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College Students' Experiences with High School Science: Promoting Interest and Achievement in Science

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Approval of the Dissertation Committee

This dissertation has been duly read, reviewed, and critiqued by the Committee listed below, which hereby approves the manuscript of Monica Wyman as fulfilling the scope and quality requirements for meriting the degree of Ph.D. in Education.

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Abstract

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Monica Wyman

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Research in the past ten years has shown that there has been a lack of professionals to fill the jobs available in science. One possible reason for the lack of participation in science fields lies in students' beliefs in their ability to do science, or science self-efficacy, which is linked to interest and achievement. Their perceptions of science are influenced by prior achievement and experiences, and serve as predictors of future interest and achievement. Since teachers provide much of early scientific experiences, this research looked at the impact of specific instructional practices as well as background factors influencing student attitudes and achievement.

Prior research supports the use of both inquiry science and direct instruction to increase achievement in science, with inquiry strongly influencing interest. Thus, the overarching question was asked: *What are college students' high school science experiences that contributed to their achievement and/or interest in science?*

Using a quantitative design, 258 participants from two different colleges were surveyed regarding their attitudes and prior experiences in high school science classes. Forty-five percent of the participants were science majors. Analysis techniques included correlations, regressions, discriminant function, path analysis, and coding of one open-ended question for a comprehensive depiction of student experiences.

Results indicated that teachers strongly influenced students' interest in pursuing science. Authentic practices and family support were predictive of science self-efficacy. Participants reported mostly experiencing direct instruction practices. It could be that teachers had not transitioned to Next Generation Science Standards yet, since the standards were fairly new at the time participants attended high school. Choice of a science major could be predicted quite well by their interest and confidence in doing science, as well as having a growth mindset. These findings suggest several implications for practice and for future research.

Dedication

I'd like to dedicate my work to my incredible husband Drew, loving daughter Addison, as well as the army of family that helped us through this journey.

To Drew, who has been understanding, extremely encouraging, and exceptionally patient. He has taken on extra parenting and household duties, and has been the most supportive life partner I could ask for.

To Addison, who inspires me to be my best self. Loving her has pushed me to work harder and finish stronger in the hopes of showing her that she also, can accomplish anything she puts her mind to in the future.

To my siblings, who fill me with pride and motivate me to dare courageously, especially in the face of challenges.

I'd like to also dedicate this work to my parents for always believing in me. To both my parents and in-laws for celebrating all of my achievements no matter how small or great, for being the #1 babysitters of all time, and for always showing up to help us when we needed it most.

Lastly, our grandparents' life stories have long inspired me. Their experiences impart values that guide my work. They have all provided me with encouragement and support in different ways in order for me to achieve my goals. My grandpa, Ernest Zoeter, frequently took interest in my work and always beamed with pride when I would share. This motivated and humbled me at the same time. I know he is smiling down on me with the completion of this degree, and I'd like to make a special dedication to his memory.

Acknowledgement

My experiences at Claremont Graduate University have been powerful both personally and professionally. I am extremely grateful for all that I have learned, and more so for the skillset I have gained. I'd like to acknowledge all of the faculty and staff at Claremont Graduate University for challenging me to be reflective, critical, and open-minded. I'd especially like to thank my committee. I am extremely grateful for the continuous support and encouragement I received from my advisor and chair, Dr. David Drew, throughout my journey at CGU. There are no bounds to my respect and appreciation for him, as he went above and beyond any faculty duties to ensure my success. I am also thankful for committee members Dr. Thomas Luschei and Dr. June Hilton, whose classes led me toward my dissertation topic. I am grateful for their time and efforts to provide me with valuable and thoughtful feedback, and their support through this process. Finally, I'd like to acknowledge and thank my fourth committee member and superintendent, Dr. Gregory Franklin, for his incredible leadership and encouragement. I feel blessed to work under a leader who cultivates a culture of learning and celebrates continued educational efforts and professional growth. I am forever indebted to my committee and Claremont Graduate University for the impact these experiences have had in my life.

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Chapter I

Introduction

Research in the past ten years has shown that there is a lack of professionals to fill the jobs available in science because only up to 23 percent of bachelor degrees in the U.S. pertain to STEM (science, technology, education, mathematics) fields (Business-Higher Education Forum, 2010; National Board of Sciences, 2010; Science and Engineering Indicators, 2016). Students pursuing science degrees represent an even smaller percentage (BHEF, 2010; U.S. Department of Labor, 2007). In fact, several news articles report an unsuccessful national push for students to enter STEM fields by encouraging better STEM education and inspiring students to pursue the field (Korn, 2015; Price, 2012). While the interest in college degrees in science is on the rise (NCSES, 2012), many American science companies such as Broadcom Corporation have had to recruit professionals from other countries such as India in order to fill positions with employees that are properly prepared to meet the demands of the company (Commission on Professionals in Science and Technology, 2007; Leal, 2012; U.S. Department of Education, n.d.).

Further, statistics have shown that women and minorities are underrepresented in the field of science; and that there is a wide achievement gap between genders and minority and non-minority groups (American Association of University Women, 2010; National Center for Education Statistics, 2011; USDL, 2007). Not only that, but for all subgroups combined, few students in 4^{th}, 8^{th}, and 12^{th} grade are reaching proficiency on national science tests (NCES, 2011). Given the impact teachers can have on interest and achievement in science (Areepattamannil, 2012; Karaarslan & Sungur, 2011; Markowitz, 2004; Patrick, Mantzicopoulos, Samarapungavan & French, 2008), effective science instructional strategies need to be analyzed and further supported to ensure that all students receive appropriate science education (NCES, 2011; U.S. Department of Education, n.d.).

Purpose of the Study

The purpose of this paper is to report on a quantitative survey study that examines college science major students' perceptions of high school instructional practices in science classes that may have influenced their achievement and interest in science. I was interested in investigating whether a combination of both inquiry and direct instruction strategies would provide the most effective science instruction. Given the vast body of literature supporting each instructional style (Cobern, Schuster, Adams, Applegate, Skjold, Undreiu, Loving & Gobert, 2010; Rosenshine, 2009), it seemed logical that a combination of inquiry infused with direct instruction would be optimal to promote interest and achievement.

Significance of the Study

Among the recent reform efforts is the release of the Next Generation Science Standards that support an investigative approach to learning and endorse Bybee's inquiry 5 E model of instruction, which includes the components: Engage, Explore, Explain, Elaborate, Evaluate (Bybee, 2015). While several states have adopted the standards, including California, and many constructivists are in support of them, advocates of direct instruction find them to be a menace to science achievement efforts. Opponents of constructivism are often supporters of direct instruction; however, Cobert et al. (2010) explained that constructivism is a theory of learning, not a theory of instruction, and they should not be compared. So, how is it that extensive research supports the use of inquiry science instruction to promote achievement and interest in science (Areepattamannil, 2012; Bybee, 2015; Cuevas, Lee, Hart & Deaker, 2005; Estrella, Au, Jaeggi, & Collins, 2018; Settlage, Madsen & Rustad, 2005) while extensive research also opposes it to support the use of direct instruction (Cobert et al., 2010; Kirschner, Sweller, & Clark, 2006; Rosenshine, 2009)?

The problem in the literature is that there are conflicting conclusions on effective science teaching. One reason might be that there are many operational definitions for inquiry instruction, and it is very complex, whereas direct instruction is more self-explanatory. The descriptions of direct instruction in research have commonalities, while inquiry takes on many definitions such as investigative, active learning, collaborative, and student led (Cobern, 2010). Cobern et al. (2010) argues that "active learning" can have many meanings, and active learning and inquiry are sometimes used synonymously, especially in relation to constructivism. Supporters of direct instruction such as Kirschner, Sweller, and Clark (2006) have described inquiry as minimally guided instruction. At times it has been found that what teachers report as inquiry instruction is not what researchers observe or agree with as inquiry (Cobern et al., 2010; Munck, 2007). It can be difficult to capture the complexity of an inquiry lesson, in order to demonstrate that the treatment provided is representative of the inquiry that readers envision. Often, many research articles, both that support and oppose inquiry instruction, fail to provide detail of what inquiry actually looks like in the classroom (Cobern et al., 2010). Thus, it is difficult to decipher what instructional practices are truly effective and what characterizes those practices. Finally, researchers have argued that despite the application of inquiry with students, achievement is measured through tests that align better with direct instruction, which could be a reason for the lack of achievement evidence in many articles investigating the effects of inquiry instruction (Cobern et al., 2010; Shepardson & Pizzini, 1994). Thus, how effective are these studies in investigating the effects of inquiry versus direct instruction? Furthermore, what characterizes the inquiry instructional practices that researchers report as effective? Lastly, if both styles have been found to be effective, would the combination of the two enhance instruction further? John Dewey (1938/1997) in his book, *Experience and Education,* argued long ago that both traditional and progressive approaches were necessary for science education, as separately they fall short.

Research Questions

Despite increased attention to science education through STEM initiatives and the adoption of the Next Generation Science Standards (NGSS), science teaching in schools remains an area of concern (Center for Research, Evaluation, and Assessment, Lawrence Hall of Science, 2007). Reform efforts focus on a singular practice over another, despite warnings from research that inquiry might not always be effective for achievement, and direct instruction can be ineffective for student engagement. Given the knowledge that student self-efficacy predicts achievement (Caprara, Barbaranelli, Steca & Malone 2006), it is important that students feel successful as well as engaged, and effective strategies that promote interest need to be explored in order to help reform efforts continue in the most effective direction. Because of mixed feelings regarding traditional tests as a form of achievement measurement and the difficulty of correlating interest and practices with young students, college students who found success in science and pursued the science field can be useful in determining effective and memorable instructional practices. The overarching question and sub questions are as follows: *What are college students' high school science experiences that contributed to their achievement and/or interest in science?*

1.) What are their perceptions of and attitudes toward their science experiences?

2.) Do certain instructional practices correlate with achievement or interest in science?

3.) Are instructional strategies such as collaboration, relevant experiences, scaffolded scientific thinking, personal experiences, and exposure to scientific processes predictive of achievement or interest in science?

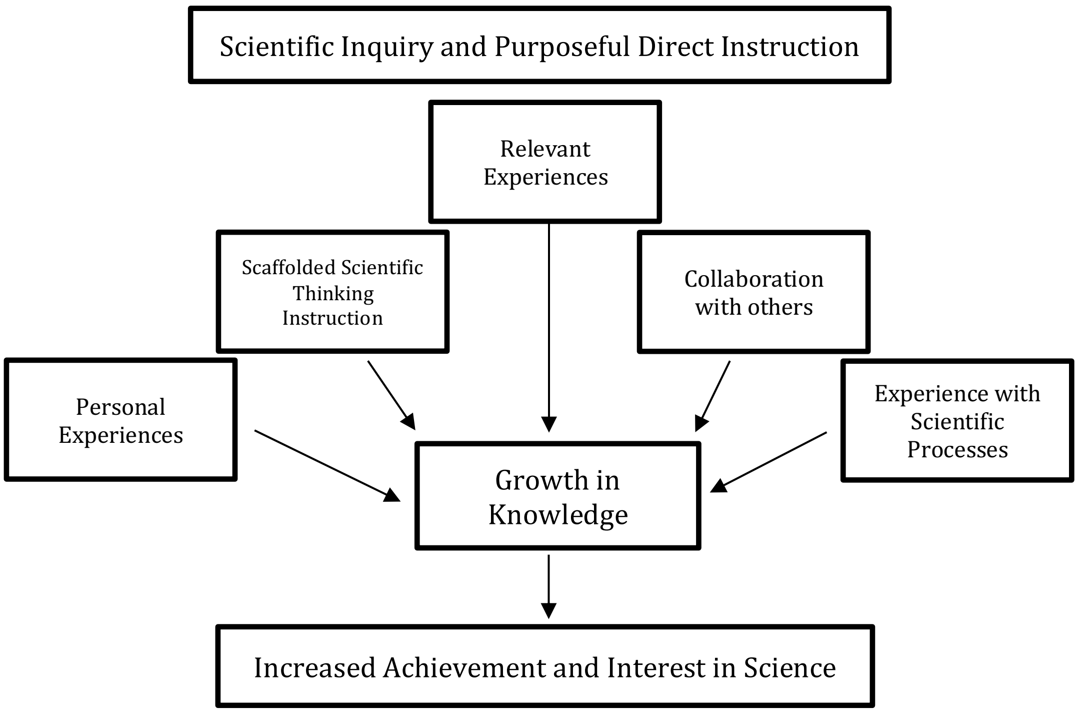
Definition of Terms

Direct Instruction is explicit teaching of a skill or technique by teacher demonstration or scaffolded transfer of information from teacher to student. In contrast, Inquiry Science Instruction is an investigative approach that provides students with personal and relevant experiences, authentic to the field, where students act as scientists to conduct experiments.

Theoretical Framework

The Scaffolded Knowledge Integration Framework for Instruction by Linn, Davis, & Eylon (2004) provides a lens through which science instruction can be seen as most effective when inquiry and direct instruction approaches are combined. In this theory, knowledge is gained through personal and relevant experiences (stemming from what students know), scaffolded scientific thinking instruction, collaboration with others, and exposure to scientific processes. It explains a method of teaching science that integrates explicit teaching of scientific thought and processes, while providing authentic investigative practices through personal and memorable experiences. This framework encompasses a comprehensive inquiry instruction definition, in which direct instruction is infused where appropriate and as needed to guide students toward concept development and understanding during genuine scientific experiences. According to this model, through the combination of the five key aspects of science instruction shown in Figure 1, students will experience success in science and ultimately achievement and interest will increase. Due to the large body of literature promoting inquiry instruction and direction instruction, this model is supported because it emphasizes the impactful factors from each model of instruction.

Figure 1. A model of The Scaffolded Knowledge Integration Framework for Instruction (graphic developed by author)



Some other researchers have presented a similar idea. For instance, Ainsworth, Bibby, and Wood (2002) argue for different representations of learning in mathematics. Huebner (2008) advances this thought explaining that in science, students should be taught scientific principles through concrete presentation then leading into abstract application. She argues that this shift will push student thinking and understanding, urging them to apply their knowledge to new situations.

History of Science Education

Glancing at the history of education reveals trends that can promote better understanding of the current state of science education. In recent years, it is common to see news publications describing a crisis when referring to science achievement and science education in United States schools (Dye, 2000; National Board of Sciences, 2010; Pappas, 2011). Similar headlines decorated newsstands in 1957 when Russia launched Sputnik (Abramson, 2007). Even before Sputnik, science education had long been in controversy as demonstrated in 1859 with Darwin's publication of The Origin of Species that continues to be a debated topic as it offends religious beliefs. Science reform efforts were already initiated before Sputnik was launched beginning in the early 1950's; however, the news that Russia invaded space before the United States caused panic and concern (National Academy of Sciences, 1997). U.S. citizens feared that Russia was spying and dreaded the thought of being second in the space race. As a result, the National Defense Education Act as was passed that provided millions of dollars of funding to improve science research and education. In 1969, the U.S. secured their place as leader in the space race when Neil Armstrong landed on and explored the moon. Because there was no longer a threat, funds for science education dwindled and an emphasis was placed on math and language arts, as achievement in those areas became the new "crisis." With the No Child Left Behind act passed in 2001 in an attempt to close the growing achievement gap, many schools reverted to textbook based science as there were not enough time and resources to spend on hands-on and investigative science while meeting strict curriculum demands in language arts and math (Al-Rehaly, Lee, Smith, Smith, Sweeney & Winsett, n.d.; Center for Research, Evaluation, and Assessment, Lawrence Hall of Science, 2007). In 2012, 6% of U.S. undergraduates were enrolled in natural sciences fields (Science and Engineering Indicators, 2016). Thus, it is vital to examine successful strategies for science education.

So how is it that U.S. scientists can design a space rover such as *Curiosity* that can function on Mars if they went through school at a time of dwindling funds in science and weak science education? Although reporters' dramatic posts regarding elementary science achievement and the lack of professionals to fill science positions available instigate concern, the U.S. remains competitive currently in the field of science. The state of science education is not considered an emergency, as it was when Sputnik was launched. At that time, science reform was fear-driven. Today, while reports may display concerning titles, they are not threatening. Curriculum developers and educators are positive and hopeful (Center for Research, Evaluation, and Assessment, Lawrence Hall of Science, 2007; Science and Engineering Indicators, 2014). Current reform efforts aim to assist teachers in meeting the needs of the students while still complying with government demands. Funds may have dwindled, but many partnerships have surfaced between schools and large-scale science companies to promote achievement (Mathematics, 2011; MSP, 2011; NASA, 2012; U.S. Department of Education, n.d.). However, it is important that these efforts focus on all encompassing strategies for instruction.

