. The proportion of variation attributed to self-efficacy for learning and understanding science topics in TOSLS scores for questions that assessed the ability to create graphical representations of data was 1.9%, the ability to read and interpret graphical representations of data was 2.0%. Whereas the proportion of variation attributed to self-efficacy for learning and understanding science topics in TOSLS scores for questions that assessed the ability to solve problems using quantitative skills was 4.3%, and the ability to understand and interpret basic statistics was 5.6%.

The Pearson's Product Moment correlations (r) also indicated a statistically significant relationship between the scores on domain two on the TOSLS assessment and item one $r = .235$, $r^2 = .055$, $p < .001$, item two $r = .171$, $r^2 = .029$, $p = .010$, item three $r = .139$, $r^2 = .019$, $p = .038$, and item four on the SELDS scale $r = .144$, $r^2 = .021$, $p = .031$. As self-efficacy on items one thru four on the SELDS scale increased, so did the scores on domain two on the TOSLS assessment. The proportion of variation in TOSLS scores for Domain II attributed to self-efficacy reported on item one was 5.5%, item two was 2.9%, item three was 1.9%, and item four was 2.1%.

Item one on the self-efficacy for learning and understanding science topics component of the SELDS scale also had a statistically significant positive relationship with the ability to create graphical representations of data ($r = .172$, $r^2 = .030$, $p = .010$) and the ability to read and interpret graphical representations of data ($r = .158$, $r^2 = .025$, $p = .018$) on the TOSLS assessment. Item one also had a statistically significant positive relationship with the ability to solve problems using quantitative skills ($r = .186$, $r^2 = .035$, $p = .005$) and the ability to understand and interpret basic statistics ($r = .204$, $r^2 = .042$, $p = .002$) on the TOSLS assessment. As self-efficacy reported on item one of the SELDS scale increased, so did the ability to create graphical representations of data, read and interpret graphical representations of data, solve problems using quantitative skills, and understand and interpret basic statistics. The proportion of variation attributed to self-efficacy on item one on the SELDS scale in TOSLS scores for questions that assessed the ability to create graphical representations of data was 3.0%, read and interpret graphical representations of data was 2.5%, solve problems using quantitative skills was 3.5%, and understand and interpret basic statistics was 4.2%.

Item two on the self-efficacy for learning and understanding science topics component of the SELDS scale indicated a statistically significant positive relationship with the ability to read and interpret graphical representations of data ($r = .148$, $r^2 = .022$, $p = .027$), solve problems using quantitative skills ($r = .212$, $r^2 = .045$, $p = .001$), and understand and interpret basic statistics ($r = .154$, $r^2 = .024$, $p = .021$). As self-efficacy reported on item two of the SELDS scale increased, so did the ability to read and interpret graphical representations of data, solve problems using quantitative skills, and understand and interpret basic statistics.

The proportion of variation attributed to self-efficacy on item two on the SELDS scale in TOSLS scores for questions that assessed the ability to read and interpret graphical representations of data was 2.2%, solve problems using quantitative skills was 4.5%, and understand and interpret basic statistics was 2.4%. Whereas item three on the self-efficacy for learning and understanding science topics component of the SELDS scale indicated a statistically significant positive relationship with the ability to solve problems using quantitative skills ($r = .135$, $r^2 = .018$, $p = .043$), and understand and interpret basic statistics ($r = .154$, $r^2 = .024$, $p = .020$) on the TOSLS assessment. As self-efficacy reported on item three of the SELDS scale increased, so did the ability to solve problems using quantitative skills, understand, and interpret basic statistics. The proportion of variation attributed to self-efficacy on item three on the SELDS scale in TOSLS scores for questions that assessed skill the ability to solve problems using quantitative skills was 1.8% and understand and interpret basic statistics was 2.4%.

Lastly, item four on the self-efficacy for learning and understanding science topics component of the SELDS scale only indicated a statistically significant positive relationship with the ability to understand and interpret basic statistics, $r = .188$, $r^2 = .035$, $p = .005$. As self-efficacy reported on item four on the SELDS scale increased, so did the ability to understand and interpret basic statistics. The proportion of variation in scores for questions that assessed the ability to understand and interpret basic statistics attributed to self-efficacy on item four on the SELDS scale was 3.5%.

Structural equation modeling (SEM) was also used to determine if there was a statistically significant relationship between the items of SELDS and skills measured on the TOSLS assessment. Figure 4.3 depicts the SEM model of the relationships between the items on the SELDS scale and the skills measured on the TOSLS assessment. The Goodness of Fit index (GFI) was .994, the Incremental Fit Index (IFI) was 1.002, and the Comparative Fit Index (CFI) value was 1.00. According to Byrne (2001), a value over .80 is an acceptable fit, and values approaching 1.0 are considered excellent. Correlation coefficients were computed among the four SELDS items and five TOSLS skills with interactions in the specified model. A p-value less than .05 was required for significance. The correlational analyses presented in Table 4.6 showed that six out of the 10 included correlations were significant.

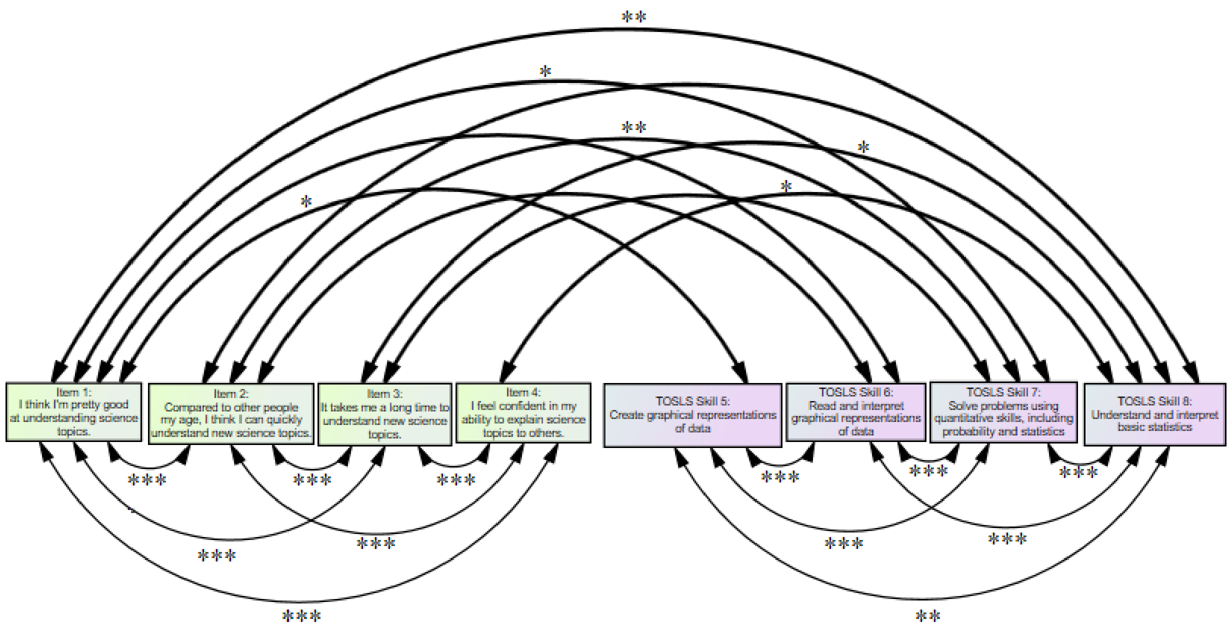

Figure 4.3 SEM: SELDS Learning Component and TOSLS Domain II

Statistically Significant *($p < .05$), ** ($p < .01$), *** ($p < .001$)

Table 4.6

SEM Correlations: SELDS Learning Component and TOSLS Domain II

	Skill 5	Skill 6	Skill 7	Skill 8
Item 1	.038*	.087	.020*	.009*
Item 2	---	.110	.007*	.066
Item 3	---	---	.062	.029*
Item 4	---	---	---	.027*

*Statistically Significant ($p < .05$)

Research Question Four

Research question four, Is there a statistically significant relationship between self-efficacy for doing scientific activities and student ability to understand methods of inquiry to develop scientific knowledge?, was answered using a Pearson's Product-Moment correlation (r). Results from the Pearson's Product Moment correlation (r) indicated that there was no statistically significant positive relationship between a student's self-efficacy for doing scientific activities and student ability to understand methods of inquiry to develop scientific knowledge, $r = .098$, $p = .142$. In other words, student's self-efficacy for doing scientific activities has nothing to do with student ability to understand methods of inquiry to develop scientific knowledge.

The items within the self-efficacy for doing scientific activities component of the SELDS scale were also individually measured with the skills in the understanding methods of inquiry to develop scientific knowledge component of the TOSLS assessment as shown in Figure 4.4 using Pearson's Product Moment correlations (r). The results of the Pearson's Product Moment correlation (r) are included in Table 4.7. Item five on the self-efficacy for doing scientific activities component of the SELDS scale indicated a statistically significant positive relationship with the ability to understand methods of inquiry that lead to scientific knowledge ($r = .157$, $r^2 = .025$, $p = .019$), identify a valid scientific argument ($r = .158$, $r^2 = .025$, $p = .018$), and evaluate the use and misuse of scientific information sources ($r = .138$, $r^2 = .019$, $p = .039$).

As self-efficacy reported on item five on the SELDS scale increased, so did the ability to understand methods of inquiry that lead to scientific knowledge, identify a valid scientific argument, and evaluate the use and misuse of scientific information sources. The proportion of variation attributed to self-efficacy reported on the ability to understand methods of inquiry that lead to scientific knowledge was 2.5%, identify a valid scientific argument was 2.5%, and evaluate the use and misuse of scientific information sources was 1.9%.

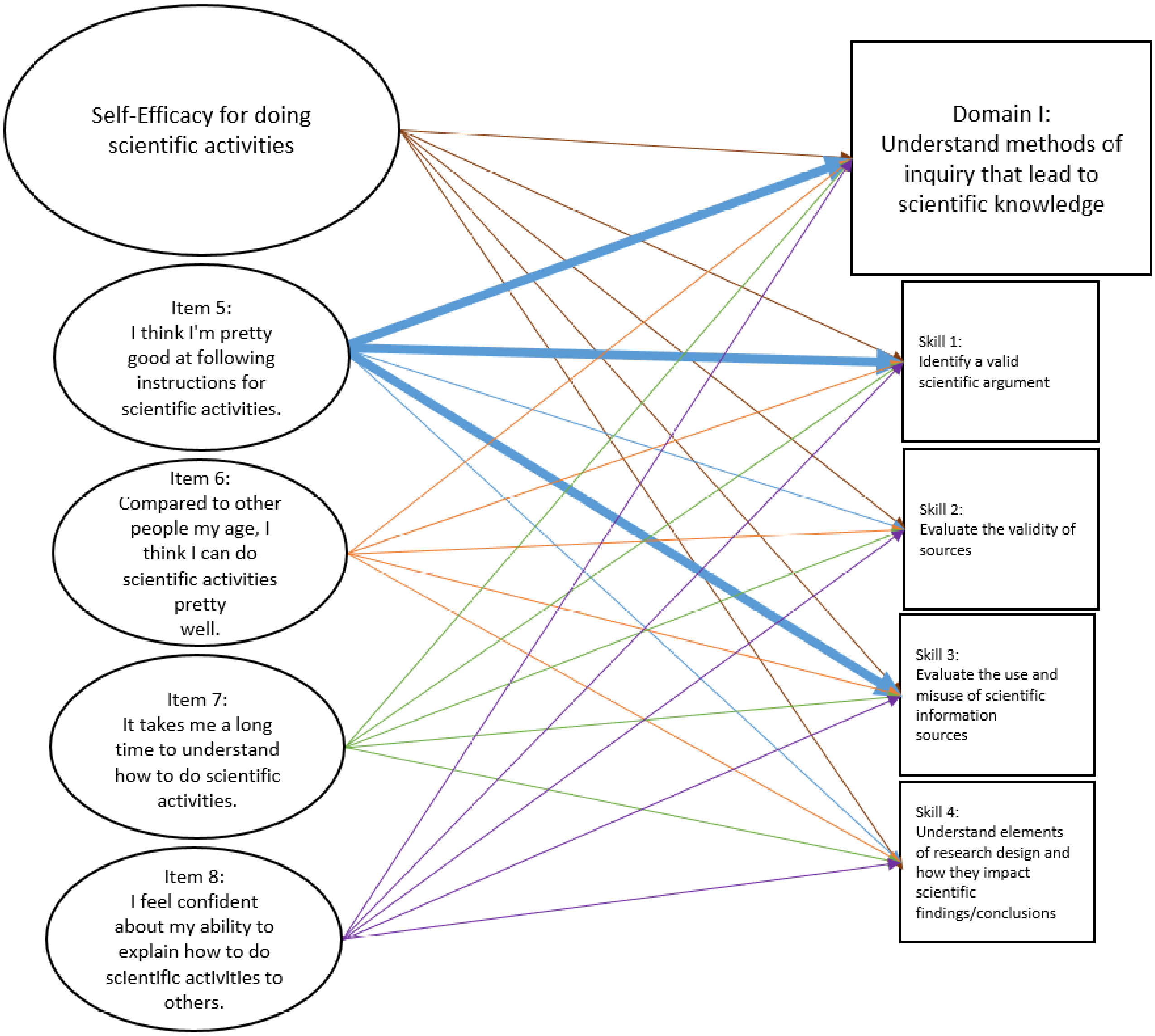

Figure 4.4 Pearson's Product Moment Correlations: SELDS Doing Component and TOSLS Domain I

Table 4.7

Correlations: SELDS Doing Component and TOSLS Domain I

	Domain I: Understand methods of inquiry that lead to scientific knowledge	Skill 1: Identify a valid scientific argument	Skill 2: Evaluate the validity of sources	Skill 3: Evaluate the use and misuse of scientific information sources	Skill 4: Understand elements of research design and how they impact scientific findings/conclus ions
Self-Efficacy for doing scientific activities	r = .098	r = .114	r = .063	r = .072	r = .053
Item 5: I think I'm pretty good at following instructions for scientific activities.	r = .157*	r = .158*	r = .106	r = .138*	r = .110
Item 6: Compared to other people my age, I think I can do scientific activities pretty well.	r = -.003	r = .034	r = -.034	r = .049	r = -.011
Item 7: It takes me a long time to understand how to do scientific activities.	r = .123	r = .114	r = .093	r = .070	r = .041
Item 8: I feel confident about my ability to explain how to do scientific activities to others.	r = .035	r =.045	r = .028	r =-.008	r = .047

*Statistically Significant ($p < .05$)

Research Question Five

Research question five, Is there a statistically significant relationship between self-efficacy for doing scientific activities and student ability to organize, analyze, and interpret quantitative data and scientific information?, was answered using a Pearson's Product-Moment correlation (r). Results from the Pearson's Product Moment correlation (r) indicated that there was a statistically significant positive relationship between a student's self-efficacy for doing scientific activities and student ability to organize, analyze, and interpret quantitative data and scientific information, $r = .144$, $r^2 = .021$, $p = .030$. As self-efficacy for doing scientific activities increased, so did their ability to organize, analyze, and interpret quantitative data and scientific information on the TOSLS assessment.

The proportion of variation in scores on questions that assessed student ability to organize, analyze, and interpret quantitative data and scientific information on the TOSLS assessment attributed to student's self-efficacy for doing scientific activities was 2.1%. The items within the self-efficacy for doing scientific activities component of the SELDS scale were also individually measured with the skills in the organize, analyze, and interpret quantitative data and scientific information component of the TOSLS assessment as shown in Figure 4.4 using Pearson's Product Moment correlations (r). The results of the Pearson's Product Moment correlation (r) are included in Table 4.8.

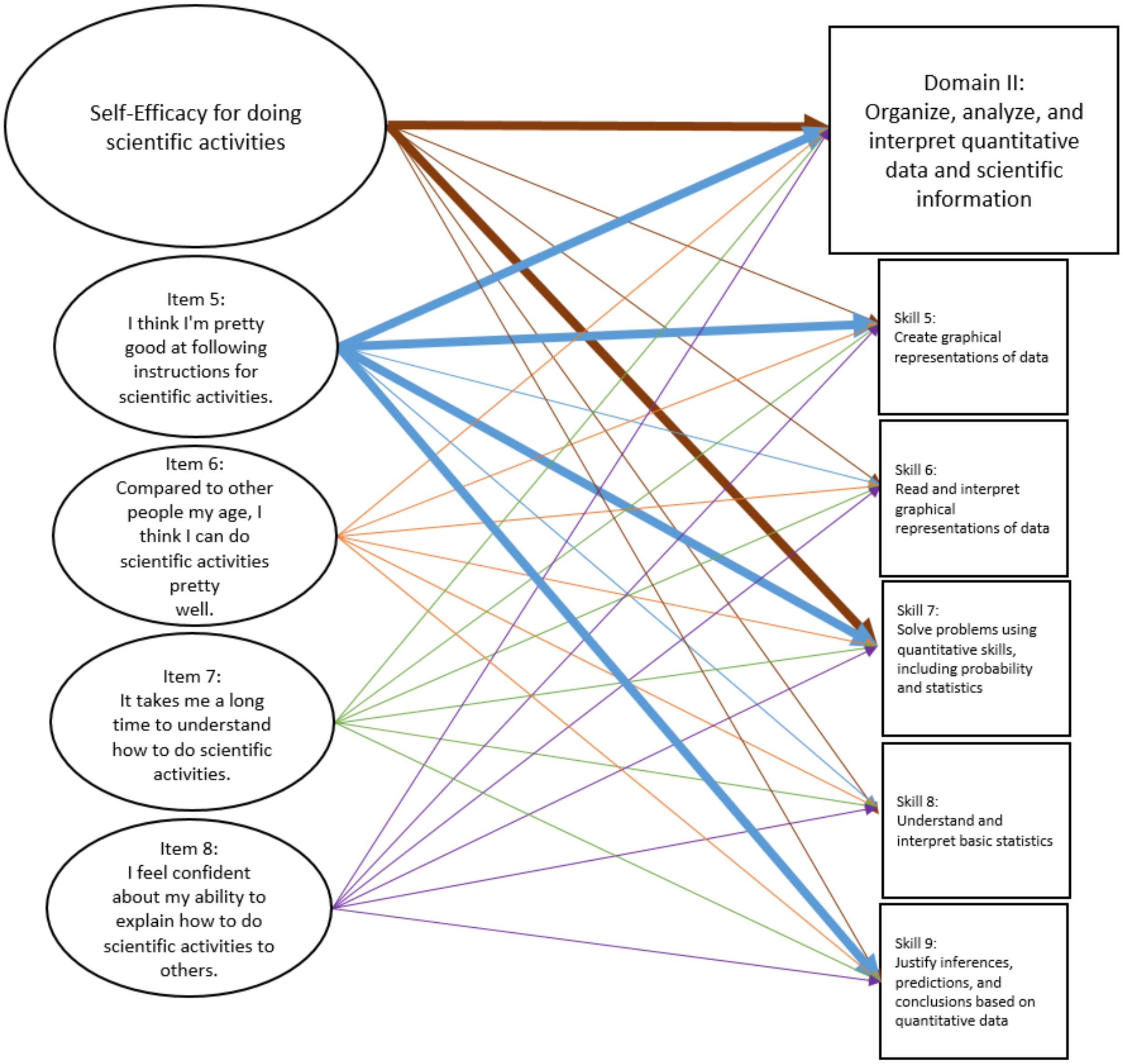

Figure 4.4 Pearson's Product Moment Correlations: SELDS Doing Component and TOSLS Domain II

The Pearson's Product Moment correlations (r) also indicated a statistically significant positive relationship between a student's self-efficacy for doing scientific activities and the ability to solve problems using quantitative skills, r = .143, r2 = .020, p = .030. As self-efficacy for doing scientific activities increased, so did the ability to solve problems using quantitative skills on the TOSLS assessment. The proportion of variation in scores on questions that assessed the ability to solve problems using quantitative skills on the TOSLS assessment attributed to student's self-efficacy for doing scientific activities was 2.0%.