Science instruction has been a topic of debate and concern for many years. It is also widely studied due to the decline in state test scores and calls for instructional reform. Practitioners endured a complete transition to new standards, the Next Generation Science Standards, which require a shift in instructional practice. Liu, Lee, and Linn (2010) argue that although many practitioners have moved from textbook based instruction to inquiry in order to improve science instruction, the assessments still being used are not appropriate to measure inquiry-based learning. The assessments reflect a more fact-based assessment, which mirrored the 1998 standards, as opposed to application of scientific skills. Thus, the researchers call into question whether that measurement for achievement is accurate. This year will be the first official release of the new CAST (California Science Test) scores, which are said to reflect and assess more authentic scientific practices and skills.

Therrien and Benson (2017) argue a different point that the main reason for poor performance on state science assessments is due to lack of language, core academic skills, and knowledge acquisition and retention. This is especially true for students with learning disabilities who often struggle with limited vocabulary knowledge, making science extra difficult.

Finally, Conderman and Woods (2012) argue that there is minimal attention given to science instruction especially at the elementary level and that the quality of instruction is low. This may be true since science is not given a specific period of time at the elementary level, but rather it is up to the teacher to put that time in during the day. There are several reasons science may be given less attention, including lack of teacher content knowledge and instructional knowledge in the subject, which leads to low confidence (Conderman & Woods, 2012). Also, students are only tested in 5th, 8th, and 11th grade in science on the state test, so teachers may not feel they are accountable for teaching science as a priority.

Science is complex, and so are the instructional practices that go along with it to promote student learning and interest. Beyond the instructional style, teachers must feel confident with a deeper understanding of science than the surface, given NGSS, which promotes higher-level thinking. On the opposite end, post-secondary teachers often have a strong background of content knowledge, but lack skills to effectively teach the content to others (Bass, 2012). Bass (2012) argues that learning assumptions need to be used as a basis for instructional practices in science for students of all ages. She argues for teachers to apply a variety of practical strategies based on many learning theories including experiential learning theory, transformational learning theory, and self-directed learning (learning through experiences). Science instruction needs to promote both achievement and interest in science, especially since self-efficacy and interest are linked, and both are related to achievement.

Importance of Science

Life Skills

Children are natural scientists. Beginning at a young age, children demonstrate an inquisitive nature full of curiosity and efforts to make sense of the foreign world around them (Eschach & Fried, 2005; Koch, 2010; Ormrod, 2008; Seefeldt et al., 2012). Somewhere in education, students lose interest in science, which is clear when looking at the percentage of students pursuing bachelor degrees in STEM fields (BHEF, 2010). It is possible that they become bored with the large amount of surface level information that teachers attempt to cover in a school year. "One experience lives on in further experiences" (Dewey, 1997, p. 27), and what students experience in traditional schools is a prediction to them of what is to come. However, when taught appropriately, science education can be enjoyable and has many benefits for students and society at large. The problem with textbooks, besides the lack of in depth material, is that they are unappealing to students, promoting memorization of the answer over scientific processes and critical thinking (Amaral et al., 2002). Even an ancient Chinese proverb said by Confucius reflects how people most effectively gain knowledge: "I hear and I forget. I see and I remember. I do and I understand" (Confucius, n.d.). Teachers who strictly use textbooks to teach science undermine the "learn by doing" philosophy that is supported by all hands-on research findings as effective (Amaral et al., 2002; Areepattamannil, 2012; Ireland, et al., 2012).

Although certain scientific concepts, funding, and teaching methods may still spark debate among curriculum and policy makers today, one aspect of science definitely does not: its value to students as members of society and future leaders in the workforce. For example, environmental science has become significant in recent years as scientists are becoming more aware of pollution and its effect on humans and the environment. As citizens, students need to be aware of methods to save natural resources and take care of the environment so they can do their part (Koch, 2010).

Science is a part of everyday life. Whether it is in the form of learning about health and environment hazards or watching the sun set in the evening, scientific phenomena are observed and studied daily. Becoming scientifically literate is vital for personal, social and global contexts, including participation in the workforce and society of the 21st century, and for the U.S. to remain competitive with other leading nations. PISA (2006) explains being scientifically literate as using scientific processes to gain new knowledge, explain phenomena, draw conclusions, understanding and awareness of scientific characteristics and its use in the world, and willingness to be involved in scientific issues as an active citizen (Bybee, 2009). In order to meet these standards, one has to be able to think critically and creatively, conduct investigations, consider multiple perspectives, perform the scientific method, build background knowledge, understand scientific concepts, and be knowledgeable in language arts and math domains. With this knowledge and skill, students can make informed decisions and problem solve. All of these skills are developed through science education and practice. When science education is left out in schools, students are not given an opportunity to develop these skills. Not only are these skills relevant for becoming scientifically literate, but they also are necessary for advancing skills in other domains.

Utility

Science instruction provides teachers with opportunities to integrate subject matter (Bossé, Lee, Swinson & Faulconer, 2010; Hanrahan, 2009; Lutz, Guthrie & Davis, 2006). Language arts and math achievement, for instance, can increase as a result of science participation (Bossé, et al., 2010; Hanrahan, 2009; Lutz, et al., 2006). Thus, teachers can integrate the subjects to help resolve the time constraints that standardized testing and curriculum places on them. Not only that, but it is important for students to make connections across content and be equipped with tools that are useful in all areas such as comprehension and problem-solving strategies. Providing students with appropriate scientific reading materials can be challenging and increase reading levels. In a correlational study, Lutz, Guthrie and Davis (2006) examined two fourth grade classrooms that received integrated science and reading instruction and compared achievement levels to a fourth grade class that used traditional methods. Researchers found that the classes receiving integrated instruction demonstrated strong growth in the use of reading strategies, complex materials and reading comprehension throughout the observed time period in comparison to the class who received traditional instruction and made little gains. Research demonstrates that many literacy strategies can be explicitly taught and practiced during a lesson focused on science content (Hanrahan, 2009; Lutz, et al., 2006). Therefore, incorporating language arts during science can improve student achievement as well as develop literacy.

Bossé, Lee, Swinson and Faulconer (2010) studied the *Principles and Standards for School Mathematics* and the *National Science Education Standards* for mathematics and science process standards and found numerous terms used in both sets that described expected student outcomes. These included terms such as problem solving, reasoning, connections, representations, exploration, explanation, evaluation and communication. Teachers need to take advantage of the similarities presented in the standards to make efficient use of time and provide students with strategies they can use successfully in other subject areas. This will enable students to receive richer experiences that extend learned processes. Integration also ensures that students receive a well-rounded education, with a means of maintaining emphasis in language arts and math.

Factors Influencing Student Interest and Achievement

Teacher Self-Efficacy

Teachers play a crucial role in promoting positive experiences and fostering student achievement. Teacher self-efficacy, or the belief in one's ability as a teacher, has been reported as a predictor of student achievement (Lumpe et al., 2012; Moseley & Taylor, 2011; Voss, et al., 2011). When teachers lack the confidence in teaching science, their students do not receive adequate instruction (Fogleman, et al., 2010) and perform lower in science. In a correlational study, Lumpe, Czerniak, Haney, and Beltyukova (2012) observed and surveyed 450 teachers while they participated in a six-year professional development (PD) program and found that the number of hours teachers participated in PD was a predictor of teaching self-efficacy and ultimately student achievement. It has also been observed that teachers with higher efficacy have greater ability to instigate motivation and interest in science among their students (Moseley & Taylor, 2011). Thus, teachers who have more confidence in science instruction tend to produce superior experiences, and stimulate higher student achievement.

Teaching instructional practices are a reflection of teachers' beliefs about the most effective method to teach and about their abilities to teach. Some instructional practices are more effective than others, depending on the learner and subject material. Teacher's that have more confidence in their instructional abilities and content knowledge are more likely to implement innovative reform efforts than those who lack teaching self-efficacy (Cousins & Walker, 1995 as cited in Caprara, Barbaranelli, Steca & Malone, 2006; E.Tabata, personal communication, October 5, 2012; Fogleman, et al., 2010). To implement new curriculum materials and methods, teachers have to accept the role of trainees and familiarize themselves with innovative resources. Often, teachers revert back to traditional methods if confidence in content knowledge or instructional abilities are lacking. This, however, can affect what students learn and defer the effectiveness of the reform (Fogleman, et al., 2010). Fogleman, McNeill and Krajcik (2010) asserted that it is not just the quality of curriculum that is vital for student success, but also the methods that teachers utilize to implement the curriculum.

Fogleman, et al. (2010) designed a correlational study to investigate how teachers' adaptions to reform curriculum, teaching self-efficacy, and experience with the materials influences student learning. The researchers speculated that low confidence could be a reason for a lack in improvement after reform efforts. Therefore, they observed, videotaped and surveyed nineteen middle school science teachers during the course of the *Stuff* unit, an inquiry based curriculum unit developed by Investigating and Questioning Our World Through Science and Technology (IQWST). Results show that on average students gained 7.49 points from pre- to post-test, and 38% of the variance in student learning was credited to the role of the teacher. Reports from the surveys suggest that teachers who had previously taught inquiry based curriculum had the greatest student gains, and teachers who used student investigations compared to traditional demonstrations also had greater student learning gains. Thus, those teachers who adapt to the suggested reform curriculum methods and those having prior experience with materials have a greater impact on student learning. Because the role of the teacher is so significant in student learning, it is important to increase teacher confidence so that adaption to reform curriculum is successful.

Student Self-Efficacy

One possible reason for the lack of participation in science fields lies in students' beliefs in their ability to do science, or science self-efficacy, which is linked to achievement (Areepattamannil, et al., 2011; Britner & Pajares, 2006; Bryan, Glynn & Kittleson, 2011; Caprara, et al., 2006; Karaarslan & Sungur). Students perform better and are more interested in science when they have positive experiences and higher self-efficacy (Ainley & Ainley, 2011b). Thus, there is a need to provide students with successful and enjoyable experiences to build self-efficacy.

Students feel they are more capable of doing science and are more successful when they have had positive prior experiences, relating back to experiences elicited by teachers. Their perceptions of science are both influenced by prior achievement and serve as predictors of achievement (Areepatamannil, et al., 2010; Britner & Pajares, 2006). Teachers who put great effort in planning and provide successful experiences for students, give students higher self-efficacy and promote higher achievement (Britner & Pajares, 2006; Lumpe, et al., 2012; Mosely & Taylor, 2011).

In a correlational study, Britner and Pajares (2006) used the Sources of Science Self-Efficacy Scale, and prior science grades from 319 middle school students to evaluate the extent to which four sources of self-efficacy (mastery experience, vicarious experiences, social persuasions, and physiological states) predict student science achievement. Results revealed that there was a significant correlation between all their categories of sources of self-efficacy themselves, and each of the sources of self-efficacy with student achievement. Mastery experience was the most significant predictor of science self-efficacy, explaining 24% of variance ($p<.0001$), meaning that prior success and achievement moderately influence science self-efficacy. Thus, students who have successful prior experiences in science, typically display higher science self-efficacy and higher student achievement.

Student Interest

As stated earlier, children are born with scientific qualities. They are intrigued by the world around them. Children build and pull apart toys when they play, ask questions, observe, and learn from their environment. It is important for teachers to take advantage of children's inquisitive nature by providing activities that meet their needs and captivate their interests. Patrick, Mantzicopoulos, Samarapungavan, and French (2008) found in their correlational study of kindergarteners that students with low motivational interests in science received less teacher support than students with high motivational interests. This is important for teachers to make sure all students receive equal opportunity in science.

Student interest in science can be sustained when teachers provide support and positive experiences. Competency has been reported as a predictor of students' positive attitudes towards science (Mantzicopoulos, Patrick & Samarapungavan, 2008) and kindergarten scores have been found as a predictor of achievement in primary grades (Sackes et al., 2011). Exposing students to science beginning at a young age will help them develop positive attitudes towards science later on (Eschach & Fried, 2005; Patrick, Mantzicopoulos, Samarapungavan & French, 2008). Thus, it is important to provide science instruction beginning at an early age to promote positive attitudes and achievement in science.

If students are provided with these experiences that promote positive attitudes and motivational interest in science throughout adolescence, then logically more students will pursue a science field for higher education as personal interest has been reported as a strong predictor of major choice (Hall, Dickerson, Batts, Kauffmann & Bosse, 2011). Hall, Dickerson, Batts, Kauffmann and Bosse (2011) found in their survey study of high school students that interest was followed by parent influence, earning potential and teacher influence as order of importance in determining their major. Even though teacher influence was rated as fourth in this particular study, it shows that teachers do impact their students' decisions and have the ability to make a change in the field of science. This is especially true as teachers have the opportunity to sustain student interest in science, and interest takes the number one spot as an indicator of major choice.

So how do teachers sustain student interest over time? Interest has been found as closely related to enjoyment (Ainley & Ainley, 2011a; Ainley & Ainley, 2011b). When students find a topic interesting, they are more likely to enjoy investigating the topic further, and when students are presented with an enjoyable activity, they are more likely to take interest in it. To students, these experiences serve as expectations of what they will experience later on. Thus, it is vital that the activities are always of high interest and enjoyable to sustain student engagement in science. Practicing effective instructional techniques such as inquiry and hands-on activities prepares students more thoroughly, another indicator of student interest in science (Markowitz, 2004). When students feel prepared, they are more confident in pursuing challenging science classes. With the appropriate strategies, teachers can better equip their students for sophisticated fields and promote positive attitudes towards science. The feeling of preparedness typically leads to higher self-efficacy and achievement. Students do not always realize that they have the potential to pursue challenging courses in science, and it is vital that teachers encourage and motivate them (Bryan, et al., 2011; Eshach & Fried, 2005). Motivation can come from stimulating successful experiences, providing enjoyable high interest activities, increasing student self-efficacy, and utilizing appropriate instructional practices.

Chapter II: Review of Literature

Analysis of Instructional Practices

In 2011, the Nation's Report Card reported significant gains for 8th graders in the area of science, and in 2015 there were more gains for grades 4 and 8, but not significant gains for grade 12. Survey results showed that students reported more hands-on science activities and collaboration among peers, as well as more enjoyment of science in 2011 than 2009 (NCES, 2011; NCES, 2015). Although gains have been made, there is still a long way to go. Today, due to high stakes testing of language arts and mathematics, curriculum focus remains largely in those subjects, decreasing attention in science and other non-tested areas as a result. In California, science testing does not begin until fifth grade, and with time allotments required for language arts and math, time left in a day is minimal.

Many reports have announced that science education is weak and of poor quality (Dorph, Goldstein, Lee, Lepori, Schneider & Venkatesan, 2007; Dye, 2000; Melina, 2011). Consistently stated beliefs for the status of science education include little time spent and to spend on the subject, lack of preparation of teachers, and dwindled efforts to increase science achievement (Dorph et al., 2007; Houston, et al., 2008). In a 2007 survey study performed in the Bay Area, California, by the Lawrence Hall of Science, also known as the developers of FOSS kits, researchers found that 80% of K-5 teachers spent 60 minutes or less per week on science education, with 16% spending no time at all (Dorph et al., 2007). Researchers also elicited that teachers reported feeling significantly underprepared to teach science compared to teaching math and language arts, including teachers designated to teach science specifically (Fulp, 2002). These findings are troubling considering the importance and benefits of science for children, future members of the workforce, and society. Thus, there is vast literature surrounding the effectiveness of science instructional practices.

Another possible reason for the lack of participation in science fields lies in students' beliefs in their ability to do science, or science self-efficacy, which is linked to achievement (Areepattamannil, Freeman & Klinger 2010; Britner & Pajares, 2006; Bryan, Glynn & Kittleson, 2011). Students perform better and are more interested in science when they have positive experiences and higher self-efficacy (Ainley & Ainley, 2011b). Their perceptions of science are both influenced by prior achievement and serve as predictors of achievement (Areepatamannil et al., 2010; Britner & Pajares, 2006). In a quantitative survey study, Hall, Dickerson, Batts, Kauffmann & Bosse (2011) found that personal interest and teachers were in the top four influences determining high school students' career choices. Thus, there is a need to provide students with successful and enjoyable experiences in science.

Inquiry Versus Direct Instruction

Inquiry is a process that involves the learner in investigation and exploration to reach a conclusion and construct knowledge. Extensive research supports the use of inquiry science instruction in elementary and secondary education (Fogleman, McNeill & Krajcik, 2010; Markowitz, 2004; Ricketts, 2011; Santau, Maerten-Rivera & Huggins, 2011). The use of inquiry is a predictor of student achievement (Cuevas et al., 2005; Ricketts, 2011) and interest in science (Amaral, Garrison & Klentschy, 2002; Areepattamannil, 2012).

However, facilitating inquiry science is challenging, requiring in-depth disciplinary knowledge and pedagogical skills that many teachers do not possess (Dorph et al., 2007; Houston, Fraser & Ledbetter, 2008). Although teachers have reported practicing inquiry-based instruction, researchers have found disconnect between their descriptions of their practice and what actually occurs in many classrooms (Munck, 2007; Tan & Wong, 2012). Bergman and Olson (2011) assert that "hands-on science is half the battle" (p. 44). Inquiry involves more than physical manipulation of materials. Critical and analytical reasoning coupled with self-discovery through exploration, are key components of an inquiry lesson (Bergman & Olson, 2011; Gibson & Chase, 2002; National Research Council, 2000). Thus, more literature on the structure of effective inquiry and instructional strategies is needed to paint a clearer picture and provide teachers with support in science teaching.

While we know inquiry is a dominant focus in science reform efforts there is still little evidence of inquiry in classrooms today (Meyer et al. 2013) and ample evidence suggesting direct instruction as a more effective strategy in some ways. Researchers who view inquiry instruction as minimally guided have had stronger achievement results for direction instruction as opposed to inquiry (Kirschner, Sweller, & Clark, 2006; Mayer, 2004; Shepardson & Pizzini, 1994). Adding to the confusion, direct instruction has been the leading strategy with English Language Learners, and yet many researchers have reported inquiry as effective for promoting language development (Ricketts, 2011; Westervelt, 2007).

Many researchers and instructional efforts favor one strategy over the other, and none combine the two. This effort would require support for teachers given the complexity of inquiry, and skill to infuse the strategic implementation of direct instruction. It is clear that as the research is synthesized, that scaffolded inquiry investigations will provide the language support and vocabulary development enriched with experiences that will promote achievement and interest in science. It is important to further analyze specific strategies teachers implemented in articles that find inquiry effective for achievement, and seek to promote an all encompassing definition of inquiry that incorporates appropriate scaffolds and practices of direct instruction that promote success. This chapter synthesizes and analyzes literature on both instruction practices, identifies limitations of each, and provides suggestions for science instructional practices and further areas of research.

Research supports the use of both inquiry science (Cuevas et al., 2005; Ricketts, 2011; Santau, Maerten-Rivera & Huggins, 2011) and direct instruction (Mayer, 2004; Kirschner, Sweller, & Clark, 2006) to increase achievement in science. How is it that there is so much support for both practices against the other? Many articles studying science practices use standardized tests as achievement data; however, standardized tests often reflect direct instruction/textbook practices as opposed to the skillset gained through discovery or inquiry learning (Shepardson & Pizzini, 1994; Rosenshine, 2009). Both instructional practices (inquiry and direct instruction) have vast support, and so the debate continues (Cobern et al., 2010). Many researchers and instructional efforts favor one strategy over the other, instead of combining the two. This effort would require support for teachers given the complexity of inquiry, and infusing the proper implementation of direct instruction.

Support for Inquiry Instruction

Inquiry instruction is an instructional practice where the learner is led by the teacher and involved in an investigation as a participant. The teacher does not begin with explicit facts or answers, but rather involves the students in a discovery procedure that mirrors authentic scientific practices. Constructivism, a theory commonly used to describe how children learn (Koch, 2011; Seefeldt et al., 2012), is at the root of inquiry and can be first seen in Dewey's written philosophy on education. Constructivists argue that students learn through experiences that allow them to build their own knowledge and meaning. Dewey argued in his statement titled "Experience and Education" that the purpose of school is to prepare students for future responsibility and success, which meant that students needed to acquire skill to help them comprehend instruction and connections between content. He saw the teacher as a facilitator who enforces proper conduct, rather than an authority who transfers factual knowledge. According to Dewey (1997), traditional methods of school were designed by adult standards and "taught as finished product" (p. 19), and then imposed upon students who were not developmentally ready to learn by those methods. Students come to the classroom with experiences, and it is up to the teacher to build upon these experiences, address misconceptions and help students to make connections. These experiences will live on in students' minds. These are the ideas behind constructivism. The process is emphasized more than the end result. Once students develop the skills to reach the end result, they can apply those skills in other situations and are able to construct their knowledge.

In recent years, inquiry can be narrowed down to a single definition, but has a variety of implementation strategies that ultimately are methods to engage students in the process. Inquiry is an instructional strategy that involves the learner in investigation and exploration to reach a conclusion and construct knowledge. Ireland, Watters, Brownlee, and Lupton (2012) categorize three different methods of inquiry implementation they found in exploring practicing teachers' conceptions: providing students with stimulating experiences (student centered), providing challenging problems or situations (teacher generated problems), and supporting students in asking and answering their own questions (student generated questions). Other initial methods to draw attention from students include presenting a fascinating issue or phenomenon, telling a personal anecdote, or asking a challenging question. After students are engaged, the process of investigation can begin, which typically involves research, manipulating materials, critical thinking, and making inferences. A typical inquiry lesson from an educator's perspective involves initial student engagement, allowing students to explore materials or the environment, drawing explanations and providing clarification, applying the topic to other contexts, and evaluating understanding. Throughout the lesson, students participate in rich conversation. This requires the teacher to ask open-ended questions, encourage collaboration and presentations, and use direct instruction when necessary. The definition of inquiry and practicing methods, however, differ based on teacher beliefs (Ireland et al., 2012).

5 E Instructional Model of Inquiry

Bybee's inquiry 5 E model encompasses five main components: engage, explore, explain, elaborate, evaluate. This model calls for teachers to take on the role of a facilitator and guide students through an investigation, while students participate in exploring materials, planning and designing experiments, and constructing explanations based on observations and evidence. There is also a focus on questioning from both teachers and students as a strategy to promote critical thinking and problem solving. These skills and strategies promoted through the model are not only effective for promoting learning and providing authentic experiences, but also align with the Next Generation Science Standards (NGSS). For instance, NGSS calls for students to define problems, make observations, use scientific tools, create models, design and build, ask questions, collect data, etc. Although the language is more specific in NGSS compared to the 5 E model, there are several parallels in the descriptions of student roles as well as similarities in processes. "The BSCS 5 E Instructional Model is a helpful way to think about an integrated instructional unit. The 5E Model provides the general framework for the translation of *NGSS* to classroom instruction" (Bybee, 2015).

Engagement and Achievement

Extensive research supports the use of inquiry science instruction in elementary and secondary education (Cuevas, Lee, Hart & Deaker, 2005; Fogleman, McNeill & Krajcik, 2010; Ricketts, 2011; Santau, Maerten-Rivera & Huggins, 2011). The use of inquiry is a predictor of student achievement (Cuevas et al., 2005; Fogleman et al, 2010; Ricketts, 2011; Santau et al., 2011) and interest in science (Amaral, et al., 2002; Areepattamannil, 2012; Settlage, Madsen & Rustad, 2005).

In general, research has supported the use of inquiry-based instruction. The use of investigations has been reported as a predictor of student gains (Cuevas, et al., 2005; Fogleman et al, 2010; Ricketts, 2011; Santau, et al., 2011) as well as interest in science (Amaral, et al., 2002; Areepattamannil, 2012).

Strong inquiry instruction can increase student achievement, higher order thinking, and conceptual understanding of scientific concepts (Marshall & Horton, 2011; Minner and Lvey, 2010; Sen & Oskay, 2017). Inquiry instruction has also proven to increase the application of scientific concepts and process skills (Koksal & Berberoglu, 2014; Yager & Akcay, 2010). Liu, Lee, and Linn (2010) designed 10 inquiry science units for high school and middle school science classes with assessments that focus on measurement coherent understanding. Traditional units were taught to a cohort of 2,060 students the first year, and the inquiry units were implemented by the same teachers the next year to the 2nd cohort of 2,685 students. Inquiry students outperformed the Typical (traditional) cohort on the assessments on both proximal and distal assessment question types (proximal relating more to skills and distal related more to standard concepts). This finding is not uncommon (Guzel, 2016; Ural, 2016). However, Marshall and Horton (2011) explained that while inquiry instruction did prove to be more effective to promote higher cognitive levels of thinking, they found that the lessons used up more class time and required teachers to have deepened knowledge of science concepts. Interestingly, they also discovered that the order of the 5 E instructional model did not make a difference on student outcomes, but that allowing more time for the explore and explain phases did make a difference.

Interest

More frequently than other instructional practices, inquiry has been found to increase student interest and attitudes in science (Guzetti, 2010; Ural, 2016). In a study, Ural (2016) determined quantitatively that inquiry classes increased positive attitudes toward chemistry and decreased anxiety. Qualitative analysis showed that students overwhelmingly (32 of 37 in the sample) preferred inquiry to a traditional lab (Ural, 2016). Koksal and Berberoglu (2014) found that guided inquiry had a medium effect size on attitude toward science compared to a traditional textbook approach.

Many researchers have also concluded that student attitudes stayed stagnant throughout an inquiry instruction period or that there was not a significant difference (Guzel, 2016; Guzette, 2010; Sen & Oskay, 2017). Several explanations have been offered. For instance, Sen and Oskay (2017) thought that possibly students in their sample did not experience the inquiry experiment long enough (only 3 weeks, 9 hours total) to change in attitude regarding the entire chemistry course or chemistry in general. Also, it would depend on if students saw the inquiry lessons as a function of their teacher or of the nature of science, as their attitude toward that teacher might increase as opposed to toward the content if they have limited exposure to the experimental treatment beforehand.

Hands-On

While inquiry refers to a *process* of learning science, the hands-on instructional approach more closely relates to how students *perform* a specific activity. Hands-on learning involves physical touch and manipulation of materials, and sometimes it is included in the definition of inquiry (Areepattamannil, 2012). Inquiry can be conducted without materials through the use of computers and textbooks when designed appropriately. However, hands-on learning is not only enjoyable for students, but also is linked to student attitudes and achievement in science (Amaral, et al., 2002; Areepattamannil, 2012; Areepattamannil et al., 2011; Ireland et al., 2012). Because enjoyment was linked to student interest (Ainley & Ainley, 2011b) and hands-on activities are a predictor of achievement, it is important for teachers to incorporate hands-on activities during science.

Although inquiry and hands-on based learning approaches each have volumes of evidence suggesting their value to students, the most effective instructional strategy is to use both simultaneously. Students enjoy subjects in school that they can be creative with. They describe these as relevant subjects during which they are "making something" or "doing something" like physical education, art, and English (Turner, Ireson & Twidle, 2010). Hands-on inquiry science provides an opportunity to engage students in active and authentic science that is more enjoyable then traditional science. Logically, it is difficult to conduct an investigation without tangibly manipulating any materials, however, research suggests that providing students with resources they can directly explore and facilitating inquiry results in improved student attitudes and higher achievement (Amaral, Garrison & Klentschy, 2002; Areepattamannil, 2012; Areepattamannil et al., 2011; Ireland et al., 2012). The positive effects can be recognized when looking at its use with English Learners.

Inquiry and English Learners

Between the years of 1979 and 2003, the number of school age children in the United States increased by 19 percent. At the same time, the number of struggling English speaking children increased by 124 percent (NCES, 2012). In the 2010-2011 school year, there were approximately 1.4 million English learners in California public schools (CDE, 2012). Thus, there is an increasing need for reform efforts that are not only qualified to increase student achievement in general, but also are effective for increasing achievement for English learners.

Research has supported that inquiry science has had positive effects for English Language Learners (ELL) (Amaral et al., 2002; Buxton, 2009; Ricketts, 2011; Santau et. al, 2011; Shanahan & Shea, 2012). Several reports indicate that strategies such as hands-on and investigative learning are effective methods to use with ELL students (Amaral, et al., 2002; Buxton, 2009; Estrella et al., 2018; Fishkin, 2010; Ricketts, 2011). Fishkin (2010) stated that hands-on activities and experiences working with other students are the most effective learning situations for ELL students. Providing visual aides is also mentioned as a strategy that benefits ELL students, and also a major aspect of inquiry.

Many researchers have noted assumptions related to teaching ELL students (Buxton, 2009; Ricketts, 2011; Westervelt, 2007). One misconception is that in order to engage in inquiry and learn science content, English Learners must first acquire English proficiency. Due to this, many English Learner classrooms focus on language acquisition over developing content knowledge, and the achievement gap on government testing continues to widen. However, inquiry instruction can be used as a means of making content accessible. Buxton (2009) encourages teachers to reject their assumptions, and utilize inquiry as a tool to increase vocabulary while building science content knowledge. He described two vignettes: one in which students examined scientific issues in their greater community, researched a project of their choice, and implemented methods of informing the public; in the other, students attended scientific workshops with their families and learned the value of science participation for their future by engaging in authentic and culturally relevant inquiry activities and informational meetings. These versions of inquiry allowed students to connect science with their interests and personal lives, as well as develop oral speaking skills, science content and English vocabulary knowledge. Thus, inquiry science can provide opportunities for all students to engage in meaningful scientific activities that are socially and culturally relevant.

Ricketts (2011), an elementary school teacher, also advocates the use of inquiry with English Learners, asserting that English is not a prerequisite to engage in inquiry. In fact, she argues that inquiry is beneficial for achieving content knowledge while building English vocabulary much like many other researchers (Amaral et al. 2002; Buxton, 2009; Ricketts, 2011; Santau et. al, 2011; Shanahan & Shea, 2012). Inquiry, therefore, provides an opportunity for teachers to integrate subject matter. Science journals are often associated with inquiry lessons. Students use journals to conduct research, record observations, and draw conclusions. Incorporating the journals allows students to develop language arts concepts while learning science, when used appropriately.

Challenges of Inquiry Instruction

Educators are faced with many challenges when it comes to implementing inquiry instruction given the complexity of the approach. First, teachers must have strong content knowledge and confidence in order to facilitate students learning, especially if the experiment is student led (Conderman & Woods, 2012). Also, teachers must be dynamic and flexible with the flow of an investigation. Xiaowei, Coffey, Elby, and Levin (2009) wanted to determine the difference in classroom dynamics between a scientific method lesson which focuses on each step in the process and the same concept taught using an inquiry approach. They argue that the scientific method was deconstructed as a strict prescribed routine, rather than what it was originally intended because it made an easy reform to carry out for the teacher. This takes away the interpretative and investigative nature of science. This was a very small qualitative case study with only one teacher participant. The researchers videotaped her scientific method lesson, and analyzed student interaction during each phase, including a small inquiry engagement after. They concluded that during the scientific method portion of the lesson, the rigidity of the steps distracted the teacher and students away from productive scientific inquiry. This is an example of how the need for control over a lesson can decrease the likelihood of true inquiry for students.

Harlow (2009) pointed out that another challenging aspect of inquiry for teachers is making real-time instructional decisions when trying to engage students in scientific models. Teachers must not only be flexible, but also they must be able to respond quickly, be comfortable with the uncertainty of a lesson, and be able to ask guiding questions in real time. Thus, pedagogical content knowledge, scientific content knowledge, and ability to adapt and improvise real time are all important aspects of inquiry and skills teachers need to successfully facilitate an inquiry lesson (Harlow, 2009).

Finally, Koksal and Berberoglu (2014) explain that there are different approaches to inquiry and that the main differences deal with the amount of freedom given to students in design and investigation. Guided inquiry is in the middle of the spectrum from complete freedom to complete control. This also may be called a semi-structured approach. With the many different inquiry styles, it is difficult to compare and control inquiry practices for experiment. It can also be unclear to many practitioners that there are varying levels of teacher involvement and structure for inquiry, and the fact that there isn't one "right" way to implement inquiry can be confusing to some.