Furthermore, item five on the SELDS scale indicated a statistically significant positive relationship with the ability to organize, analyze and interpret quantitative data and scientific information $r = .176$, $r2 = .031$, $p = .008$. Item five also resulted in a statistically significant positive relationship with the ability to create graphical representations of data ($r = .149$, $r2 = .022$, $p = .025$), solve problems using quantitative skills ($r = .147$, $r2 = .022$, $p = .028$), and justify inferences, predictions, and conclusions based on quantitative data ($r = .142$, $r2 = .020$, $p = .033$). As self-efficacy reported on item five on the SELDS scale increased, so did the ability to organize, analyze and interpret quantitative data and scientific information, create graphical representations of data, solve problems using quantitative skills, and justify inferences, predictions, and conclusions based on quantitative data. The proportion of variation attributed to item five on the SELDS scale in the ability to organize, analyze and interpret quantitative data and scientific information was 3.1%, create graphical representations of data was 2.2%, solve problems using quantitative skills was 2.2%, and justify inferences, predictions, and conclusions based on quantitative data was 2.0%.

Table 4.8

Correlations: SELDS Doing Component and TOSLS Domain II

	Domain II: Organize, analyze, and interpret quantitative data and scientific information	Skill 5: Create graphical representations of data	Skill 6: Read and interpret graphical representations of data	Skill 7: Solve problems using quantitative skills, including probability and statistics	Skill 8: Understand and interpret basic statistics	Skill 9: Justify inferences, predictions, and conclusions based on quantitative data
Self-Efficacy for doing scientific activities	r = .144*	r = .113	r = .101	r = .143*	r = .122	r = .040
Item 5: I think I'm pretty good at following instructions for scientific activities.	r = .176*	r = .149*	r = .112	r = .147*	r = .093	r = .142*
Item 6: Compared to other people my age, I think I can do scientific activities pretty well.	r = .072	r = .064	r =.087	r = .098	r = .074	r = -.071
Item 7: It takes me a long time to understand how to do scientific activities.	r = .100	r = .043	r = .064	r = .076	r = .079	r = .082
Item 8: I feel confident about my ability to explain how to do scientific activities to others.	r = .105	r =.082	r = .074	r =.111	r = .125	r = -.015

*Statistically Significant ($p < .05$)

Summary of Results

This chapter provided an analysis of the quantitative data collected during the study to address the five research questions. Surveys were sent to nine professors teaching various undergraduate Biology courses at the participating university to share with their students. All of the participants were enrolled in at least one undergraduate Biology course at the time of participation. An analysis of the quantitative data collected through Qualtrics revealed a statistically significant relationship between student science self-efficacy and their scientific literacy.

Further analysis of the quantitative data on the subcomponents and domains within the instruments revealed a statistically significant relationship between self-efficacy for learning and understanding science topics and student ability to understand methods of inquiry. There was also a statistically significant relationship between self-efficacy for learning and understanding science topics and student ability to organize, analyze, and interpret quantitative data and scientific information. Analysis of self-efficacy for doing scientific activities and student ability to organize, analyze, and interpret quantitative data and scientific information resulted in a statistically significant relationship. However, analysis of the quantitative data for self-efficacy for doing scientific activities and student ability to understand methods of inquiry revealed that there was not a statistically significant relationship.

Conclusion

This chapter presented the participant demographics, analysis of the quantitative data collected from surveys for each research question, and processes of answering each research question. In the next chapter, findings will be presented to compare what was found through this study with existing literature. Implications of this study in education and future research will also be discussed.

CHAPTER V:

DISCUSSION

The purpose of this correlational study was to analyze the relationship between scientific literacy and science self-efficacy in undergraduate students enrolled in science courses. This chapter includes a discussion of major findings as related to the literature on science self-efficacy and scientific literacy as they relate to student learning. Also included is a discussion on implications that may be valuable for use by legislators, curriculum developers, and educators who hope to improve science education. The chapter concludes with a discussion of the limitations of the study, areas for future research, and a brief summary.

This chapter contains discussion and future research possibilities for the following research questions and the results seen in this study:

R1: Is there a statistically significant relationship between science self-efficacy and scientific literacy?

H_a: A statistically significant relationship does exist between science self-efficacy and scientific literacy.

R2: Is there a statistically significant relationship between self-efficacy for learning and understanding science topics and student ability to understand methods of inquiry to develop scientific knowledge?

H_a: A statistically significant relationship does exist between self-efficacy for learning and understanding science topics and student ability to understand methods of inquiry to develop scientific knowledge.

R3: Is there a statistically significant relationship between self-efficacy for learning and understanding science and student ability to organize, analyze, and interpret quantitative data and scientific information?

H_a: A statistically significant relationship does exist between self-efficacy for learning and understanding science and student ability to organize, analyze, and interpret quantitative data and scientific information as measured by the TOSLS.

R4: Is there a statistically significant relationship between self-efficacy for doing scientific activities and student ability to understand methods of inquiry to develop scientific knowledge?

H_0: A statistically significant relationship does not exist between self-efficacy for doing scientific activities and student ability to understand methods of inquiry to develop scientific knowledge.

R5: Is there a statistically significant relationship between self-efficacy for doing scientific activities and student ability to organize, analyze, and interpret quantitative data and scientific information?

H_a: A statistically significant relationship does exist between self-efficacy for doing scientific activities and student ability to organize, analyze, and interpret quantitative data and scientific information.

All five of research questions were analyzed for a relationship with Pearson's product moment correlation (r), and question one was additionally analyzed using structural equation modeling (SEM).

Discussion of Results

The present study sought to determine if there were any relationships between science self-efficacy and scientific literacy, as well as within the deeper components of science self-efficacy and scientific literacy. Science self-efficacy, which was measured using the Self-Efficacy for Learning and Doing Science (SELDS) scale, was divided into two components of the scale: self-efficacy for learning and understanding science topics and self-efficacy for doing scientific activities. Scientific literacy, which was assessed using the Test of Scientific Literacy Skills (TOSLS) assessment, was divided into the two domains on the assessment: student ability to understand methods of inquiry and student ability to organize, analyze, and interpret quantitative data and scientific information.

Research Question One

The first research question analyzed the overall relationship between science self-efficacy and scientific literacy based on their overall scores on the SELDS scale and TOSLS assessment. Upon analysis of the data, a p value considerably less than .05 confirms the alternate hypothesis in that there is a statistically significant relationship between student science self-efficacy and their scientific literacy. While there is a lack of research analyzing the relationship between science self-efficacy and specifically scientific literacy in undergraduate students, the results from this study conform to related theories involving science self-efficacy and student achievement as students with higher science self-efficacy had a higher achievement on the TOSLS assessment (Dorfman & Fortus, 2019; Trujillo & Tanner, 2014; Ucar & Sungur, 2017; Villafañe & Lewis, 2016; Zusho et al., 2003). Gwilliam and Betz (2001) also maintain that science self-efficacy at the college level is a means to predict student achievement. Similarly, the positive relationship between students' science efficacy beliefs and their academic achievements in those subjects occurs because students believe they will achieve positive outcomes (Dorfman & Fortus, 2019; Trujillo & Tanner, 2014; Ucar & Sungur, 2017; Villafañe & Lewis, 2016; Zusho et al., 2003).

The results for this research question also align with an analysis of the 2015 PISA assessment data by the Organization for Economic Co-operation and Development (OECD), despite the fact that their population consisted of High School Students. According to an analysis of data by the OECD of the 2015 PISA assessment, students with lower science self-efficacy performed worse on the assessment than those with a higher science self-efficacy (OECD, 2016). The OECD results noted a positive and significant relationship across all participating countries and economies, which included the United States (OECD, 2016). This study recognized a similar positive and significant relationship between student science self-efficacy and their scientific literacy assessment in undergraduate students, despite the use of different instruments.

According to Pastorelli (2001), if students have high self-efficacy levels, they are typically more likely to challenge themselves because their goal acquisitions are higher. Therefore, the students in the present study that had higher science self-efficacy due to their current courses or major may have been more persistent throughout the TOSLS assessment, resulting in higher TOSLS scores. The remaining research questions in the study addressed the gap in the literature with an analysis of the deeper interwoven relationship between scientific literacy and science self-efficacy, as previous studies either analyzed science self-efficacy and scientific literacy separately or analyzed the broad relationship between the two in high school students. Research questions two thru five in the current study explored the relationship between the self-efficacy for learning and understanding science topics, self-efficacy for doing scientific activities, and scores on the domains on the TOSLS assessment.

Research Questions Two and Three

The first domain on the TOSLS assessment is designed to measure the understanding of the Nature of Science, which Gormally et al. (2012) describe as the understanding of the methods of inquiry that lead students to develop scientific knowledge. It includes four categories of skills: identifying a valid argument, evaluating sources, evaluating the use of information, and the understanding of research design (Gormally et al., 2012). The second domain on the TOSLS includes five categories of skills that focus on the ability to “organize, analyze, and interpret quantitative data and scientific information” (Gormally et al., 2012, p. 367). An analysis of the relationship between the skills within these domains and self-efficacy for learning science addresses the gap in the literature, as individual scientific literacy skills have not previously been examined.