Effectiveness of Direct Instruction

Direct instruction is a method of content delivery that is explicit. The teacher models the skill, and directly teachers how to do the skill. Lectures and textbook reading are a form of direct instruction. Students listen and apply information. Critics often claim that direct instruction does not push higher-level thinking or encourage questioning, application, and other authentic practices. Students are passive learners and not involved in real life processes related to professional fields in that content area. Proponents claim that students are not professionals and need explicit direction and examples so that there is limited confusion and misconceptions, especially of challenging concepts.

Direct Instruction and Achievement

Like inquiry, direct instruction has a fan base. Researchers have argued that explicit teaching is more effective than less guided activities (Hmelo-Silver, Duncan, & Chinn, 2007; Mayer, 2004; Rosenshine, 2009). These researchers worry that unguided instruction and active learning techniques allow for too much student error and misconception. Direction instruction uses an expert, the teacher, as a model for students as opposed to each other. Mayer (2004) argues that active behavior can lead to passive learning since the students do not have the prior knowledge required to think scientifically yet.

Wenno, Wattimena, & Maspaitela (2016) conducted a quasi experiment design to research 8th and 9th grade students' participation in a physics lesson in which one group was taught using a drill skill method, and the other using an inquiry method (concept attainment). The sample size was small (the study didn't even really specify, saying about 30 students in each group). Also, the two groups were given a pre-test and their initial ability in the subject matter differed. The researchers found that the drill skill model increased student content knowledge. The concept attainment model did not have a significant influence on student learning.

Relatedly, Dexter, Park, and Hughes (2011) recognize that students must use a variety of inductive and deductive reasoning skills during science and that content becomes increasingly complex as students increase grade level. Thus, students with disabilities particularly struggle and fall behind. Graphic organizers, used to show explicit relationships of content, support both semantics of recognizing relevant information and visually displaying information in a way that students can make meaning. Dexter et al. (2011) reviewed articles that fit criteria of using graphic organizers in science instruction with an experimental design and included students with Learning Disabilities. Findings indicate that graphic organizers improve comprehension and vocabulary knowledge of students with learning disabilities and the researchers found that often teachers would spend time teaching how to use the graphic organizer explicitly. This type of direct instruction showed more effective than text reading or lectures during science for students with learning disabilities. Thus, both general education students and students with disabilities can benefit at times from direct and explicit instructional methods (Dexter et al., 2011; Wenno et al., 2016).

Direct Instruction and English Language Learners

Several studies have reported that direct and explicit instruction is effective and valuable for English Language Learners, particularly in the areas of reading and vocabulary development (Kamps, Abbott, Greenwood, 2007; Sibold, 2011; Crevecoeur, 2014). Direct instruction is best utilized when it is explicitly targeting specific skills (Kamps, Abbott, Greenwood, 2007). This suggests that direct instruction can be beneficial for academic vocabulary development within the science domain. Teachers who facilitate inquiry can provide students with experiences and context for a scientific concept, then explicitly teach and connect the academic vocabulary for the concept. Reasonably, that would provide the ultimate science instruction for English Language Learners.

Analysis of Reform Efforts

Science Kits

One of the most prevalent reform efforts visible in schools comes in the form of several boxes, called science kits. While President Obama's campaign sparked many new efforts, science kits were actually designed in the mid 1900's by researchers and educators in labs across the country, including at UC Berkeley's Lawrence Hall of Science as one of the many reform efforts stemming from the Sputnik era. The kits were reintroduced in California after the 2005 revisions were made and were referred to as Full Option Science System (FOSS) kits. The kits are complete with materials and teacher guides based on grade level standards that promote inquiry and hands-on learning, collaboration, and writing. The effort to bring back the kits into the classrooms was successful, however, the issues relating to time constraints and teacher preparation is still pressing (Tan and Wong, 2012).

Due to the previously reported low scores on the Nation's Report Card in regards to 4th, 8th, and 12th grade science achievement, reform efforts have been called to better support teachers in science instruction. The irony is that the recent kit-based reform efforts that have been termed as "new" or "fairly recent" to many school districts were actually developed in the mid 1900's by organizations such as the Lawrence Hall of Science, who developed the Full Operations Science Systems (FOSS). The kits are designed to provide teachers with a full year worth of lesson plans and hands-on materials that are inquiry based and aligned with state standards. The lesson plans detail step-by-step instructional procedures, discussions and activities, along with providing set up advice and background information on the lesson topic. Because the kits provide visual objects, hands-on materials, promote inquiry, and encourage collaboration, English Learners can also greatly benefit from engaging in kit-based activities.

While these kits seem like the ideal package to promote science learning, attitudes, and achievement through its combination of investigation and hands-on activities, research has elicited mixed results. It seems logical to trust reports stating the kits as having a positive correlation with student attitudes and achievement (Amaral et al., 2002; Dickerson et al., 2006; Houston, et al., 2008); however, some researchers blame the implementers for incorrectly using the materials (Rennie, Howitt, Evans & Mayne, 2010; Tan & Wong, 2012). Teachers' beliefs and intended practices do not always match up with what actually happens in the classroom (Munck, 2007). It seems that more researchers, however, have reported kits as a predictor of student achievement as opposed to textbooks when implemented correctly (Dickerson, Clark, Dawkins & Horne, 2006; Houston, et al., 2008; Young & Lee, 2005). Thus, it is vital to not only provide teachers with the materials to implement new reform efforts, a possible reason past efforts failed, but also supply them with the proper instructional support as well. This way, curriculum makers can work with the factors in student achievement that can be manipulated, such as teacher instructional practices, content knowledge and materials, in order to find a way to best support student learning.

Next Generation Science Standards

Conceptual shifts in the NGSS include an emphasis on the interconnected nature of science, a deeper understanding and application of fewer concepts, and alignment with Common Core State Standards for English Language Arts and Math (NGSS Lead States, 2013)

NGSS calls for students to make observations, use tools and materials, design and build, ask questions to obtain information, gather information, etc.

NGSS focuses on concept and skill progression and provides an outline on each standard. It emphasizes process over product. For example, Standard MS-PS1-3 states, "Obtaining, evaluating, and communicating information in 6-8 builds on K-5 and progresses to evaluating the merit and validity of ideas and methods."

As NGSS becomes more fully implemented, it may heighten awareness of the use of specific terminology and engineering practices.

Problems with the Literature

The various forms of inquiry are vast and more research is needed to analyze specific practices (Minner & Lvey, 2010). Often, small sample sizes are used in inquiry research because it is too difficult to collect solid evidence of inquiry instruction for a large sample size. Researchers would need to rely on teacher self-reporting or giving explicit direction and lesson plans to control varying forms of inquiry being implemented. With smaller sample sizes, observation and objectivity is more practical and less scientific. More research specifying instructional technique and thick description of the lesson design is necessary to get a full picture. For example, Minner and Lvey (2010) asked what impact inquiry science instruction has had on K-12 students. To accomplish this, they synthesized research from 1984-2002 both numerically and qualitatively. They had a total of 443 research reports fit their criteria for entering the study. They further fragmented these studies into categories based on their analysis of themes. They found that only half of the studies showed positive impacts of some level of inquiry science instruction on student learning and retention, and that there was no significant relationship between amount of inquiry time and increased conceptual learning. The only positive was that in some cases, inquiry predicted likelihood of understanding of science content. In the end, the positive effects of inquiry were not overwhelming but did tend to improve student understanding of science concepts, especially when hands-on experiences or phenomena were involved. Scientific investigations are more likely to increase conceptual understanding as opposed to passive teaching techniques. One reason for this underwhelming finding could be that inquiry looks different in each study and that researchers seek to prove one instructional method more effective than another, rather than seeking to apply a comprehensive approach to include both inquiry and direct instruction.

Teaching Concerns

Some researchers have found inquiry investigations as a negative predictor of achievement (Areepattamannil et al., 2011). Several explanations have been offered as the reason for the mismatched data. First, due to the variety of ways to implement inquiry, oftentimes there is a misunderstanding of how to effectively implement or design an inquiry lesson (Ireland et al., 2012). Some researchers have even found a disconnect between what teachers say they believe and do, and what actually occurs in the classroom (Munck, 2007; Tan & Wong, 2012). Another issue is the difficulty of implementing inquiry. Teachers must be comfortable with the uncertainty that is involved as sometimes lessons do not always go in the direction as planned when students are leading the investigation (B. Campbell, personal communication, October 3, 2012; E.Tabata, personal communication, October 5, 2012; Tan & Wong, 2012). With a deep understanding of inquiry and how it is conducted, teachers can more effectively facilitate investigations. It is also necessary for teachers to feel confident in their pedagogical and content knowledge, in the case that an inquiry based activity drifts from the plan. Thus, inquiry requires teacher preparation to implement successfully.

When teachers lack confidence in content and pedagogical knowledge, they tend to revert back to traditional methods that contradict reform efforts. Also, teacher self-efficacy has been reported as a predictor of student achievement (Caprara et al., 2006; Lumpe, Czerniak, Haney & Beltyukova, 2012). If teachers lack confidence in teaching science, their students suffer. Providing enjoyable and successful experiences for students has demonstrated an increase in student self-efficacy and attitudes towards science (Britner & Pajares, 2006; Areepattamannil et al., 2010; Karaarslan & Sungur, 2011). Self-efficacy is based, in part, on previous experiences (BHEF, 2010; Britner and Parjares, 2006) and teachers are responsible for providing most of those experiences. Thus, policy makers need to ensure that these needs are being met. This effort needs to start in early education by improving K-6 foundational preparation in science and further defining and exploring what effective instructional practices look like, given the conflicting reports. If effective strategies promoting achievement and interest from literature are strategically combined, logically, this will encourage participation and interest in middle school and beyond as student successes and attitudes increase.

Instructional Concerns

Facilitating inquiry science is challenging, requiring in-depth disciplinary knowledge and pedagogical skills that many teachers do not possess (Dorph et al., 2007; Houston, Fraser & Ledbetter, 2008). Although teachers have reported practicing inquiry-based instruction, researchers have found disconnect between their descriptions of their practice and what actually occurs in many classrooms (Munck, 2007; Tan & Wong, 2012). Bergman and Olson (2011) assert that "hands-on science is half the battle" (p. 44). Inquiry involves more than physical manipulation of materials. Critical and analytical reasoning coupled with self-discovery through exploration, are key components of an inquiry lesson (Bergman & Olson, 2011; Gibson & Chase, 2002; National Research Council, 2000).

Teachers must also be comfortable with the uncertainty that is involved as lessons do not always go as planned when investigations are student led (Tan & Wong, 2012). Teacher educators have addressed candidate concerns in this area. For example, to build confidence in teaching a lesson that might not progress as planned and to develop a deeper understanding of the inquiry process, Baumgartner (2010) models lessons that veer from the instructional plan to build content and pedagogical knowledge in her preservice elementary teachers. Students in her course had expressed concern and nervousness over the indefinite nature of an inquiry activity. During a planned class inquiry experiment, an unexpected occurrence made her original plan ineffective. Rather than fixing the experiment so that the preservice teachers could continue on track with the original plan, she seized the teachable moment and put the learning in the hands of her students, acting as a facilitator for their self-created investigations. Baumgartner argues that activities such as this "foster a lifelong love of exploration, learning, and a sense of empowerment" (p. 57). With a deep understanding of inquiry instruction combined with confidence in pedagogical and content knowledge, teachers can more effectively facilitate investigations and feel comfortable with a lesson that may drift off course as students pursue their questions and needs.

Science inquiry is complex and knowing the subject matter is not enough. Teachers must also have pedagogical skills and a sense of self-efficacy. Bhattacharyya, Volk & Lumpe state that "science teachers' training consisting of only content knowledge and pedagogy, without attention to increasing teachers' self-efficacy, is not likely to transform science teaching in the desired manner" (Bhattacharyya, Volk & Lumpe, 2009). Teachers enter the classroom and their instructional strategies are influenced not only by the teacher education programs but by their experiences as a student themselves and in science, much of what they learned was by direct instruction and not through inquiry based instruction so it is understandable that this approach is unfamiliar and even uncomfortable to them. In order to support classroom teachers in meeting the demands of current science reform, they must be provided multiple professional development opportunities where they experience authentic inquiry based instruction as learners themselves (Lederman & Lederman, 2012; McLaughlin & McFadden). Ultimately, the goal is to improve science education for students and increase interest in science. However, since NGSS is a recent adoption by the state, district and school leaders must first analyze teacher needs and attitudes before making decisions on moving forward with support strategies.

Professional Development and Science Instruction

Due to the complex nature of science and leading students through authentic scientific experiences, professional development is necessary to support teachers in the process. Researchers have found that ongoing and supportive professional development can increase confidence and instructional content to teach using inquiry (Yager & Akcay, 2010; Liu, Lee, & Linn, 2010). Also, teachers who need less support demonstrate greater gains, implying that teachers who were more comfortable with inquiry have more success with their students (Liu et al., 2010).

Gerard, Sputnik, and Linn (2009) studied teachers' use of student data to customize their instruction during inquiry science and the impact of customization on student learning. In the study, the curriculum incorporated a Plate Tectonics inquiry project and teachers received professional development on evidence-based customization of instruction. Both experience and practice teaching the unit and collaborative customization opportunities for teachers increased students' knowledge integration in the subject matter. The professional development on customization helped teachers develop pedagogical content knowledge in inquiry teaching and increased capacity to motivate student interest, tailor curriculum, and make abstract phenomena comprehensible. Overall, both teacher knowledge with customization and student achievement grew as a result of the professional development and customized instructional practice. Harlow (2009) found similar results in that with professional development, teachers became better at making real time instructional decisions.

Inadequate Reports

Due to the intricate nature of inquiry, it is difficult to conduct a strong study due to the many threats to internal and external validity. For instance, applying a treatment for an experimental study is challenging since teachers would have to be well trained and a singular idea of what inquiry looks like would be necessary. Also, detailed observations would be required to ensure that the description of inquiry is happening in the classroom. Surveys are self-reported and researchers have found previously that teachers do not always practice what they report as occurring in their classroom. Finally, the definition of inquiry is so broad, that it can be implemented in several ways, making it difficult to capture. Many studies that capture detailed classroom instruction are qualitative and have few participants.

Studies have reported positive findings for each instructional style, but none have given a clear and consistent portrayal of inquiry instruction, leading to confusion over best practices. Also, research in the area of direct instruction and student engagement is severely lacking, or reports have not found any relationship. Thus, I wonder: could it be that there are two bests?

Both inquiry instruction and direct instruction have received support and been determined to raise student achievement (Dexter et al., 2011; Marshall & Horton, 2011; Minner and Lvey, 2010; Sen & Oskay, 2017; Wenno et al., 2016). While most articles implicate one practice over the other, using aspects from both instructional strategies and direct instruction strategically within areas of the 5E model would seem to be the most effective given the synthesis of research findings on each instructional style. Given the findings that inquiry instruction can have a positive impact on interest and motivation in science (Minner and Lvey, 2010; Sen & Oskay, 2017), increase application of skills and conceptual understanding (Guzetti, 2010; Ural, 2016), and direct instruction can increase understanding of concepts (Dexter et al., 2011; Wenno et al., 2016), both strategies need to be used. Bass (2012) argues that explicit and direct components of lessons need to be purposeful for the learner and included in necessary instances, but should not take the place of every lesson.

Zepeda, Richey, Ronevich, & Nokes-Malach (2015) employed an experimental design using puzzle problems as an intervention designed to increase student metacognition, motivation, learning, and preparation for science experiences in physics. The puzzle problems increased student declarative knowledge for planning, monitoring, and evaluating their own learning. Thus, these problem types, which relate to inquiry in the form of problem posing and providing time for exploration, can increase conceptual knowledge of physics. This ultimately increased motivation for science courses.

Yager and Akcay (2010) designed a study to involve a total of 724 students. They found that both direct and inquiry instructional practices increased student mastery of basic concepts. However, in the domain of application, students who experienced inquiry were far more successful in illustrating their abilities to apply concepts to new situations than the students of direct instruction. Students in the inquiry classes also grew in creativity significantly, whereas the students with direct instruction did not (Yager and Akcay, 2010). Thus, direct instruction may be used for explaining basic concepts or as intervention for misconceptions, but inquiry is successful to push that content attainment further to application.

When students pursue authentic scientific questions, they developed investigations without obeying the steps of the scientific method, which ultimately can promote stronger articulation and learning (Xiaowei, Coffey, Elby, and Levin, 2009).

Guided inquiry serves as a good in-between for implementing both an investigative approach to instruction and also some explicit instruction. Lazonder and Wiskerke-Drost (2015) found that when teachers provide some guidance without giving away directly the answers, students perform better in scientific reasoning. They suggest for teachers who use inquiry to give a lot of guidance as opposed to unguided inquiry or to be direct before an activity with instruction. Therrien and Benson (2017) further this point by arguing that the definition of inquiry by the NGSS does not provide evidence of instructional approaches such as explicit or discovery learning, and argue that a range can be used within the construct of inquiry to include explicit instruction. They conclude that since explicit instruction in many other content areas is beneficial for students with learning disabilities, it should also be used for science instruction when appropriate to support investigations and understanding. Koksal, Cakiroglu, & Geban (2014) found that lecturing, demonstration, and questioning instructional techniques were not sufficient for students to advance academically, and that embedded reflection instruction was effective to develop understanding of scientific concepts. While there are some similarities of explicit embedded reflection (EER) to lecturing, demonstration, and questioning, the difference is that EER is purposeful in the explicit planning and embedded reflection of content. It relates to inquiry in that is allows time for processing information and for students to explain and elaborate after experiencing content. Thus, some explicit or direct instruction within an inquiry lesson is necessary for student achievement in science.

The review of literature has revealed a mixture of results regarding the most effective approach for science instruction, as well as broad understanding of teacher practices that promote interest and achievement in science. It is important to understand what specific teacher practices and student experiences contribute most to interest and achievement, so that schools can adopt those practices. Thus, the following study was designed to determine which school and background factors contributes most to college students' attitudes toward and achievement in their science classes. Chapter 3 outlines the methods used to conduct the study, Chapter 4 reveals the results, and Chapter 5 discusses the findings.

Chapter III: Methods

Research Questions and Design

A detailed portrayal of effective instructional practices is lacking from the literature. Since most science instructional practice research favors either inquiry or direct instruction, it was important to take a look through a student lens at their experiences with teacher practices and to identify if there were any relationships between student interest and achievement in science and their experiences with certain teacher practices. Predictions about instructional practices and student achievement and interest will be explored. This study employed a survey design with a short response question for science majors. The following questions guided the survey creation and analysis of the responses:

What are college students' high school science experiences that contributed to their achievement and/or interest in science?

1.) What are their perceptions of and attitudes toward their science experiences?
2.) Do certain instructional practices correlate with achievement or interest in science?
3.) Are instructional strategies such as collaboration, relevant experiences, scaffolded scientific thinking, personal experiences, and exposure to scientific processes predictive of achievement or interest in science?

The quantitative design allowed for relationships and predictions to be determined between different instructional practices, or the combination of instructional practices and experiences, on college student attitudes and achievement in science (See Appendix B). Several statements reflected achievement beliefs including self-efficacy and growth mindset measures, and there were several statements that reflected interest and engagement with science in general. Also, while written in non-educator friendly terminology, the instructional practice statements targeted practices aligned with either inquiry or direct instruction definitions, and particularly addressed the *The Scaffolded Knowledge Integration Framework for Instruction* by Linn, Davis, & Eylon (2004). A short response open-ended question helped to determine themes about interest in science for majors pursuing the field.

Sample

Three large undergraduate general education (GE) college lecture classes were sent the survey, which totaled approximately 700 students between the three classes. Two hundred fifty-eight participants responded to gather enough data for significant quantitative analysis. The participation rate was approximately 37%, or about 1 in 3. Participants attend one of two colleges and are between the ages of 18-20 years old. The age requirement was determined in order for participants to have more recent reflections of their high school experiences.

One college is a large public university of California, with a strong and competitive STEM program. The university has a large Asian population. Two of the three surveyed classes were at this university; one was a smaller science specific GE lecture class (approximately 200 students), and the second was a large GE liberal studies class (approximately 400 students). The second college is a large California state university, which is a Hispanic serving institution (HIS). One GE science and math class of approximately 90 students was surveyed by paper. A cluster sampling technique was employed. Willing faculty members at the colleges sent out the survey via e-mail or paper copies. A connection at each university recruited a colleague to help with the distribution, so the researcher only had direct contact with one of the three instructors that sent out the survey. Education, science, math, and technology fields made up the majority of the majors, since those were the focuses of the courses the survey went out to. Since interest was specifically in science majors for this study, the descriptive statistics and tables report and compare science majors and others, for relevancy to the study objectives. In total, 117 science majors took the survey. The majority of the participants were female, with 75.6% being female and 24.4% males. The most common ethnicity checked was Hispanic or Latina/o (115), with Asian or Asian American as the second (97). The totals add up to more than 100% due to some participants identifying with more than one ethnicity. Table 3 shows how many science majors took the survey at the individual colleges. The survey can be found in Appendix A.

Table 1: Gender

Gender	N (%)
Female	195 (75.6)
Male	63 (24.4)

N=258

Table 2: College Major

Major	N (%)
Science	117 (45.3)
Other	141 (54.7)

N=258

Table 3: College Major by University

College	University of California	California State College
Science Majors	62	55
Non Science Majors	127	14
Total Participants	189	69

N = 258

Table 4: Ethnicity

Ethnicity	N (%)

American Indian or Native American or Pacific Islander	6(2)
Asian or Asian American	97(35)
Black or African American	8(2.8)
Hispanic or Latina/o	115(41.5)
White	45(16.2)
Other	6(2)

*Check all that apply (total adds to more than 100%)
N= 258; Total Responses= 277

Protection of Human Subjects

This study needed IRB approval because it was primary data collection. IRB was first obtained from the researcher's university, and then each of the two universities participants were surveyed from. Approval was given to have a letter written by the researcher sent out to students via the class instructor. The instructor could pass it out, e-mail it, or post it on a class website, but the researcher made it clear in the letter that the survey was not connected to coursework. The letter explained the purpose of the study to the students, and also offered researcher contact information with any questions or concerns. The participants were promised complete confidentiality and the nature and intentions of the study were fully disclosed. The letter also explained that all students, whether completing the survey or not, would have the opportunity to enter into a drawing for a 10 dollar coffee gift card by e-mailing the researcher. To ensure confidentiality, the researcher did not collect contact information or identifying information (just major, ethnicity, gender) on the participants in the survey, but rather the participants would have to reach out to the researcher via e-mail to enter. The researcher had no way of connecting a participant to any survey, or to know if the student e-mailing even took the survey unless that information as offered in the student's initial e-mail. The researcher also could not connect the student that e-mailed to any particular class or school, just if they offered that information. In order to ensure protection of subjects, the survey and short response question did not have any unethical or questionable content that could harm individuals. Since participants were 18 years or older, parent consent was not necessary and students were able to choose if they wanted to participate independently.

Pretest

A pretest was performed with 15 college-age survey participants. In order to avoid dwindling the sample size of the college students that met the criteria, the pilot survey was opened to any college students that fit the age criteria. Recruitment for the pilot survey was done through snowball sampling, because any colleague the researcher knew with children in college at the time, asked their child to take the survey. Feedback was requested to ensure that the survey questions were not offensive or misleading. Five questions were sent via e-mail to the pilot participants:

1. Was any question/statement on the survey confusing or unclear? If so, which one(s)?
2. About how long did the survey take you to complete?
3. Did any question/statement make you uncomfortable or offend you? If so, which?
4. Are there any teacher practices that you experienced that were left out of the survey? You can share any form of instruction you remember that your teachers did in your science classes.
5. Did you feel obligated to answer any questions a certain way? If so, which?
6. Do you have any suggestions or feedback for the survey items?

Ten participants responded to the questions. Participants who responded felt that the survey was not offensive and clear to understand. The survey averaged in time spent for participants between 7-8 minutes. None provided any more teacher practices, as they felt the survey covered all that they had experienced and more. None reported feeling obligated to answer in any certain way. Only one gave a suggestion, which was to change "I enjoy doing science," the first statement on the pilot survey, to something different as he didn't really understand "doing" or what that would mean. The statement was changed in the final survey to "I enjoy participating in science related activities." The questions/statements seemed to target the intended purpose based on the results, and science majors responded more positively to the interest and engagement statements on the survey. The responses on the final survey reflect the trends on the pretest on a much larger scale.

Instrumentation

Instruments included an attitude and achievement survey that was developed by the researcher. After initial survey analysis, one short response question was coded for themes. The survey requested personal information such as age, G.P.A., year in school, major, and other demographic information to ensure participants meet the requirements for participation. Pursuing science degrees and selecting agree or strongly agree for interest/engagement in science statements served as interest measurements. Feeling confident and successful with science classes served as outcome measurements. The rest of the survey consisted mostly of Likert scale items related to attitudes and perceptions of prior science experiences in high school. Response options ranged from strongly disagree to strongly agree for items such as: 1) I have been successful in prior science classes 2) If I try hard, I can do well in science 3) I find science interesting. In another section participants were asked to choose from Never to Always for how often they experienced certain teacher instructional practices. The following lists detail items in the survey that reflect inquiry or direct instruction, as well as the *The Scaffolded Knowledge Integration Framework for Instruction* (Linn, Davis, & Eylon, 2004) criteria.

Inquiry Instructional Practices:
1. Students investigate and explore science concepts through hands on engagement with materials. 2. Guided discovery (teacher provides hints and prompts while students seek explanation to a scientific phenomenon). 3. Teacher poses open-ended questions about scientific concepts. 4. Students ask and answer their own questions with teacher guidance. 5. Collaborating with peers to understand a concept. 6. Teacher poses a problem or phenomena, and students seek ways to solve it through provided resources and materials. 7. Students conduct an investigation and record data. 8. Students are provided opportunities to engage in authentic (real life) scientific experiences. 9. Teacher models scientific thinking and reasoning.
Direct Instruction Practices:
1. Teacher lectures. 2. Reading about science concepts through textbooks or other reputable sources. 3. Traditional labs (teacher provides specific step by step instructions for completing the experiment). 4. Explicit and direct explanations of concepts. 5. Students copy notes from the teacher or textbook about a scientific concept. 6. Teacher demonstrations (teacher models an experiment for class to watch). 7. Videos that show or explain scientific concepts. 8. Read and respond to questions in a textbook or on a worksheet.

***Scaffolded Knowledge Integration Framework* Components:**
Personal experiences 1. I went to science camps when I was younger. 2. My family went on science related outings when I was younger (visits to scientific museums, centers, activities, etc.) 3. My teachers were supportive and helpful with my science studies. 4. I had family support for my science studies. 5. I had family members that modeled the work of a scientist for me. 6. I had peers and/or friends that were interested in or enjoyed science. 7. My science classes contributed to how I feel about science today. *Relevant experiences* 1. Teacher poses a problem or phenomena, and students seek ways to solve it through provided resources and materials. 2. Students ask and answer their own questions with teacher guidance. *Scaffolded scientific thinking*

1. Teacher models scientific thinking and reasoning.
2. Guided discovery (teacher provides hints and prompts while students seek explanation to a scientific phenomenon).

Collaboration with others

1. Collaborating with peers to understand a concept.
2. My peers and/or friends were supportive and helpful with my science studies.

Exposure to scientific processes

1. Traditional labs (teacher provides specific step by step instructions for completing the experiment).
2. Students investigate and explore science concepts through hands on engagement with materials.
3. Guided discovery (teacher provides hints and prompts while students seek explanation to a scientific phenomenon).
4. Students ask and answer their own questions with teacher guidance.
5. Teacher poses a problem or phenomena, and students seek ways to solve it through provided resources and materials.
6. Students conduct an investigation and record data.
7. Students are provided opportunities to engage in authentic (real life) scientific experiences.
8. I had family members that modeled the work of a scientist for me.

Procedures

Data Collection

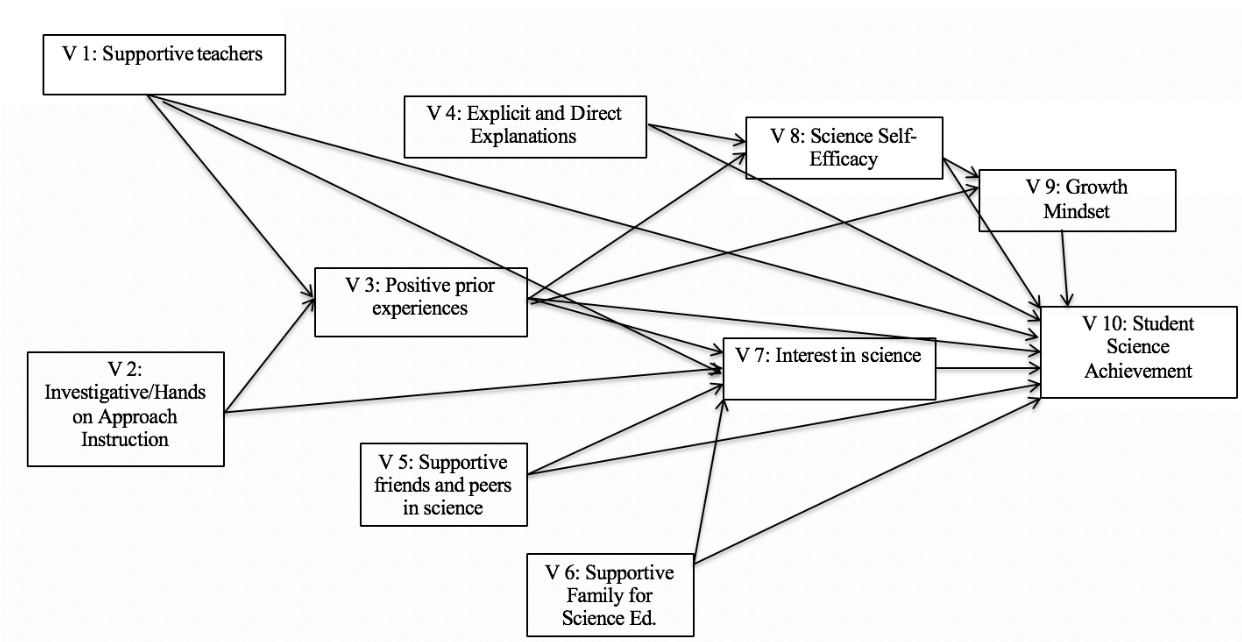
After IRB was obtained from all three institutions, communication was established with a main contact at each university. That contact received the letter with the survey link, and recruited colleagues to send it out or post it on their site. The incoming surveys slowed after about 1 month from when the surveys were sent out. In total, the survey link was left open for responses for two months. The instructors reminded students that the survey would close at the end of the second month. Once closed, the students who e-mailed to enter the drawing were put in computer based platform that randomly selected 5 e-mail addresses. Coffee gift cards were e-mailed to the e-mails drawn. Survey data was downloaded from Qualtrics for analysis.

Data Analysis

Survey data was analyzed using correlations to determine if there is a relationship between achievement, teacher practices, interest, and attitude toward science. Step-wise regression was run to determine if teacher practices or other independent variables on the survey can predict achievement or interest. To further the analysis, discriminant function was performed to see how well some of the independent variables can predict science majors or other majors. A path diagram shows the direct dependencies among variables in predicting achievement in science. Finally, the short response question was coded revealing several themes.

The following diagram represents the before path diagram, which helps to demonstrate the analysis decisions in Chapter 4.

Before Path Diagram for Student Achievement



Each variable represents at least one of the major ideas presented in the conceptual model. For example, variables 2 and 4 are inquiry and direct instruction practices. They are included since each fall under a component of the *Scaffolded Knowledge Integration*

Framework, and have research support as presented in Chapter 2. Inquiry provides exposure to scientific content, and direct instruction supports scaffolded scientific thinking. Peer support encompasses collaborating with others and family support includes items regarding relevant and personal experiences as participants reflect on scientific experiences and exposure in their childhood. All of these components are linked to achievement. Further based on research synthesized in Chapter 2, teacher support and enjoyment of science are also presented in the before diagram as predictors of science achievement. The results of the path analysis, as well as several other analyses techniques are presented in Chapter 4.

Chapter IV: Results

The analyses in this chapter were designed to fully explore the research questions in this study. In this section, descriptive statistics are provided, correlations are discussed, then the data tables for regressions, discriminant function, and path analysis are presented. Finally, results are shared from the analysis of the open-ended question. The survey and correlation tables can be found in Appendix B.