According to the results, students’ self-efficacy for learning and understanding science topics is positively related to their ability in their overall scores on both domains of the TOSLS assessment. The skills within both domains of the TOSLS assessment can all be found as cross-cutting skills (or concepts) in the Next Generation Science Standards (NGSS) and process skills in Texas Essential Knowledge and Skills (TEKS) standards (National Research Council, 2013;

TEC, 2018). Their inclusion within both the NGSS and TEKS standards highlights their importance in student scientific literacy.

Further analysis of the relationships between the overall self-efficacy for learning and understanding science topics and the skills within the domains on the TOSLS assessment resulted in several interesting correlations. According to the analysis of the data, students with higher self-efficacy for learning and understanding science topics scored higher on questions that assessed their ability to evaluate the validity of sources, create a graphical representation of data, read and interpret graphical representations of data, solve problems using quantitative skills, and understand and interpret basic statistics. In accordance with the present results, Chiou and Liang (2012) and Phan (2011) have established students who believe they are capable of understanding science topics typically learn them faster than their peers do. The items within the SELDS scale were also analyzed against the domains and skills on the TOSLS assessment to further understand the deeper relationships between their science self-efficacy and specific scientific literacy skills. The analysis of components of self-efficacy for learning science specifically with individual scientific literacy skills is unique to this study, as this has not previously been analyzed in the literature.

The first item on the SELDS scale, “I think I'm pretty good at understanding science topics,” had a statistically significant positive relationship with the overall scores on domain two, which assessed student ability to organize, analyze, and interpret quantitative data and scientific information along with several skills that fell within domain two. Students with a higher self-efficacy for learning and understanding science topics scored higher on the questions on the TOSLS assessment that assessed student ability to create a graphical representation of data, read and interpret graphical representations of data, solve problems using quantitative skills, and understand and interpret basic statistics. These results corroborate Duschl (2008), who indicates that conceptual understanding of scientific knowledge, as well as reasoning and critical thinking, are important aspects to include within science learning in science education research.

Analysis of item two on the SELDS scale, “Compared to other people my age, I think I can quickly understand new science topics,” resulted in a statistically significant positive relationship with domain two as well as several skills within domain two. Students with a higher self-efficacy reported on this item scored higher on domain two overall, more specifically on their ability to read and interpret graphical representations of data, solve problems using quantitative skills, and understand and interpret basic statistics on the TOSLS assessment. Comparatively, item three on the SELDS scale, “It takes me a long time to understand new science topics,” had a statistically significant positive relationship with both domains on the TOSLS assessment as well as several skills within the domains. Students with a higher self-efficacy on item three had higher scores on questions that assessed their ability to evaluate the validity of sources, solve problems using quantitative skills, and understand and interpret basic statistics on the TOSLS assessment. Both items two and three on the SELDS scale relate to the time it would take to learn science as in either learning quickly or taking longer to learn, they can therefore be associated with student approach to learning, which according to Chin and Brown (2000), specify the methods a student utilizes to refine their academic tasks. According to the literature on approaches to learning, deep approaches to learning have shown to have a positive relationship with learner’s self-efficacy (Diseth, 2011; Moneta et al., 2007; Prat-Sala & Redford, 2010). Therefore, the students that reported higher self-efficacy on these items utilize deep approaches to learning. It is also likely a connection exists between deep approaches to learning and student ability to solve problems using quantitative skills and understand and interpret basic statistics.

The last item within the self-efficacy for learning and understanding science topics, item four on the SELDS scale, “I feel confident in my ability to explain science topics to others,” resulted in a statistically significant positive relationship with the overall score on domain two of the TOSLS assessment and one of the skills within domain two. Students that reported a higher self-efficacy on this item, which is focused on student ability to communicate about science topics, scored higher on their ability to understand and interpret basic statistics on the TOSLS assessment. These results, therefore, support the work of multiple studies that have established the communication component of scientific literacy should also be applied within classrooms to further science learning (Chang et al., 2011; Yore et al., 2003).

Research Questions Four and Five

The second component of the SELDS scale analyzed in this study, self-efficacy for doing scientific activities, presented a statistically significant positive relationship with the overall scores for domain two and student ability to solve problems using quantitative skills. An analysis of the relationship between individual scientific literacy skills and specifically self-efficacy for doing science activities is another unique component of this study as the current literature does not examine the relationships between these components of science self-efficacy and scientific literacy.

Further analysis of the items within this component of the SELDS scale surprisingly only resulted in statistically significant relationships for item five, “I think I’m pretty good at following instructions for scientific activities.” According to the analysis, students with a higher reported self-efficacy on this item scored higher on both domains of the TOSLS assessment. More specifically, higher self-efficacy on this item resulted in higher scores on questions that assessed their ability to identify a valid scientific argument, evaluate the use and misuse of scientific information sources, create graphical representations of data, solve problems using quantitative skills, and justify inferences, predictions, and conclusions based on quantitative data. These results align with the literature on science activities in that they give students an opportunity to apply the scientific concepts they have learned, which is an essential ability to become scientifically literate (Millar & Osborne, 1998; Roberts, 2007).

Implications of the Study

Scientific literacy skills are imperative skills to cultivate within all students, as they are essential in real-world situations that may depend on an individual’s ability to evaluate and utilize data to make knowledgeable decisions (AAAS, 2011); therefore, fostering these skills in students is essential. On the other hand, student science self-efficacy is influential in shaping student achievement in science, their motivation to learn science, and their future aspirations for science related careers (Lofgran et al., 2015). The relationships between individual components of science self-efficacy and scientific literacy have not previously been studied at the undergraduate level. Results from this study can improve the understanding of the deeper relationships between these variables and address the gap in the literature. This study's results align with the current theories in the field as they relate to self-efficacy and achievement. According to the Social Cognitive Theory, the theoretical framework for this study, there should be a significant positive relationship between science self-efficacy and scientific literacy. The analysis of the data showed a statistically significant positive relationship between not only their science self-efficacy and scientific literacy but also between various components of their science self-efficacy and scientific literacy skills.

Therefore, the findings of this study can be an important factor in the way that professors curate the learning experience for their students. The combination of results from this study provides some support for the conceptual premise that by reinforcing specific aspects of a student's science self-efficacy through curated learning experiences, professors can help to improve components of their scientific literacy. Similarly, the results of this study also suggest that by reinforcing specific scientific literacy skills in their course, professors can improve student science self-efficacy.

Improving Scientific Literacy through Science Self-Efficacy

In his foundational work on student self-efficacy, Bandura (1977) establishes that student self-efficacy in any domain comes derives from the following sources: performance accomplishments, vicarious experiences, physiological states, and verbal persuasion. Professors can target these sources of self-efficacy for their students, thereby increasing their scientific literacy skills. Performance accomplishments are considered the most influential on student self-efficacy as they provide the students with reliable evidence of mastery experiences, wherein repeated successes increase their self-efficacy or repeated failures lower their self-efficacy (Britner & Pajares 2006; Kiran & Sungur 2012; Klassen 2004; Usher & Pajares 2006).

Therefore, by providing their students with opportunities to master the material with repeated success, professors can increase their self-efficacy for learning science. Another source for student self-efficacy is vicarious experiences or experiences gained from observing others modeling a task (Bandura, 1997; Margolis & Mccabe, 2006). Cheung and Cheung (2015) maintain that by having the opportunity to observe a task successfully performed, students will be more likely to believe that they too can successfully complete the task, thereby improving their self-efficacy. According to Cheung and Cheung (2015), efficacy-enhancing strategies can be incorporated into inquiry teaching by "providing appropriately challenging problems and facilitating cooperative team work so that students are exposed to personal mastery and vicarious experiences."

The current study helps us to understand which components of science self-efficacy may help improve student scores on assessments, depending on the scientific literacy skills involved in that assessment. The results from this study suggest that during a unit or course in which there are key scientific literacy skills for students to grasp or utilize, professors can curate their learning experiences to build on their self-efficacy at following instructions for scientific activities to reinforce several of their scientific literacy skills. For instance, professors could build in an activity in which students are provided with a logical sequence of steps to utilize for completing a science activity, as Lenz et al. (2004) note, "these steps make the task at hand manageable and provide students with a place to start" (p. 261). By providing students an opportunity to do well at following instructions for scientific activities and interpret their success positively, their self-efficacy for doing so will be strengthened through enactive mastery (Margolis & Mccabe, 2006). The present study then raises the possibility that by increasing their self-efficacy for following instructions for scientific activities, professors will improve their ability to identify a valid scientific argument, evaluate the use and misuse of scientific information sources, create graphical representations of data, and solve problems using quantitative skills.

Students who reported a higher self-efficacy for learning and understanding science topics performed better on questions that assessed their ability to evaluate the validity of sources, create graphical representations of data, read and interpret graphical representations of data, solve problems using quantitative skills, and understand and interpret basic statistics. Therefore, another implication of the current study is the possibility that by helping students increase their self-efficacy for learning and understanding science topics, professors can increase their achievement on assessment questions that utilized the aforementioned scientific literacy skills. According to the data in the current study, we can infer that by increasing their self-efficacy for learning and understanding science topics, professors will also increase their ability to evaluate the validity of sources, create graphical representations of data, read and interpret graphical representations of data, solve problems using quantitative skills, and understand and interpret basic statistics. Alternatively, results from this study can also be utilized by professors to increase student science self-efficacy through targeted strategies reinforcing specific scientific literacy skills.