Descriptive Statistics

Survey Items

Table 5: Demographic and Descriptive Items

Item	N	Min.	Max.	Mean	Standard Deviation
1. What is your current major? (Science or Other)	258	1	2	1.55	.499
2. What was your high school G.P.A.?	257	1	6	1.77	.822
3. Were you the first person in your family to go to college (besides a sibling)?	257	1	2	1.49	.501
4. Were you in the English Language Learner program in grades 6-12?	242	1	2	1.89	.310
5. To the best of your memory, which year did you exit the English Language Learner program?	26	1	9	4.15	.398
6. What is your gender?	258	1	2	1.76	.430
7. What is your age?	258	1	4	2.59	1.239
8. What year are you in college?	258	1	5	2.46	1.272
9. What is your ethnicity? American Indian or Pacific Islander	257	1	2	1.02	.151
10. What is your ethnicity? Asian or Asian American	258	1	2	1.38	.485
11. What is your ethnicity? Black or African American	258	1	2	1.03	.174
12. What is your ethnicity? Hispanic or Latina/o	258	1	2	1.45	.498
13. What is your ethnicity? White	258	1	2	1.17	.380
14. What is your ethnicity? Other	258	1	2	1.02	.151

Of the 258 participants who took the survey, 195 were female (75.6%), and 63 were male (24.4%). Nearly half or 45.3% (117) were science majors. Only 26 students who took the survey reported themselves as being in the English Learner program in grades 6-12 (Item 4). There were 3 options for responding to that survey item: 1. Yes; 2. No; 3. I am not sure. If students selected yes, it would lead to Item 5, in which there were 9 options: 1. 6th; 2. 7th; 3. 8th; 4. 9th; 5. 10th; 6. 11th; 7. 12th; 8. I was not exited; 9. I am not sure.

Table 6: Interest and Achievement Survey Items

Item	Strongly Agree	Agree	Disagree	Strongly Disagree	Mean	Standard Deviation
	N (%)	*N (%)*	*N (%)*	*N (%)*	1-4	
1. I enjoy participating in science related activities.	39(15.1)	164(63.6)	50(19.4)	5(1.9)	2.92	.646
2. I have enjoyed my prior experiences with science.	31(12)	165(64)	56(21.7)	5(1.9)	2.86	.632
3. I find science interesting.	68(26.4)	159(61.6)	26(10.1)	4(1.6)	3.13	.642
4. Science comes easy to me.	19(7.4)	85(32.9)	121(46.9)	32(12.4)	2.35	.792
5. If I try hard, I can do well in science.	75(29.1)	160(62)	19(7.4)	3(1.2)	3.19	.613
6. I have been successful in my prior science classes.	54(20.9)	147(57)	52(20.2)	2(0.8)	2.99	.670

Understandably, 78.7% agreed or strongly agreed that they enjoy participating in science related activities (see Appendix A). Notably, however, over half (59.3%) didn't agree that science came easy to them, acknowledging the difficulty or complexity of the content (or experiences with learning it). Nevertheless, 76% of participants enjoyed their prior experiences with science, with only 21% feeling unsuccessful in prior classes as shown in Table 6.

Table 7: Support for science survey items.

Item	Strongly Agree	Agree	Disagree	Strongly Disagree	Mean	Standard Deviation
	N (%)	*N (%)*	*N (%)*	*N (%)*	1-4	
1. I had family support for my science studies.	52(20.2)	117(45.3)	58(22.5)	30(11.6)	2.74	.912
2. My teachers were supportive and helpful with my science studies.	57(22.1)	171(66.3)	23(8.9)	6(2.3)	3.09	.632
3. My peers and/or friends were supportive and helpful with my science studies.	59(22.9)	156(60.5)	32(12.4)	9(3.5)	3.04	.705
4. I had peers and/or friends that were interested in or enjoyed science.	65(25.2)	155(60.1)	28(10.9)	9(3.5)	3.07	.706
5. My science classes have contributed to how I feel about science today.	64(24.8)	143(55.4)	44(17.1)	6(2.3)	3.03	.717

N= 258

The majority of participants reported teachers as supportive and helpful with their science studies (88.4%), which is greater than the reports of family support (65.5%) and peer/friend support (83.4%); although peer/friend support was a close second. This makes sense considering 80.2% of participants identified science classes as contributing to their current attitudes toward science. Descriptive statistics about the science classes are reported below in Table 8.

Table 8: Teacher Practices Survey Items

Item	Always	Frequently	Occasionally	Never	Mean	Standard Deviation
	N (%)	*N (%)*	*N (%)*	*N (%)*	1-4	
1. Teacher lectures	118(45.7)	96(37.2)	38(14.7)	2(.8)	3.30	.747
2. Reading about science concepts through textbooks or other reputable sources	56(21.7)	101(39.1)	77(29.8)	17(6.6)	2.78	.869
3. Students investigate and explore science concepts through hands on engagement with materials	26(10.1)	110(42.6)	114(44.2)	8(3.1)	2.60	.711

4. Traditional labs (teacher provides specific step by step instructions for completing the experiment)	31(12)	121(46.9)	95(36.8)	10(3.9)	2.67	.736
5. Guided discovery (teacher provides hints and prompts while students seek explanation to a scientific phenomenon)	15(5.8)	89(34.5)	122(47.3)	32(12.4)	2.34	.768
6. Explicit and direct explanations of concepts.	56(21.7)	128(49.6)	69(26.7)	5(1.9)	2.91	.746
7. Students copy notes from the teacher or textbook about a scientific concept.	115(44.6)	89(34.5)	46(17.8)	7(2.7)	3.21	.832
8. Teacher poses open ended questions about scientific concepts.	18(7)	95(36.8)	129(50)	14(5.4)	2.46	.707
9. Teacher demonstrations (teacher models an experiment for class to watch)	27(10.5)	105(40.7)	116(45)	9(3.5)	2.58	.725
10. Students ask and answer their own questions with teacher guidance.	18(7)	100(38.8)	104(38.8)	34(13.2)	2.40	.805
11. Videos that show or explain scientific concepts.	36(14)	129(50)	85(32.9)	6(2.3)	2.76	.715
12. Collaborating with peers to understand a concept.	49(19)	138(53.5)	63(24.4)	5(1.9)	2.91	.715
13. Read and respond to questions in a textbook or on a worksheet.	76(29.5)	109(42.2)	65(25.2)	7(2.7)	2.99	.812
14. Teacher poses a problem or phenomena, and students seek ways to solve it through provided resources and materials.	17(6.6)	97(37.6)	113(43.8)	30(11.6)	2.39	.779
15. Students conduct an investigation and record data.	33(99.6)	114(44.2)	90(34.9)	20(7.8)	2.62	.806
16. Teacher models scientific thinking and reasoning.	32(12.4)	119(46.1)	95(36.8)	9(3.5)	2.68	.735
17. Students are provided opportunities to engage in authentic (real life) scientific experiences.	17(6.6)	95(36.8)	113(43.8)	32(12.4)	2.38	.787

N= 258 *Highlights are considered by the researcher as direct instruction practices

In Table 8, highlighted variables represent direct instruction practices. Of the teacher practices items in the survey, 8 fell under the category of traditional or direct instruction (items 1, 2, 4, 6, 7, 9, 11, and 13), and 9 were considered inquiry facilitation practices. The most commonly reported teacher practices in the "always" or "frequently" categories were teacher lectures (82.9%) and students copying notes from the teacher or textbook (79.1%) with means of 3.30 and 3.21. Both of these practices fall under a traditional direct instruction approach. The teacher practices reported as most infrequent under the categories of "occasionally" or "never" were inquiry facilitation strategies including guided discovery (59.7%), opportunities for authentic scientific experiences (56.2%), and teachers posing phenomena for students to seek ways to solve (55.4%) with means of 2.34, 2.38, and 2.39. The most frequent practice for inquiry instruction was collaborating with peers, with 72.5% of participants reporting collaborating frequently or always. Overall, direct instruction practices were more frequently experienced than inquiry practices.

Table 9: Personal experiences survey items.

Item	Agree	Disagree	Mean	Standard Deviation
	N (%)	*N (%)*	1-2	
1. I had science tutoring.	30(11.6)	162(62.8)	1.84	.364
2. I went to science camps when I was younger.	41(15.9)	151(58.5)	1.79	.411
3. My family went on science related outings when I was younger (visits to scientific museums, centers, activities, etc.).	63(24.4)	129(50)	1.67	.471
4. I had family members that modeled the work of a scientist for me.	24(9.3)	168(65.1)	1.88	.332

Survey items in Table 9 requested personal information such as having science tutoring or science experiences as a family when the participant was younger. The means were on the higher end of the range because the majority of respondents answered "disagree" to the statements. Sixty-three participants reported that their family went on science related outings, which was the highest number of agree responses in that section of the survey. Overall, most participants did not have personal outside science experiences such as tutoring, science camps, outings, or family members in the field.

Key Survey Descriptive Items by Ethnicity

I thought it would be important to examine whether there are differences between major ethnic groups represented in the sample. Table 10 includes mean scores on 20 key variables for 3 major ethnic groups represented in the sample, Asian or Asian-American, Hispanic or Latina/o, and White.

Table 10: Key Variables by Ethnicity

		Means *Min: 1 Max: 4*	
Key Variables	Asian or Asian-American	Hispanic or Latina/o	White
I have enjoyed my prior experiences with science.	2.91	2.85	2.86
I find science interesting.	3.23	3.03	3.12
Science comes easy to me.	2.44	2.34	2.33
If I try hard, I can do well in science.	3.30	3.11	3.17
I have been successful in my prior science classes.	3.11	2.90	2.96
I had family support for my science studies.	2.79	1.84	2.70
My teachers were supportive and helpful with my science studies.	3.15	3.06	3.07
I had peers and/or friends that were interested in or enjoyed science.	2.99	3.17	3.08
My science classes have contributed to how I feel about science today.	3.07	2.99	3.01
Teacher lectures	3.29	3.29	3.30

Students investigate and explore science concepts through hands on engagement with materials	2.60	2.62	2.58
Traditional labs (teacher provides specific step by step instructions for completing the experiment)	2.66	2.73	2.65
Explicit and direct explanations of concepts.	2.93	2.94	2.88
Students copy notes from the teacher or textbook about a scientific concept.	3.24	3.19	3.22
Teacher poses open ended questions about scientific concepts.	2.54	2.42	2.45
Collaborating with peers to understand a concept.	2.89	2.93	2.91
Teacher poses a problem or phenomena, and students seek ways to solve it through provided resources and materials.	2.38	2.40	2.42
Students are provided opportunities to engage in authentic (real life) scientific experiences.	2.38	2.40	2.38
My family went on science related outings when I was younger (visits to scientific museums, centers, activities, etc.).	1.72	1.61	1.69
I had family members that modeled the work of a scientist for me.	1.88	1.84	1.90

Results from comparing the means on key variables indicate that there weren't many notable differences in responses, but Asian or Asian-American students had slightly higher means for interest and achievement measures. The higher the mean, the more strongly the respondents agreed with statements regarding feeling interested and successful in science. Another interesting finding was the difference in means for the variable, "I had family support for my science studies." Asian or Asian-American and White ethnic groups had a similar mean, while the Hispanic or Latina/o mean showed the most drastic difference for this variable. Hispanic or Latina/o students reported less family support for science studies than their ethnically different peers reported. The teacher practice variables were reported being experienced at similar frequencies amongst groups, with traditional direct instruction practices being more frequent than inquiry practices across all three groups.

Correlations

Aligning with research reported in the introduction, attitudes toward science, self-efficacy, and achievement in science are related. For example, finding science interesting was moderately correlated with the feeling that science comes easy (Pearson $r = .589$; $p < 0.01$). Similarly, finding success in prior science classes was related to enjoyment of prior experiences in science at a significant and moderate level (Pearson $r = .445$; $p < 0.01$), along with having a growth mindset about if one can try hard, he/she can do well in science (Pearson $r = .569$; $p < 0.01$). None of this is surprising and only validates prior research results (Areepattamannil, 2012; Bybee, 2015; Cuevas, Lee, Hart & Deaker, 2005; Settlage, Madsen & Rustad, 2005).

While there isn't much prior research in the area of specific teacher practices, several correlations were revealed between practices as expected. For instance, teacher lectures and reading about science concepts through textbooks or reputable sources were correlated at the .472 level ($<.01$), which both reflect traditional teacher practices or direct instruction. Similarly, specific teacher practices that reflect an inquiry-based instruction were found to be moderately correlated with each other. For example, students exploring and investigating concepts was moderately correlated with guided discovery (Pearson $r = .428$; $p < 0.01$). It also makes sense that students experiencing authentic scientific practices was also correlated moderately with guided discover (Pearson $r = .527$; $p < 0.01$), an inquiry based practice. Interestingly, traditional labs as a direct instruction practice moderately correlated with students exploring and investigating concepts, an inquiry practice (Pearson $r = .450$; $p < 0.01$).

There was a lack of evidence of moderate or strong connections between specific teacher practices, and interest and achievement, only weak relationships not worthy of reporting. However, having family support in science, as well as teacher support in science were moderately correlated with interest and achievement at <.01 significance level, teacher support having the stronger correlation with each. Finally, participants feeling that science classes contributed toward attitudes toward science moderately correlated with finding science interesting (Pearson $r = .315$; $p < 0.01$), and major choice (choosing science) positively correlating with all three interest in science measures.

While a few negative correlations were weak in strength, they were significant and worth noting. Guided discovery had a negative relationship with note taking for teacher practices (-.137; $p < 0.05$), meaning that students who had experienced the inquiry practice of guided discovery experienced direct instruction via note taking less often (Pearson $r = -.137$; $p < 0.05$). Similarly, those who had authentic scientific experiences more frequently, also took notes less often (-.171; $p < 0.05$). Science majors had a negative correlation (Pearson $r = -.161$; $p < 0.05$) with explicit and direct explanations from teachers, meaning that science majors experienced explicit and direct explanations less frequently than other majors.a

Step-Wise Regressions

I was interested in predicting what prior experiences participants had with science that might contribute to their achievement and overall attitude toward science. I wanted to see if certain teacher practices, school experience, or other background experience such as family activities predicted interest in science or feeling successful with science classes. Hence, both specific inquiry based and direct instruction practices, along with outside school activities and experiences were entered into a step-wise regression model as independent variables with interest and achievement dependent variables. I first entered them with each interest measure and achievement measure, including the growth mindset variable, entered separately.

The following lists detail the dependent variables and the independent variables put into the separate regressions.

	Regression 1	**Regression 2**
Dependent Variable	Enjoyment of prior experiences in science.	Finding science interesting.
Independent Variables	1. Science comes easy 2. Growth mindset 3. Teacher lectures 4. Reading about science concepts through textbooks or other reputable sources 5. Students investigate and explore concepts through hands on engagement with materials 6. Traditional Labs 7. Guided discovery 8. Explicit and direct explanation of concepts 9. Students copy notes from the teacher or textbook 10. Teacher poses open ended questions about concepts 11. Teacher demonstrations 12. Students ask and answer their own questions 13. Collaborating with peers 14. Read and respond to questions in a textbook 15. Students conduct an investigation and record data 16. Teacher models scientific thinking and reasoning 17. Students engage in authentic scientific experiences 18. Family support for science studies 19. Teachers supportive and helpful with science studies	1. Science comes easy 2. Growth mindset 3. Teacher lectures 4. Reading about science concepts through textbooks or other reputable sources 5. Students investigate and explore concepts through hands on engagement with materials 6. Traditional Labs 7. Guided discovery 8. Explicit and direct explanation of concepts 9. Students copy notes from the teacher or textbook 10. Teacher poses open ended questions about concepts 11. Teacher demonstrations 12. Students ask and answer their own questions 13. Collaborating with peers 14. Read and respond to questions in a textbook 15. Students conduct an investigation and record data 16. Teacher models scientific thinking and reasoning 17. Students engage in authentic scientific experiences 18. Family support for science studies 19. Teachers supportive and helpful with science studies

	20. Peers/Friends interested or enjoyed science 21. Science classes contributed toward attitudes 22. Science camps 23. Family went on science related outings 24. Family members that modeled the work of a scientist 25. Gender	20. Peers/Friends interested or enjoyed science 21. Science classes contributed toward attitudes 22. Science camps 23. Family went on science related outings 24. Family members that modeled the work of a scientist 25. Gender
	Regression 3	**Regression 4**
Dependent Variable	Enjoyment of participating in science related activities.	I have been successful in my prior science classes.
Independent Variables	1. Science comes easy 2. Growth mindset 3. Teacher lectures 4. Reading about science concepts through textbooks or other reputable sources 5. Students investigate and explore concepts through hands on engagement with materials 6. Traditional Labs 7. Guided discovery 8. Explicit and direct explanation of concepts 9. Students copy notes from the teacher or textbook 10. Teacher poses open ended questions about concepts 11. Teacher demonstrations 12. Students ask and answer their own questions 13. Collaborating with peers 14. Read and respond to questions in a textbook 15. Students conduct an investigation and record data 16. Teacher models scientific thinking and reasoning 17. Students engage in authentic scientific experiences 18. Family support for science studies 19. Teachers supportive and helpful with science studies	1. Teacher lectures 2. Reading about science concepts through textbooks or other reputable sources 3. Students investigate and explore concepts through hands on engagement with materials 4. Traditional Labs 5. Guided discovery 6. Explicit and direct explanation of concepts 7. Students copy notes from the teacher or textbook 8. Teacher poses open ended questions about concepts 9. Teacher demonstrations 10. Students ask and answer their own questions 11. Collaborating with peers 12. Read and respond to questions in a textbook 13. Students conduct an investigation and record data 14. Teacher models scientific thinking and reasoning 15. Students engage in authentic scientific experiences 16. Family support for science studies 17. Teachers supportive and helpful with science studies 18. Peers/Friends supportive and helpful with science studies

20. Peers/Friends interested or enjoyed science
21. Science classes contributed toward attitudes
22. Science camps
23. Family went on science related outings
24. Family members that modeled the work of a scientist
25. Gender

19. Science classes contributed toward attitudes
20. Science tutoring
21. Family went on science related outings
22. Family members that modeled the work of a scientist
23. English Learner Program
24. Peers/Friends enjoyed and were interested in science
25. Gender

Regression 5

Dependent Variable If I try hard, I can do well.

Independent Variables

1. Teacher lectures
2. Reading about science concepts through textbooks or other reputable sources
3. Students investigate and explore concepts through hands on engagement with materials
4. Traditional Labs
5. Guided discovery
6. Explicit and direct explanation of concepts
7. Students copy notes from the teacher or textbook
8. Teacher poses open ended questions about concepts
9. Teacher demonstrations
10. Students ask and answer their own questions
11. Collaborating with peers
12. Read and respond to questions in a textbook
13. Students conduct an investigation and record data
14. Teacher models scientific thinking and reasoning
15. Students engage in authentic scientific experiences
16. Family support for science studies
17. Teachers supportive and helpful with science studies

Regression 6

Dependent Variable Science comes easy to me.

Independent Variables

1. Teacher lectures
2. Reading about science concepts through textbooks or other reputable sources
3. Students investigate and explore concepts through hands on engagement with materials
4. Traditional Labs
5. Guided discovery
6. Explicit and direct explanation of concepts
7. Students copy notes from the teacher or textbook
8. Teacher poses open ended questions about concepts
9. Teacher demonstrations
10. Students ask and answer their own questions
11. Collaborating with peers
12. Read and respond to questions in a textbook
13. Students conduct an investigation and record data
14. Teacher models scientific thinking and reasoning
15. Students engage in authentic scientific experiences
16. Family support for science studies
17. Teachers supportive and helpful with science studies

18. Peers/Friends supportive and helpful with science studies
19. Science classes contributed toward attitudes
20. Science tutoring
21. Family went on science related outings
22. Family members that modeled the work of a scientist
23. English Learner Program
24. Peers/Friends enjoyed and were interested in science
25. Gender

18. Peers/Friends supportive and helpful with science studies
19. Science classes contributed toward attitudes
20. Science tutoring
21. Family went on science related outings
22. Family members that modeled the work of a scientist
23. English Learner Program
24. Peers/Friends enjoyed and were interested in science
25. Gender

The final tables and analysis are presented below. Interest variables are presented in Tables 11, 12, and 13. Achievement variables are presented in tables 14, 15, and 16.

Table 11: I have enjoyed my prior experiences in science.

Independent Variable	Beta	t	Sig t
Science comes easy to me	.428	7.872	<.001
My teachers were supportive and helpful with my science studies.	.208	3.929	<.001
Students investigate and explore science concepts through hands on engagement with materials.	.124	2.517	<.05
Growth Mindset- If I try hard, I can do well	.139	2.449	<.05

R= .649 R^2= .421 F= 45.951 SigF= <.001 N= 258

For enjoyment of prior experiences in science, 4 variables were statistically significant, two at the <.001 level and two at the <.05 level. The R^2 shows that independent variables predicted 42.1% of the variance. The Beta for the statement "science comes easy to me" was the most powerful predictor and demonstrates moderate strength. Feeling confident with one's ability in science influences positive attitudes toward experiences in the subject.

Table 12: I find science interesting.

Independent Variable	**Beta**	**t**	**Sig t**
If I try hard, I can do well in science.	.336	6.022	<.001
Science comes easy to me.	.318	5.786	<.001
My science classes have contributed to how I feel about science today.	.174	3.434	<.001

R= .623 R^2= .388 F= 53.664 SigF= <.001 N= 258

In another analysis presented in Table 12, I wanted to see if a general interest in science could be predicted. Four independent variables were significant (<.001), with a growth mindset attitude being the strongest predictor at a moderate level (Beta = .336). Overall, the variables predicted 38.8% of the variance. Feeling confident with the ability to learn science can impact one's interest in the subject matter.

Table 13: I enjoy participating in science related activities.

Independent Variable	**Beta**	**t**	**Sig t**
Science comes easy to me.	.491	8.946	<.001
If I try hard, I can do well in science.	.160	2.880	<.01
My science classes have contributed to how I feel about science today.	.139	2.741	<.01

R= .625 R^2= .391 F= 54.358 SigF= <.001 N= 258

For the third attitudes measure, I wanted to see if enjoyment of participating in science related activities in general could be predicted. Only reaffirming that idea that confidence predicts interest and enjoyment, the statement "science comes easy to me" was the strongest predictor in regression with a Beta of .491 (p <.01). The independent variables predicted 39.1% of the variance. This also further explains the strong correlations between interest variables, as similar achievement measures predicted the different interest measures in each regression. It seems that attitudes, both feeling confident in scientific abilities or feeling that achievement in science is attainable for oneself, predicts interest and enjoyment of science stronger and more significantly than any specific teacher practices or outside experiences with science.

Three statements, "I have been successful in my prior science classes," "if I try hard, I can do well," and "science comes easy to me" represented different types of achievement beliefs. The first statement reflects prior achievement, the second statement reflects growth mindset, and the third statement reflects science self-efficacy. Tables 14, 15, and 16 present regression data using variables to predict each of the 3 beliefs around achievement.

Table 14: I have been successful in my prior science classes.

Independent Variable	Beta	t	Sig t
My teachers were supportive and helpful with my science studies.	.267	4.409	<.001
Explicit and direct explanations of concepts.	.170	3.077	<.01
Gender	-.258	-2.982	<.01
Teacher lectures.	.126	2.351	<.05
Teacher poses open ended questions about scientific concepts.	.150	2.667	<.01
Teacher demonstrations (teacher models an experiment for class to watch)	-.114	-2.067	<.05

$R = .477$ $R^2 = .227$ $F = 12.296$ SigF= <.001 $N = 258$

As noted above, I wanted to predict achievement in science. The regression predicting students feeling successful in science classes yielded 6 results, the strongest of which being teachers supportive and helpful. Two direct instruction practices (explicit, direct explanations of concepts and teacher lectures) and one inquiry practice (teacher poses open ended questions about scientific concepts) weakly predicted feelings of success in classes. Teacher demonstrations, a direct approach, negatively predicted prior achievement, meaning that students felt more successful less frequently when experiencing teacher demonstrations. Interestingly, gender had a negative Beta of -.258, revealing that girls tended to have lower feelings of success. The next regression used the same independent variables to predict a growth mindset regarding learning science.

Table 15: If I try hard, I can do well.

Independent Variable	Beta	t	Sig t
My teachers were supportive and helpful with my science studies.	.312	5.343	<.001
Explicit and direct explanations of concepts.	.168	2.859	<.01
I had family support for my science studies.	.140	2.404	<.05
Teacher poses open ended questions about scientific concepts.	.111	2.012	<.05
Students copy notes from the teacher or textbook about a concept.	.112	2.003	<.05

R= .514   R^2= .265   F= 18.138   SigF= <.001   N= 258

The results of the growth mindset regression revealed again the importance of teachers, since supportive teachers predicted growth mindset the strongest of the variables and at a moderate level. Two of the same instructional practices appear in this model as the last (one direct instruction and one inquiry), and there is one different practice of students copying notes. Another different independent variable predicting growth mindset is family support, which did not appear in interest or prior achievement regressions. Table 16 shows results from a third achievement regression about achievement regarding the feelings of confidence in science abilities.

Table 16: Science comes easy to me.

Independent Variable	Beta	t	Sig t
I had family support for my science studies.	.327	5.775	<.001

Explicit and direct explanations of concepts.	.180	3.099	<.01
Gender	-.159	-2.874	<.01
Students investigate and explore science through hands on engagement with materials.	.118	2.053	<.05

R= .483 *R^2= .233* *F= 19.208* *SigF= <.001* *N= 258*

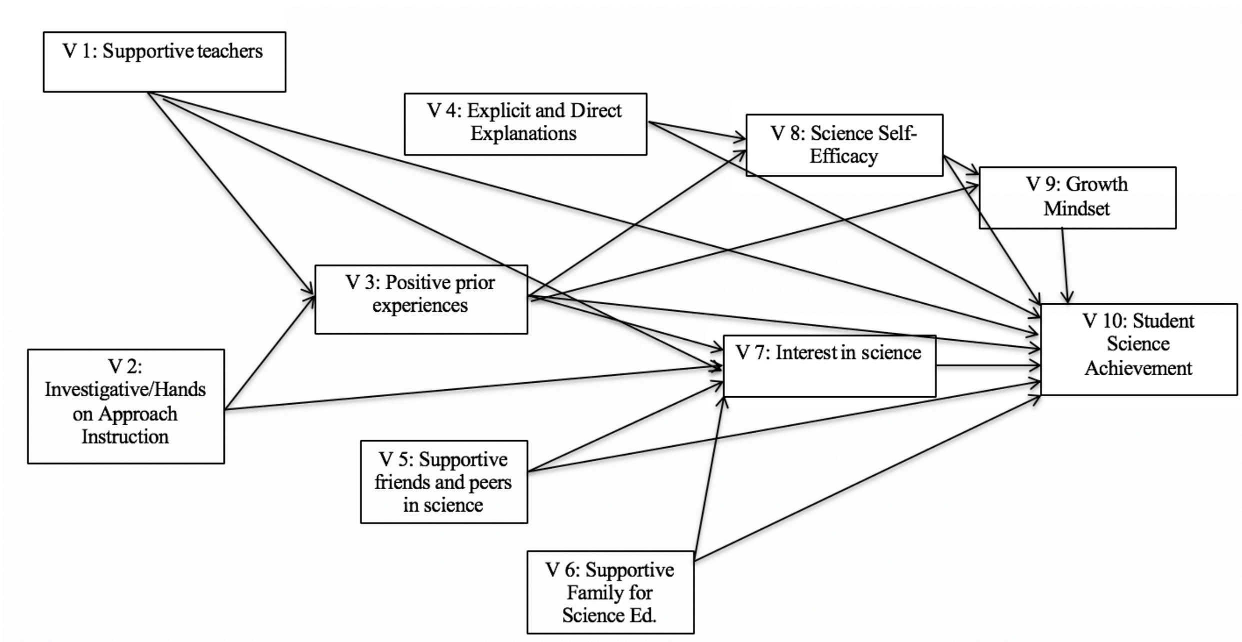
In terms of feeling confident with science abilities, family support was the strongest predictor at a moderate strength. This is an interesting and important finding, demonstrating the influence family can have on students' self-efficacy in a particular subject area. Each kind of instructional practice appears in the model again in this regression, and gender has a negative predictive relationship again as well. Girls were more likely to have more negative feelings about their abilities to do science.

The goals of the analysis were to assess which variable contributed the most to the R^2 and which variables were the most important predictions. A few instructional practices appeared in each of the achievement regressions, but less frequently in the interest regressions. Students who had positive prior experiences and confidence, along with supportive teachers, were more interested in science. Teacher support also was an important predictor for achievement measures, which makes sense, especially if students' only exposure to doing science is in the classroom.

Path Analysis

A path analysis was conducted to see what variables predicted the science achievement variable, "I have been successful in my prior science classes." In the before diagram, several variables representing both attitudes and experiences were included. Experiences included school and home variables such as teacher practices (investigative approach) and having a supportive family for science studies. Attitude variables such as having strong science self-efficacy, interest in science, and a growth mindset were also represented. The following before diagram represents the flow of direct and indirect relationships presumed, based on the literature review and conceptual model.

Figure 2: Before Diagram

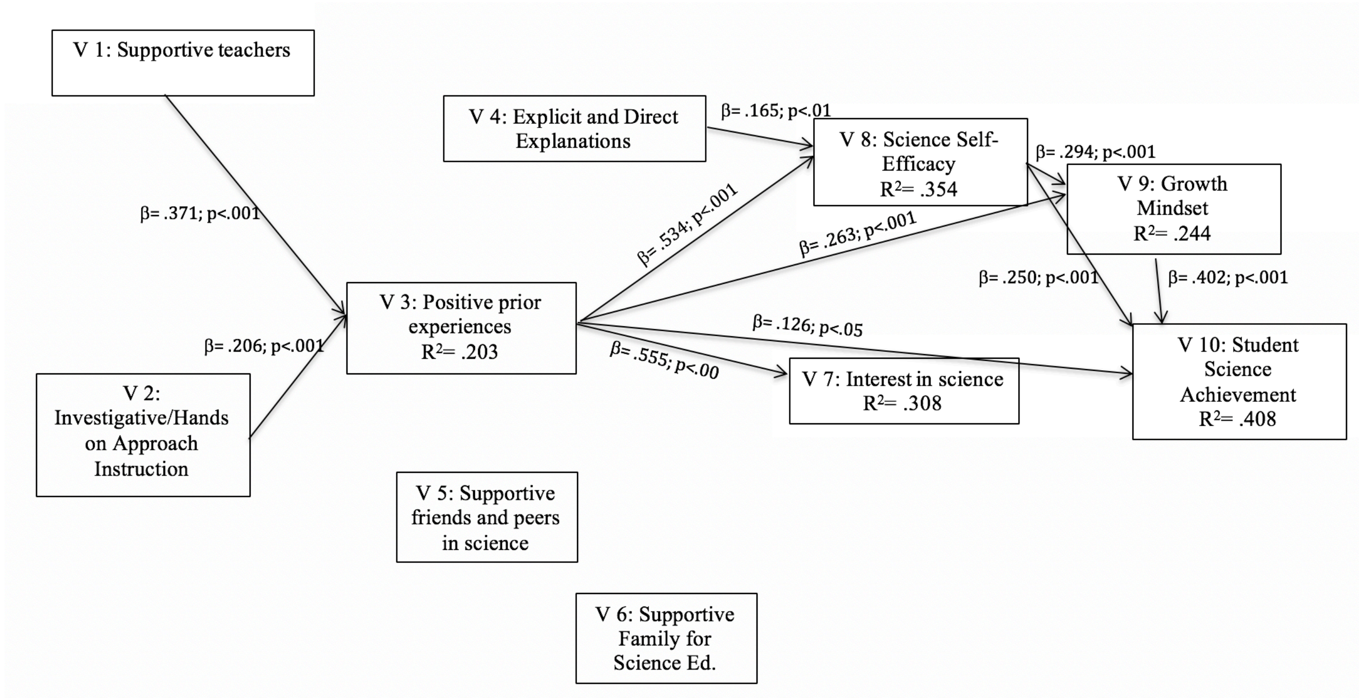


The following regressions were run for the intermediate diagram. The intermediate diagram shows the betas and significance for each variable.