Improving Science Self-Efficacy through Scientific Literacy

Student science self-efficacy plays a role in their engagement, persistence, and achievement in their science class (Cheung & Cheung, 2015). Another important implication of this study is that by increasing scientific literacy skills in their students, professors can increase their science self-efficacy. The NSES established scientific inquiry as the doing of science, such as observing, inferring, or concluding and Nature of Science (NOS), the knowledge of science as integral components of scientific literacy (Lederman, 2019). According to research, students can only develop key NOS skills if it is explicitly integrated into instruction (Abd-El-Khalick & Lederman, 2000; Lederman, 2007; Lederman & Lederman, 2014; Lederman, 2019). Lederman (2019) claims that to effectively integrate NOS into instruction, students should be given the opportunity to reflect and discuss their experiences as they struggle with developing their scientific understanding of a phenomenon.

The results of this study indicate that improving student ability to evaluate the validity of sources will improve their self-efficacy for learning and understanding science topics, and improving their ability to identify valid scientific arguments will improve their efficacy at following instructions for scientific activities. Professors can help students improve their ability to evaluate the validity of sources and identify a valid scientific argument by incorporating opportunities to evaluate scientific articles within their curriculum. Through a system of modeling the evaluation of a sample scientific article with students and then allowing them to evaluate an article on their own, Porter et al. (2010) report significant improvement in similar student informational and scientific literacy skills.

Another implication from the results of this study is that professors can improve student self-efficacy for learning and understanding science topics by improving their ability to create, read, and interpret graphical representations of data. Professors can improve student graphing skills through the use of various targeted instructional strategies, thereby also improving their science self-efficacy. According to Maltese et al. (2015), due to possible overestimation of students' baseline grasp of graphing, science professors are likely to inadequately incorporate it in their instruction. Harsh and Schmitt-Harsh (2016) suggest that students should be exposed to data in courses through experiences similar to what practitioners would be exposed to in the field. By allowing students to actively participate in authentic scientific inquiry, professors can develop their graphing skills (Harsh & Schmitt-Harsh, 2016; Kjelvik & Schultheis, 2019). Harsh and Schmitt-Harsh (2016) also encourage exposure to messy or complex data to develop advanced graphing skills in students as complex data better reflects scientific research. Therefore, the results from this study suggest that by allowing students to interact and learn with complex authentic data to improve their graphing skills, professors can also increase their self-efficacy for learning and understanding science topics. While this study can offer new insight to professors, it is not without its limitations.

Limitations

While the researcher agrees that quantitative research was the right method for this study, qualitative research tools, such as interviews or open-ended response questions, could have captured more information from participants. More credibility could be given to this study if coupled with qualitative research as a mixed-methods study (Johnson & Onwuegbuzie, 2004). For example, subsequent interviews following the survey could have offered more evidence to better analyze student's self-efficacy. Another limitation in the design of the study was the singular focus on students currently enrolled in undergraduate Biology courses at the participating university. The inclusion of students enrolled in other undergraduate science courses in addition to undergraduate Biology courses can add to the results of this study. By focusing only on students in Biology courses, the findings do not consider any variation in student science self-efficacy and scientific literacy across different courses or other disciplines.

Another limitation of this study is that students were asked to volunteer to participate and complete the survey on their own. This limited the study to a small sample and included only the students that completed the survey by choice. There may have been students that did not complete the survey with lower levels of self-efficacy or even lower levels of scientific literacy. Conducting the study in one university and only in undergraduate courses led to a small sample and a lack of diversity of participants. There is also the inability to generalize the results to the population, which means that it may not be an accurate representation of undergraduate students. The administration of the survey online also creates a limitation, as students had the ability to look up the answers to the TOSLS assessment could inflate their scores for the assessment. The findings from this study make it apparent that there is a need to evaluate the relationship between science self-efficacy and scientific literacy at the undergraduate level to determine if the current literature, which stems from studies conducted in a K-12 setting, can be generalized to undergraduate students. Based on the limitations of this study and the gap in the literature, there are several recommendations for future research.

Recommendations for Future Research

The first recommendation for future research would be to conduct this study on a larger scale across multiple higher education institutions. The results from this study can be further developed and enhanced by conducting this study across various science courses in multiple institutions with targeted demographics. Conducting this study on a larger scale can also allow researchers to collect responses from all of the enrolled students. Another recommendation would be to collect the data within their science courses as a closed paper-based administration so that students are less likely to attempt to look up the answers to the TOSLS assessment. Collecting the data within the science courses would also ensure responses are better reflective of the students' abilities as they are less likely to breeze through the survey.

Further studies need to be carried out at a larger scale in a higher education setting in order to establish a better understanding of the relationships between the different components of science self-efficacy and scientific literacy. A natural progression of this work is to analyze these relationships in the K-12 setting as well since the focus of this study was on undergraduate students. There is a significant gap in the literature when it comes to the relationships between science self-efficacy and scientific literacy. Furthermore, there is limited literature available on the possible relationships between specific components of science self-efficacy and the various skills associated with scientific literacy. By researching and developing a better understanding of this, educators and curriculum developers can have new avenues of targeting scientific literacy skills in the classroom.

Conclusion

There is a significant need for individuals in the STEM field in the United States; however, Holmes (2017) and PCAST (2010) explain that there has been a decrease in interest in the STEM fields among students throughout the last 50 years. There have been many researchers that have called for reform in science education due to the decreasing interest in scientific disciplines (Holmes, 2017), the poor performance on international science exams (Auerbach, 2017; Sparks, 2016), and a lack of public understanding for STEM fields (Llorente, 2019).

Further, the National Science Board (2018) has shared that it is vital that the United States increase interest in STEM fields in the 21st century if they are to be successful. This is problematic because the lack of a qualified STEM workforce will mean that the US will fall further behind in the global economy than it already has (Teitelbaum, 2014). The National Science Foundation also maintains that there is a need to identify risks and challenges to STEM pathways in order to ensure continued competitiveness by fostering a stronger STEM-capable workforce (NSF, 2015).

Farrington et al. (2012) note there must be a larger focus on the relationship between student achievement and noncognitive factors such as self-efficacy. Previous research has found there is an increase in academic achievements when self-efficacy is high but that there is a decrease in academic achievements when self-efficacy is low (Dibenedetto, 2015; Pajares, 1997; Schunk, 2012). Additionally, when exploring science literacy, research demonstrated that when both science literacy and self-efficacy are high, students will also achieve better academic scores compared to when it was lower (Dorfman & Fortus, 2019; Trujillo & Tanner, 2014; Ucar & Sungur, 2017; Villafañe et al., 2016; Zusho et al., 2003). However, previous research has not examined the relationships between individual components of science self-efficacy and scientific literacy in undergraduate students. Thus, it was vital to explore this relationship in the present study.

Both the Test of Scientific Literacy Skills, developed by Gormally et al. (2012) and social cognitive theory, developed by Bandura (1986), was utilized as the foundation of this study to demonstrate the importance of exploring the connection between science self-efficacy and science literacy. Further, a quantitative correlational research approach was utilized to gain a purposeful sample of undergraduate students taking biology courses in order to explore the relationship between both the Self-Efficacy for Learning and Doing Science Scale (SELDS; Porticella et al., 2017) and the Test of Scientific Literacy Skills (TOSLS). Moreover, Pearson product-moment correlations and Structural Equation Modeling (SEM) was utilized for analysis of the research data.

The results of the current study were statistically significant, and they can be beneficial to educators working with undergraduate students to help determine their science literacy. Further, the results can be an important factor in the way that professors curate the learning experience for their students based on their student's science self-efficacy, self-efficacy to learning, and science literacy. The significant results from this study help to develop a better understanding of the overall relationship between science self-efficacy and scientific literacy and address the gap in literature with a deeper analysis of the relationships between specific components of each. The results of this study can be used to create a study on a larger scale to determine if the outcome was related to the narrow demographics of the participants. Finally, it is also recommended that the relationship between science self-efficacy and scientific literacy be explored in students that are in grades K-12 to determine if there is an increase or decrease in the relationship as the student progresses through their academic careers.

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APPENDIX A:

COVER LETTER PRESENTED THROUGH QUALTRICS

University of Houston Clear Lake

Dear Student:
Greetings! You are being solicited to complete the Test of Scientific Literacy and science self-efficacy survey. The purpose of these surveys is to examine the relationship between scientific literacy and science self-efficacy in undergraduate students. The data obtained from this study will allow me to understand the relationship between scientific literacy and science self-efficacy which can be useful in increasing student science self-efficacy.
Please answer all questions completely. Filling out the attached survey is entirely voluntary but answering each response will make the survey most useful. This survey will take approximately 35-45 minutes to complete and all of your responses will be kept completely confidential. No obvious undue risks will be endured, and you may stop your participation at any time. In addition, you will also not benefit directly from your participation in the study.

Title of Study: The relationship between scientific literacy and science self-efficacy in undergraduate science students
Principal Investigator: Faryal Shaukat
Student Researcher: Faryal Shaukat
Faculty Sponsor: Dr. Omah Duncan
Purpose: The purpose of this research is to investigate the relationship between scientific literacy and science self-efficacy in students in undergraduate biology courses.
Procedures: You will take a science self-efficacy survey which is 8 questions and then take the test of scientific literacy which consists of 28 multiple choice questions which need to be answered within 35 minutes without the use of a calculator.
Expected Duration: The total anticipated time commitment will be approximately 36-45 minutes.
Risks of Participation: There are no anticipated risks associated with participation in this project.
Benefits to the Subject: There is no direct benefit received from your participation in this study, but your participation will help the investigator(s) better understand: the relationship between science self-efficacy and scientific literacy in undergraduate science students.
Confidentiality of Records: Every effort will be made to maintain the confidentiality of your study records. The data collected from the study will be used for educational and publication purposes, however, you will not be identified by name. For federal audit purposes, the participant's documentation for this project will be maintained and safeguarded for a minimum of three years after completion of the study. After that time, the participant's documentation may be destroyed.
Financial Compensation: There is no financial compensation to be offered for participation in the study.
Investigator's Right to Withdraw Participant: The investigator has the right to withdraw you from this study at any time.
Contact Information for Questions or Problems: If you have additional questions during the

course of this study about the research or any related problems, you may contact the Student Researcher, Faryal Shaukat, by email at shaukatf8421@uhcl.edu.

The purpose of this study, procedures to be followed, and explanation of risks or benefits have been explained to you. You have been allowed to ask questions and your questions have been answered to your satisfaction. You have been told who to contact if you have additional questions. You have read this consent form and voluntarily agree to participate as a subject in this study. You are free to withdraw your consent at any time by contacting the Principal Investigator or Student Researcher/Faculty Sponsor.

Your cooperation is greatly appreciated and your willingness to participate in this study is implied if you proceed with completing the survey. Your completion of the surveys is not only greatly appreciated, but invaluable. If you have any further questions, please feel free to contact me at shaukatf8421@uhcl.edu. Thank you!

Sincerely
Faryal Shaukat
Doctoral Student
College of Education
Shaukatf8421@uhcl.edu

By clicking the button below, you acknowledge your voluntary participation in this research project. Such participation does not release the investigator(s), institution(s), sponsor(s) or granting agency(ies) from their professional and ethical responsibility to you. By signing the form, you are not waiving any of your legal rights.

- ○ I Consent, Continue to Survey
- ○ I Do Not Consent

>>

APPENDIX B:

SELF-EFFICACY FOR LEARNING AND DOING SCIENCE (SELDS) BY CORNELL LAB OF ORNITHOLOGY EVALUATION RESEARCH

Self-Efficacy for Learning and Doing Science Scale

Please indicate how much you **DISAGREE** or **AGREE** with each of the following statements by circling the number in the appropriate column. Please respond as you really feel, rather than how you think "most people" feel.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
These statements are about how you feel about learning and understanding science topics.					
1. I think I'm pretty good at understanding science topics.	1	2	3	4	5
2. Compared to other people my age, I think I can quickly understand new science topics.	1	2	3	4	5
3. It takes me a long time to understand new science topics.	1	2	3	4	5
4. I feel confident in my ability to explain science topics to others.	1	2	3	4	5
These statements are about how you feel about doing scientific activities.					
5. I think I'm pretty good at following instructions for scientific activities.	1	2	3	4	5
6. Compared to other people my age, I think I can do scientific activities pretty well.	1	2	3	4	5
7. It takes me a long time to understand how to do scientific activities.	1	2	3	4	5
8. I feel confident about my ability to explain how to do scientific activities to others.	1	2	3	4	5

APPENDIX C:

TEST OF SCIENTIFIC LITERACY SKILLS ASSESSMENT

Directions: There are 28 multiple-choice questions. You will have about 35 minutes to work on the questions. Be sure to answer as many of the questions as you can in the time allotted.

Mark your answers on the scantron sheet.

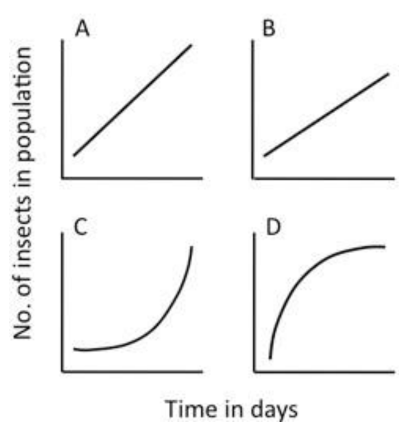
Bubble in your #ID on your scantron.

Do NOT use a calculator. Thank you for your participation in this project!

1. Which of the following is a valid scientific argument?
   a. Measurements of sea level on the Gulf Coast taken this year are lower than normal; the average monthly measurements were almost 0.1 cm lower than normal in some areas. These facts prove that sea level rise is not a problem.
   b. A strain of mice was genetically engineered to lack a certain gene, and the mice were unable to reproduce. Introduction of the gene back into the mutant mice restored their ability to reproduce. These facts indicate that the gene is essential for mouse reproduction.
   c. A poll revealed that 34% of Americans believe that dinosaurs and early humans co-existed because fossil footprints of each species were found in the same location. This widespread belief is appropriate evidence to support the claim that humans did not evolve from ape ancestors.
   d. This winter, the northeastern US received record amounts of snowfall, and the average monthly temperatures were more than 2°F lower than normal in some areas. These facts indicate that climate change is occurring.

2. While growing vegetables in your backyard, you noticed a particular kind of insect eating your plants. You took a rough count (see data below) of the insect population over time. Which graph shows the best representation of your data?

Time (days)	Insect Population (number)
2	7
4	16
8	60
10	123



3. A study about life expectancy was conducted using a random sample of 1,000 participants from the United States. In this sample, the average life expectancy was 80.1 years for females and 74.9 years for males. What is one way that you can **increase your certainty** that women truly live longer than men in the United States' general population?
   a. Subtract the average male life expectancy from the average female expectancy. If the value is positive, females live longer.
   b. Conduct a statistical analysis to determine if females live significantly longer than males.
   c. Graph the mean (average) life expectancy values of females and males and visually analyze the data.
   d. There is no way to increase your certainty that there is a difference between sexes.
4. Which of the following research studies is **least likely** to contain a confounding factor (variable that provides an alternative explanation for results) in its design?
   a. Researchers randomly assign participants to experimental and control groups. Females make up 35% of the experimental group and 75% of the control group.
   b. To explore trends in the spiritual/religious beliefs of students attending U.S. universities, researchers survey a random selection of 500 freshmen at a small private university in the South.
   c. To evaluate the effect of a new diet program, researchers compare weight loss between participants randomly assigned to treatment (diet) and control (no diet) groups, while controlling for average daily exercise and pre-diet weight.
   d. Researchers tested the effectiveness of a new tree fertilizer on 10,000 saplings. Saplings in the control group (no fertilizer) were tested in the fall, whereas the treatment group (fertilizer) were tested the following spring.

5. Which of the following actions is a valid scientific course of action?
   a. A government agency relies heavily on two industry-funded studies in declaring a chemical found in plastics safe for humans, while ignoring studies linking the chemical with adverse health effects.
   b. Journalists give equal credibility to both sides of a scientific story, even though one side has been disproven by many experiments.
   c. A government agency decides to alter public health messages about breast-feeding in response to pressure from a council of businesses involved in manufacturing infant formula.
   d. Several research studies have found a new drug to be effective for treating the symptoms of autism; however, a government agency refuses to approve the drug until long term effects are known.

Background for question 6: The following graph appeared in a scientific article[1] about the effects of pesticides on tadpoles in their natural environment.

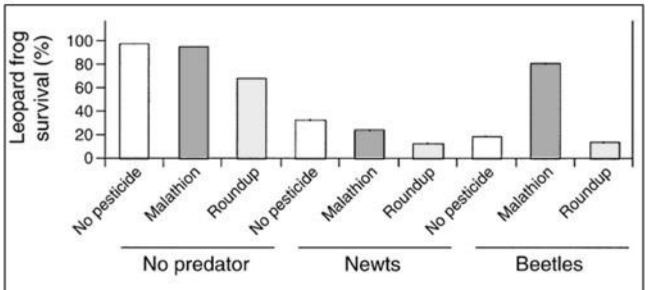
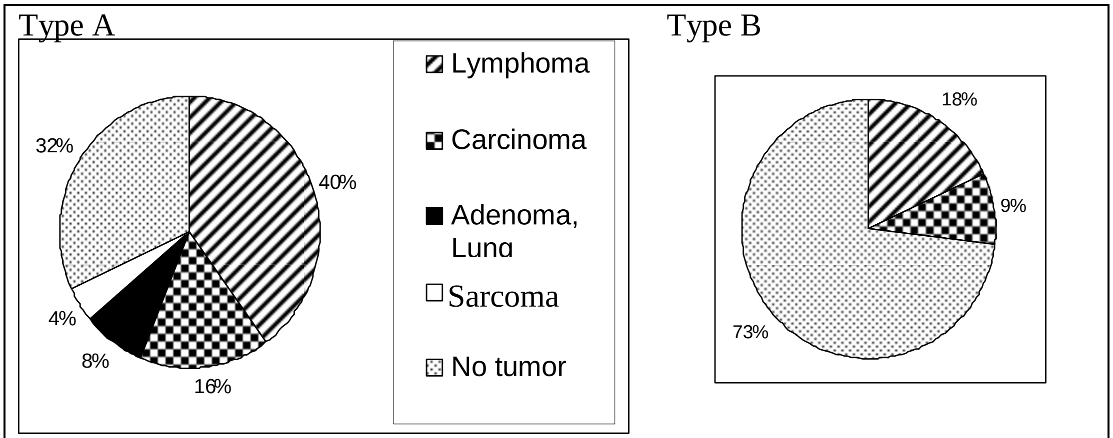


Fig. 2. Total survival of Leopard frog tadpoles living in ponds with 2 pesticides added (Malathion and Roundup) and 2 tadpole predators present (newts and beetles).

6. When beetles were introduced as predators to the Leopard frog tadpoles, and the pesticide Malathion was added, the results were unusual. Which of the following is a plausible hypothesis to explain these results?
   a. The Malathion killed the tadpoles, causing the beetles to be hungrier and eat more tadpoles.
   b. The Malathion killed the tadpoles, so the beetles had more food and their population increased.
   c. The Malathion killed the beetles, causing fewer tadpoles to be eaten.
   d. The Malathion killed the beetles, causing the tadpole population to prey on each other.

7. Which of the following is the **best** interpretation of the graph below?



Tumors found in type A and type B mice. Pie chart depicts relative incidence of tumors. Numbers outside each slice denote the percentage of specific tumor type.

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[1] Modified from Relyea, R.A., N.M. Schoeppner, J.T. Hoverman. 2005. Pesticides and amphibians: the importance of community context. Ecological Applications 15: 1125-1134

a. Type “A” mice with Lymphoma were more common than type “A” mice with no tumors.
b. Type “B” mice were more likely to have tumors than type “A” mice.
c. Lymphoma was equally common among type “A” and type “B” mice.
d. Carcinoma was less common than Lymphoma only in type “B” mice.

8. Creators of the Shake Weight, a moving dumbbell, claim that their product can produce “incredible strength!” Which of the additional information below would provide the **strongest evidence** supporting the effectiveness of the Shake Weight for increasing muscle strength?
   a. Survey data indicates that on average, users of the Shake Weight report working out with the product 6 days per week, whereas users of standard dumbbells report working out 3 days per week.
   b. Compared to a resting state, users of the Shake Weight had a 300% increase in blood flow to their muscles when using the product.
   c. Survey data indicates that users of the Shake Weight reported significantly greater muscle tone compared to users of standard dumbbells.
   d. Compared to users of standard dumbbells, users of the Shake Weight were able to lift weights that were significantly heavier at the end of an 8-week trial.

9. Which of the following is **not** an example of an appropriate use of science?
   a. A group of scientists who were asked to review grant proposals based their funding recommendations on the researcher’s experience, project plans, and preliminary data from the research proposals submitted.
   b. Scientists are selected to help conduct a government-sponsored research study on global climate change based on their political beliefs.
   c. The Fish & Wildlife Service reviews its list of protected and endangered species in response to new research findings.
   d. The Senate stops funding a widely used sex-education program after studies show limited effectiveness of the program.

Background for question 10: Your interest is piqued by a story about human pheromones on the news. A Google search leads you to the following website:

10. For this website (Eros Foundation), which of the following characteristics is <u>**most important**</u> in your confidence that the resource is accurate or not.
    a. The resource may not be accurate, because appropriate references are not provided.
    b. The resource may not be accurate, because the purpose of the site is to advertise a product.
    c. The resource is likely accurate, because appropriate references are provided.
    d. The resource is likely accurate, because the website's author is reputable.

Background for questions 11 – 14: Use the excerpt below (modified from a recent news report on MSNBC.com) for the next few questions.

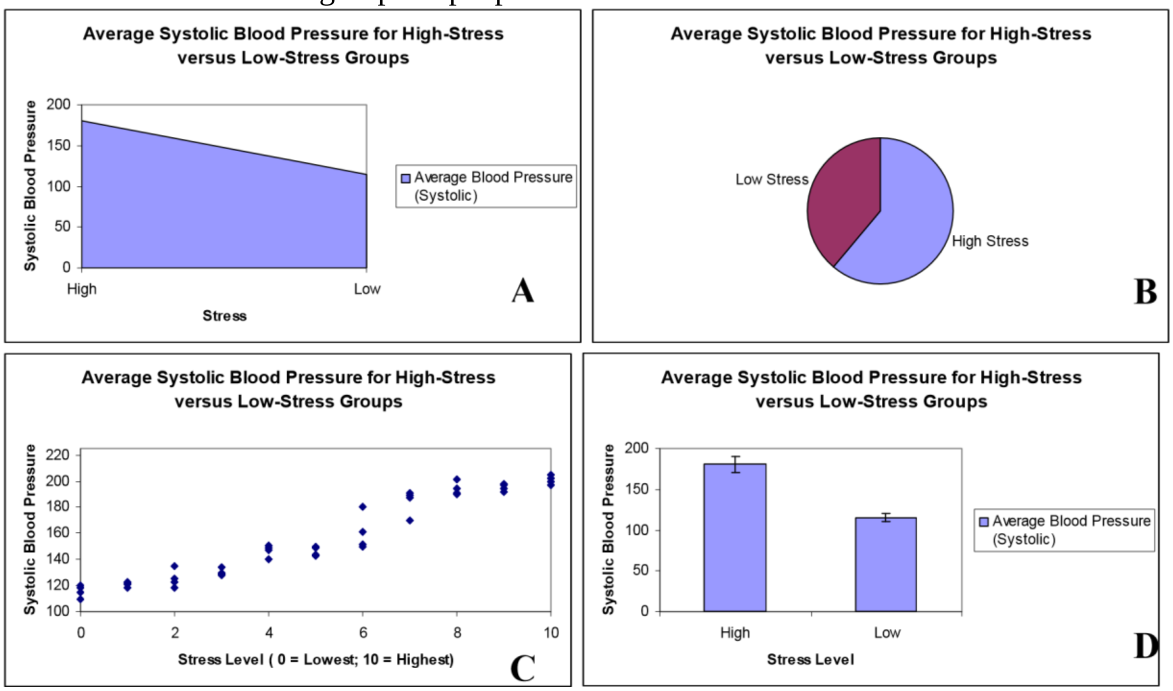
"A recent study, following more than 2,500 New Yorkers for 9+ years, found that people who drank diet soda every day had a 61% higher risk of vascular events, including stroke and heart attack, compared to those who avoided diet drinks. For this study, Hannah Gardner's research team randomly surveyed 2,564 New Yorkers about their eating behaviors, exercise habits, as well as cigarette and alcohol consumption. Participants were also given physical check-ups, including blood pressure measurements and blood tests for cholesterol and other factors that might affect the risk for heart attack and stroke. The increased likelihood of vascular events remained even after Gardener and her colleagues accounted for risk factors, such as smoking, high blood pressure and high cholesterol levels. The researchers found no increased risk among people who drank regular soda."

11. The findings of this study suggest that consuming diet soda might lead to increased risk for heart attacks and strokes. From the statements below, identify **additional evidence that supports** this claim:
    a. Findings from an epidemiological study suggest that NYC residents are 6.8 times more likely to die of vascular-related diseases compared to people living in other U.S. cities.
    b. Results from an experimental study demonstrated that individuals randomly assigned to consume one diet soda each day were twice as likely to have a stroke compared to those assigned to drink one regular soda each day.
    c. Animal studies suggest a link between vascular disease and consumption of caramel-containing products (ingredient that gives sodas their dark color).
    d. Survey results indicate that people who drink one or more diet soda each day smoke more frequently than people who drink no diet soda, leading to increases in vascular events.
12. The excerpt above comes from what type of source of information?
    a. Primary (Research studies performed, written and then submitted for peer-review to a scientific journal.)
    b. Secondary (Reviews of several research studies written up as a summary article with references that are submitted to a scientific journal.)
    c. Tertiary (Media reports, encyclopedia entries or documents published by government agencies.) d. None of the above
13. The lead researcher was quoted as saying, "I think diet soda drinkers need to stay tuned, but I don't think that anyone should change their behaviors quite yet." Why didn't she warn people to stop drinking diet soda right away?
    a. The results should be replicated with a sample more representative of the U.S. population.
    b. There may be significant confounds present (alternative explanations for the relationship between diet sodas and vascular disease).

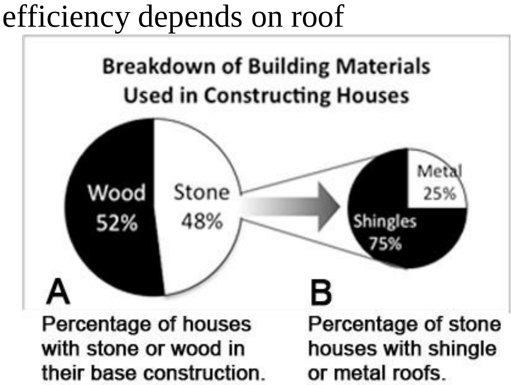
c. Subjects were not randomly assigned to treatment and control groups.
d. All of the above

14. Which of the following attributes is **not** a strength of the study's research design?"
 a. Collecting data from a large sample size.
 b. Randomly sampling NYC residents.
 c. Randomly assigning participants to control and experimental groups.
 d. All of the above.

15. Researchers found that chronically stressed individuals have significantly higher blood pressure compared to individuals with little stress. Which graph would be most appropriate for displaying the mean (average) blood pressure scores for high-stress and low-stress groups of people?



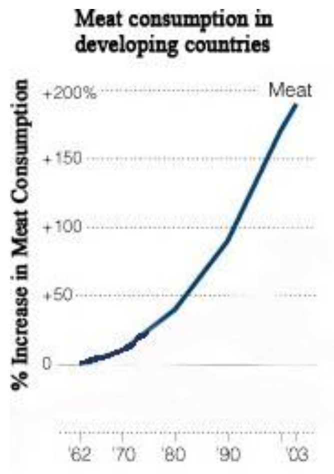
Background for question 16: Energy efficiency of houses depends on the construction materials used and how they are suited to different climates. Data was collected about the types of building materials used in house construction (results shown below). Stone houses are more energy efficient, but to determine if that efficiency depends on roof style, data was also collected on the percentage of stone houses that had either shingles or a metal roof.



16. What proportion of houses were constructed of a stone base with a shingled roof?
 a. 25%
 b. 36%
 c. 48%
 d. Cannot be calculated without knowing the original number of survey participants.

17. The **most important** factor influencing you to categorize a research article as trustworthy science is: a. the presence of data or graphs
   b. the article was evaluated by unbiased third-party experts
   c. the reputation of the researchers
   d. the publisher of the article

18. Which of the following is the **most accurate** conclusion you can make from the data in this graph[2]?



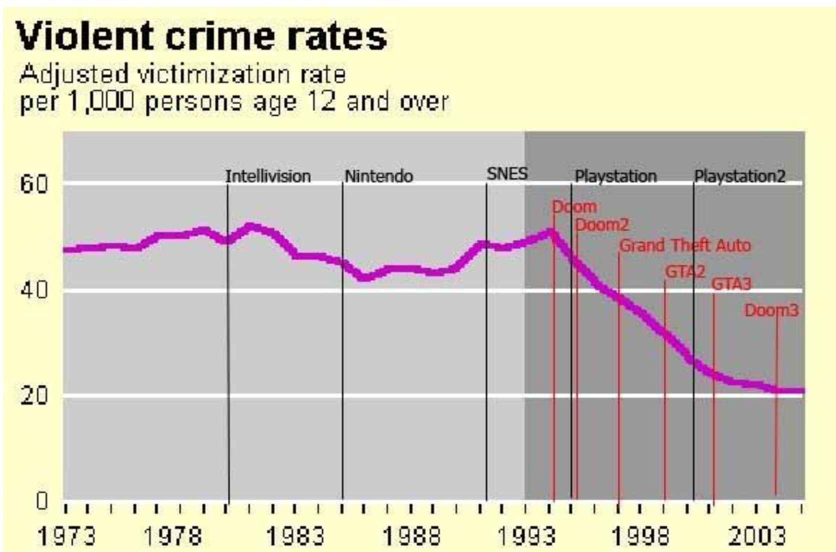
   a. The largest increase in meat consumption has occurred in the past 20 years.
   b. Meat consumption has increased at a constant rate over the past 40 years.
   c. Meat consumption doubles in developing countries every 20 years.
   d. Meat consumption increases by 50% every 10 years.

19. Two studies estimate the mean caffeine content of an energy drink. Each study uses the same test on a random sample of the energy drink. Study 1 uses 25 bottles, and study 2 uses 100 bottles. Which statement is true?
   a. The estimate of the actual mean caffeine content from each study will be equally uncertain.
   b. The uncertainty in the estimate of the actual mean caffeine content will be smaller in study 1 than in study 2.
   c. The uncertainty in the estimate of the actual mean caffeine content will be larger in study 1 than in study 2.
   d. None of the above

[2] Modified from Rosenthal, Elizabeth. 2008. As More Eat Meat, a Bid to Cut Emissions. New York Times, December 3, 2008. Accessed June 9, 2011 http://www.nytimes.com/2008/12/04/science/earth/04meat.html

20. A hurricane wiped out 40% of the wild rats in a coastal city. Then, a disease spread through stagnant water killing 20% of the rats that survived the hurricane. What percentage of the original population of rats is left after these 2 events?
    a. 40%
    b. 48%
    c. 60%
    d. Cannot be calculated without knowing the original number of rats.

Background for question 21: A videogame enthusiast argued that playing violent video games (e.g., Doom, Grand Theft Auto) does not cause increases in violent crimes as critics often claim. To support his argument, he presents the graph below. He points out that the rate of violent crimes has decreased dramatically, beginning around the time the first "moderately violent" video game, Doom, was introduced.



21. Considering the information presented in this graph, what is the **most critical flaw** in the blogger's argument?
    a. Violent crime rates appear to increase slightly after the introduction of the Intellivision and SNES game systems.
    b. The graph does not show violent crime rates for children under the age of 12, so results are biased.
    c. The decreasing trend in violent crime rates may be caused by something other than violent video games
    d. The graph only shows data up to 2003. More current data are needed.

22. Your doctor prescribed you a drug that is brand new. The drug has some significant side effects, so you do some research to determine the effectiveness of the new drug compared to similar drugs on the market. Which of the following sources would provide the **most accurate** information? a. the drug manufacturer's pamphlet/website

b. a special feature about the drug on the nightly news
c. a research study conducted by outside researchers
d. information from a trusted friend who has been taking the drug for six months

23. A gene test shows promising results in providing early detection for colon cancer. However, 5% of all test results are falsely positive; that is, results indicate that cancer is present when the patient is, in fact, cancer-free. Given this false positive rate, how many people out of 10,000 would have a false positive result and be alarmed unnecessarily? a. 5
    b. 35
    c. 50
    d. 500

24. Why do researchers use statistics to draw conclusions about their data?
    a. Researchers usually collect data (information) about everyone/everything in the population.
    b. The public is easily persuaded by numbers and statistics.
    c. The true answers to researchers' questions can only be revealed through statistical analyses.
    d. Researchers are making inferences about a population using estimates from a smaller sample.

25. A researcher hypothesizes that immunizations containing traces of mercury **do not** cause autism in children. Which of the following data provides the **strongest** test of this hypothesis? a. a count of the number of children who were immunized and have autism
    b. yearly screening data on autism symptoms for immunized and non-immunized children from birth to age 12
    c. mean (average) rate of autism for children born in the United States
    d. mean (average) blood mercury concentration in children with autism

Background for Question 26: You've been doing research to help your grandmother understand two new drugs for osteoporosis. One publication, *Eurasian Journal of Bone and Joint Medicine*, contains articles with data only showing the effectiveness of one of these new drugs. A pharmaceutical company funded the *Eurasian Journal of Bone and Joint Medicine* production and most advertisements in the journal are for this company's products. In your searches, you find other articles that show the same drug has only limited effectiveness.

26. Pick the **best** answer that would help you decide about the credibility of the *Eurasian Journal of Bone and Joint Medicine*:
    a. It is not a credible source of scientific research because there were advertisements within the journal.

b. It is a credible source of scientific research because the publication lists reviewers with appropriate credentials who evaluated the quality of the research articles prior to publication.
c. It is not a credible source of scientific research because only studies showing the effectiveness of the company's drugs were included in the journal.
d. It is a credible source of scientific research because the studies published in the journal were later replicated by other researchers.

27. Which of the following actions is a valid scientific course of action?
    a. A scientific journal rejects a study because the results provide evidence against a widely accepted model.
    b. The scientific journal, Science, retracts a published article after discovering that the researcher misrepresented the data.
    c. A researcher distributes free samples of a new drug that she is developing to patients in need.
    d. A senior scientist encourages his graduate student to publish a study containing ground-breaking findings that cannot be verified.

Background for question 28: Researchers interested in the relation between River Shrimp
(Macrobrachium) abundance and pool site elevation, presented the data in the graph below. Interestingly, the researchers also noted that water pools tended to be shallower at higher elevations.

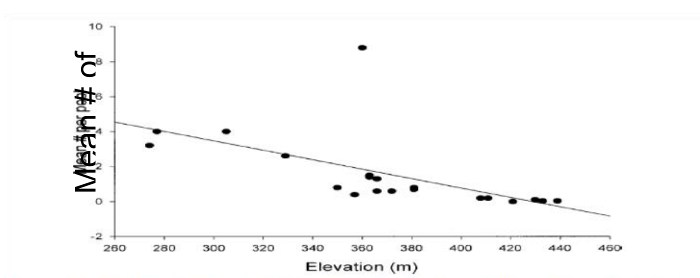


FIG. 3. Relationship between total abundance of *Macrobrachium* (1988–2002) and elevation in Quebrada Prieta.

28. Which of the following is a plausible hypothesis to explain the results presented in the graph?

    a. There are more water pools at elevations above 340 meters because it rains more frequently in higher elevations.
    b. River shrimp are more abundant in lower elevations because pools at these sites tend to be deeper.
    c. This graph cannot be interpreted due to an outlying data point.
    d. As elevation increases, shrimp abundance increases because they have fewer predators at higher elevations.

APPENDIX D:

SCORING GUIDELINES FOR SELF EFFICACY FOR LEARNING AND DOING SCIENCESCALE

SELF-EFFICACY FOR LEARNING AND DOING SCIENCE

The Self-Efficacy for Learning and Doing Science questionnaire (see page 2) measures one's confidence in learning science topics, engaging in scientific activities, and more generally in being a scientist. Self-efficacy for science is associated with persistence in the pursuit of science-oriented activities. This questionnaire was developed and tested in the context of informal science learning environments (primarily with participants of Citizen Science projects).

Cleaning your data
Some project participants will not respond as carefully as you might hope. It is important to clean your data to account for this. Once you have entered the data into a spreadsheet such as Microsoft Excel, keep the original as a master, and make a copy from which to work. Do the following simple checks:

1.) Go down each row (observer) and look across the set of responses for that observer – if two or more responses are missing, exclude that row from your analysis.

2.) Once again, go down each row (observer) and look across the set of responses for that observer. Then scroll through the rows looking for sets where all of the responses are the same.

   In general, seeing the same response across all of the items is an indication that the respondent was not reading the items carefully. In particular, items 3 and 7 are "reverse coded," which means they are worded in such a way that they should receive opposite answers from other questions if respondents are answering all questions in a consistent manner. We recommend excluding sets where all answers are the same from your analysis *unless* the answers are all 3s, as many respondents do legitimately use midpoint responses to all questions.

Scoring instructions
Once you have implemented the Self-Efficacy for Learning and Doing Science questionnaire and have cleaned your data, calculate the self-efficacy score as follows:

1.) Reverse the responses to questions 3 and 7 such that 1s become 5s, 2s become 4s, 3s stay 3s, 4s become 2s, and 5s become 1s.

2.) Average together the scores for all of the items for each participant.

3.) You can also average together the overall scores from all of your participants for an overall group score.

4.) Scores below 3 indicate low levels of confidence in learning project-related information and/or participating in project activities. Given that the questionnaire includes separate sets of items for learning (items 1-4) and doing (items 5-8), you might want to average those sets of responses (either for individual or group) separately to investigate whether participants are more or less confident with one or the other concept.

   Note that if you are administering the questionnaire before and after program participation and comparing the two sets of scores as part of a pre-post evaluation, you might want to consider first grouping your participants into those who started out relatively low in self-efficacy and those who started out relatively high in self-efficacy. While it is reasonable to expect an increase among participants who started out relatively low in self-efficacy, you should not expect to see much, if any, increase in those who started out already quite confident in their abilities. You should consider merely maintaining that high level as a positive outcome.