Endogenous and Exogenous Variables

Regression	Independent Variables	Dependent Variable
1	V 1, V 2	V 3
2	V 1, V 2, V 3, V 5, V 6	V 7
3	V 3, V 4	V 8
4	V 3, V 8	V 9
5	V 1, V 3, V 4, V 5, V 6, V 7, V 8, V 9	V 10

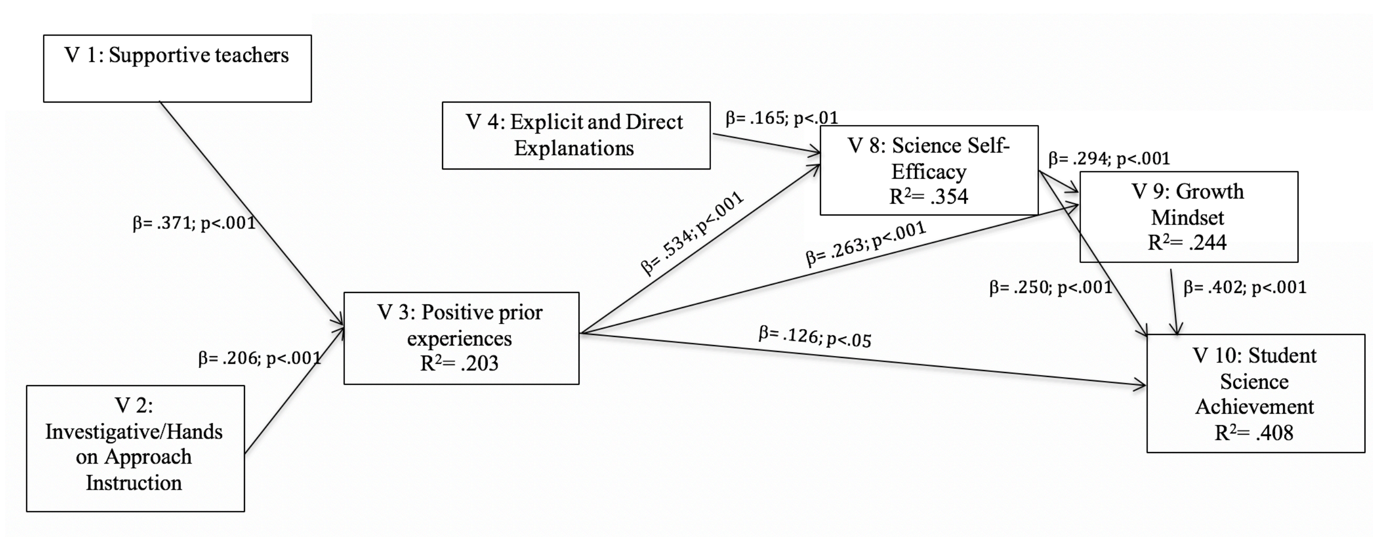
Figure 3: Intermediate Diagram



*The Betas in the path diagrams are path coefficients, but to avoid confusion that would result if p was used for path coefficient and also for probability, I labeled them as Betas in the diagram.

Several pathways were insignificant and removed from the after diagram. In eliminating those paths, the variables supportive friends and peers, supportive family, and interest in science were removed.

Figure 4: After Diagram



Several variables were removed for the after diagram due to significance of the path coefficient. To analyze the path results, I did a decomposition of bivariate covariation to determine fit of the model and to see which variables had the greatest total causals toward the ultimate endogenous variable of achievement.

Table 17: Decomposition of Bivariate Covariation

Variable Numbers	1/10	2/10	3/10	4/10	8/10	9/10
Original Covariation	.320	.152	.445	.309	.501	.569
Direct Causal	0	0	.126	0	.250	.402
Indirect Causal	.158	.089	.303	.061	.118	0
Total Causal	.158	.089	.429	.061	.368	.402
Noncausal	.162	.063	.016	.248	.133	.169

The variable that had the greatest total causal prediction of achievement was positive prior experiences (.429), and it was a reasonable fit at .056. Having a growth mindset, although the fit was weak (.169), had the second highest total causal of .389. Supportive teachers and investigative, hands-on instructional practice had an indirect prediction of achievement, both through positive prior experiences. Personal experiences such as having family support and peer support in science were removed in the intermediate diagram. Interestingly, the interest variable was also removed. It's possible that having positive experiences in science does not necessarily spark interest. Interest may not be necessary for achievement.

Discriminant Function

I wanted to use a number of independent variables about science attitudes and experiences in high school coursework to predict major choice of either science or not. I coded the majors in two categories, science major or other. The independent variables mainly consisted of specific teacher practices, interest, and achievement in science, as well as a few personal experience questions such as having peer and family support for science studies. I performed a discriminant function analysis in which all independent variables were entered simultaneously. Missing data for predictor variables were replaced with the mean.

Table 18 presents summary statistics about the discriminant that was derived. The Eigenvalue was of moderate strength at .411 and the canonical correlation was .540, with a significance of <.001. The structure matrix is presented in Table 19. The largest absolute correlations associated with the function were enjoying prior experiences in science and finding science interesting (both signifying attitudes toward science). Finally, the classification table is presented in Table 20. Note that in this analysis, 70.2 % of the cases were predicted correctly. Science majors can be predicted much better than chance.

Table 18: Summary of Canonical Discriminant Function

Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	.411	100	100	.540

Wilk's Lambda

Test of Function(s)	Wilk's Lambda	Chi-square	Df	Sig.
1	.709	75.973	25	<.001

Table 19: Structure Matrix

Structure Matrix	
Enjoy prior experiences in science	.628
Find science interesting	.595
I had family support for my science studies	.546
Science comes easy to me	.372

My teachers were supportive and helpful with my science studies	.357
If I try hard, I can do well	.321
Explicit and direct explanations of concepts	.285
I have been successful in my prior science classes	.274
Students ask and answer their own questions with teacher guidance	.218
Read and respond to questions in a textbook or a worksheet	.192
Guided discovery (teacher provides hints and prompts while students seek explanation to a scientific phenomenon)	.183
Collaborating with peers to understand a concept	.135
Reading about science concepts through textbook or other reputable sources	-.132
Students are provided opportunities to engage in authentic (real life) scientific experiences	.124
My science classes have contributed to how I feel about science today	.107
Students conduct an investigation and record data	.079
Teacher lectures	.069
Traditional labs (teacher provides step by step instructions for completing the experiment)	.062
Teacher models scientific thinking and reasoning	.057
Teacher demonstrations (teacher models experiment for class to watch)	.057
Videos that show or explain scientific concepts	-.050
Students copy notes from the teacher or textbook about a scientific concept	.048
Students investigate and explore science concepts through hands on engagement with materials	.047
Teacher poses open ended questions about scientific concepts	.046
Teacher poses problem or phenomena, and students seek ways to solve it through provided resources and materials	.043

Table 20: Classification Table

Predicted Group Membership

	What is your current major?	Science Major	Non Science Major	Total
Count	Science Major	76	41	117
	Other	36	105	141
%	Science Major	65	35	100
	Other	25.5	74.5	100

70.2% of original group cases correctly classified.

Table 21: Prior Probabilities for Groups

What is your current major?	Prior	Unweighted	Weighted

Science Major	.455	107	107.000
Other	.545	128	128.000
Total	1.000	235	235.000

Proportional Reduction in Error: 34.5%

The top variables predicting science majors were enjoyment of science and finding science interesting, followed by family support. This is an interesting finding because family support for science studies has not been strong in any other analysis. It was a variable removed from the path analysis. Teacher practices mostly tended to fall toward the end of the structure matrix, meaning that practices did not tend to matter as much as a feeling of enjoyment or interest with the subject matter. Also important for predicting science majors was having teacher support and feeling successful in science courses, which are not surprising. Clearly, teachers need to be using practices that encourage confidence and interest. The findings from the short response analysis below support this conclusion. Lastly, just behind teacher support for predicting science majors was having a growth mindset (If I try hard, I can do well). This demonstrates that science majors typically had a belief that they could achieve success in science if they worked hard at it. This is important because it differentiates science majors from other majors not by a scientific skill set or natural ability, but by their ability to recognize that learning something new takes time.

Short Answer Response

Students were asked to respond to the prompt: If you were a science major, please describe how you became interested in science. In total, 69 participants responded to the prompt. The coding of the responses revealed 6 major themes regarding who or what influenced students' pursuance of a science major. Every response fit under one of the six themes, and some responses included multiple themes so the total N (mentions of themes) is higher than the number of participants. See the table below.

Table 22: Short Answer Response Themes

Theme	N (%)
Inspired by particular class or teacher	32 (37%)
Enjoyment of scientific processes	19 (22%)
Interest in a particular career requiring science	19 (22%)
Family influence	5 (6%)
Personal experiences related to science	9 (11%)
Other experience provided by school	2 (2%)

*N=86 total mentions under these themes

The theme mentioned the most was inspired by a particular class or teacher, 31 out of 86 times, or 36% of the time. This is significant because it demonstrates the impact that an individual teacher can have on students. Of the students that reported a class or teacher as their inspiration, 4 dated it back to an elementary or middle school experience. Students in this theme explained their interest in pursuing science with responses like "In high school I took an anatomy class, and right away I knew that I wanted to learn more about the human body," "An AP environmental class that was taught by an amazing teacher," "My fifth, sixth, and seventh grade science classes were really what kept me interested to pursue learning science," and "I enjoyed every minute of it [biology] because of the passion my teacher taught me." Twice, responses under this theme included that a particular teacher did not adequately prepare them or did not have the best experience due to a teacher, but that one experience did not discourage them since they had other positive experiences in other classes.

A general enjoyment of scientific processes tied with interest in a particular science related career tied for the second most mentions at 22% of the time. Under enjoyment for scientific process, students didn't necessarily have a particular experience that sparked their interest to pursue science, but rather felt that it was built in to them from a young age or that they had a natural curiosity about something they wanted to explore. Responses in this theme included ideas such as "I was interested in the scientific process that was necessary in order to find unbiased and systematic answers to particular research questions," "Experiments would interest me," "I've always liked the concept of plate tectonics," "I've always had a passion to discover...I have always had questions about everything," and "I've just always found science interesting. I don't remember how it started."

It was very direct and clear when coding for the science career theme which occurred 22% of the time. Respondents mentioned wanting to pursue a specific job, and science was the way to get there. For instance, participants wrote "I want to go into healthcare and science is a big part of the process," "I want to go into med school and see what I want to become," or "I wanted to become a pediatrician and help kids."

Family influence responses contained explanations such as "Growing up my family always went to the California Science Center" and "My sister inspired me to do the same major as her which is Geology." These occurrences were less frequent at 6%, but it would require that the family had an interest in providing science experiences for their children, or there was a family member as a model or influence for scientific practice.

Personal experiences related to science included statements such as "I've spent a lot of time in hospitals," "I saw documentaries on TV and videos on Youtube, then I started reading articles," and "When I had braces, I became interested in how orthodontics worked." This theme explains experiences that students had specific personal experiences that sparked their interest, mostly by chance.

Other experiences provided by school such as clubs, internships, were mentioned less than <1% of the time, but it could be that these opportunities have not been readily accessible or offered to students.

Chapter V: Summary

Discussion

The objective of this research was to better understand the experiences college students had with science and high school science classes, in order to determine the impact of those experiences. One overarching question was how those experiences may have contributed to their interest and achievement in science today. In regards to this question, the survey was designed to draw on several aspects of participants' science experiences, and so the question was broken down into sub questions for analysis. The first question, what are participant's attitudes toward their science experiences, was measured by the first few statements on the survey regarding participants' interest in science, enjoyment of prior experiences in classes, feelings of success or the ability to achieve success in science, and whether or not classes contributed to their attitudes toward science currently. Confirming prior research, there were significant and moderate correlations amongst achievement and interest measures.

Sub Question 1: What are their [college students'] perceptions of and attitudes toward their science experiences?

In general, there were more positive attitudes overall toward science than not, with the mean scores ranging 2.35-3.19 for interest and achievement variables. The higher the score on a 1-4 scale the more strongly participants agree with interest and achievement statements as opposed to disagree or strongly disagree. Nearly 90% of participants stated that they found science interesting, but only 76% enjoyed their prior experiences with science classes. It seems that there is a missed opportunity there for students to engage in science classes and with science content, considering participants found science interesting but had negative views about science courses. It is important to recognize that students have a natural spark and curiosity for science outside of the classroom, and given the influence teachers can have on students as demonstrated by the short response analysis, teachers must keep the flame growing. Supporting this point further, correlations showed that being influenced by science classes is moderately related to interest in science. Students are influenced by their courses, and therefore a teacher can build upon positive or create negative feelings toward science. The discrepancy between participants' responses above tells me that authentic science practices may be lacking in classrooms, especially since students find an interest in science, yet don't have as positive experiences in courses.

Descriptive statistics for teacher practices clearly show that teachers of the participants mostly practice direct instruction based on frequency percentages for practices. This demonstrates the need to incorporate an inquiry-based approach in science classrooms, where students act as scientists, investigate relevant and relatable concepts of interest, and are driven by phenomena. Since students have an interest in science overall, classes modeled similarly to authentic practices have the potential to offer more positive experiences for students. Further validating this point, direct instruction practices were moderately correlated with each other and inquiry practices were correlated with other inquiry practices, meaning that students who experienced more frequently certain direct instruction practices, experienced other direct instruction practices more frequently as well, and vice versa. Teachers tend to gravitate to one instructional style, direct or inquiry, and they stick with that. Students do not seem to experience a variety of teacher practices, such as the combination of inquiry and direct instruction.

While only 40% of participants felt science came easy to them, 91% had a growth mindset, agreeing that if they worked hard they could do well in the subject. This was a very positive finding, considering science can be complex. It also means that given the right supports, students have the confidence that they can be successful in the subject area. This is important because of the impact that teachers and classes have on student interest and success, as confirmed by both quantitative and qualitative evidence. Teacher support had a stronger positive correlation for confidence with doing well in science compared to friend/peer support and family support. There was a significant positive correlation between science classes contributing to attitudes toward science and interest in science. Although correlations had a weak Beta at .315, on all four regressions to predict attitudes, teacher support or positive prior experiences with classes made it into each model as one of the predicting variables. Also, 32 of 86 science majors reported classes or teachers as their reason for pursuing a science degree specifically in their short response. Nineteen more mentioned the idea of enjoying some sort of specific scientific concept or process, but it was unclear whether or not that exposure to the concept or process was in school or not. It is reasonable to think that some of those experiences could have been initiated by teachers.

Furthermore, the strongest correlation in the structure matrix for the discriminant function to predict science majors was enjoyment of prior experiences in science courses. Teachers provide those experiences for students. Hence, teachers can make a major impact on students' interest and achievement in science by providing positive experiences for their students, sparking interest with exciting science phenomena, and ensuring student success through differentiated and scaffolded instruction techniques so that all students can feel confident with science coursework. Ultimately, these practices can increase interest and achievement in the science field.

The second and third sub questions further investigate whether specific teacher practices are effective for promoting interest or achievement in science. There is ample evidence that supports inquiry to be effective to promote interest in science (Areepattamannil, 2012; Bybee, 2015; Cuevas, Lee, Hart & Deaker, 2005; Estrella, Au, Jaeggi, & Collins, 2018), and mixed evidence regarding the most effective practice (inquiry or direct instruction) for achievement (Cobert et al., 2010; Kirschner, Sweller, & Clark, 2006; Rosenshine, 2009). Since the definitions can be broad, each instructional style was broken down into specific teacher practices. The practices that would fall under a direct instruction style are highlighted in Appendix A. Sub question 2 seeks relationships between teacher practices and interest and achievement, while sub question 3 focuses on predictions of interest and achievement, based on a variety of prior experiences related to science.

Sub Question 2: Do certain instructional practices correlate with achievement or interest in science?

While there was evidence that teachers and courses have an impact on student interest and achievement as presented with sub question 1, there were very weak significant correlations between most specific inquiry and direct instruction practices and achievement and/or interest. The only instructional strategy that had a moderate correlation was direct instruction with confidence and achievement. This could be because that is what students have experienced mostly in classes as it is a more traditional approach, and not all teachers have shifted to an inquiry practice, or because students tend to feel more confident when they are explicitly explained a concept versus having to develop their own understanding. This conclusion is supported by looking at the frequency of responses to the survey items in Appendix A, where it is clear that the highest "always" or "frequently" responses are for direct instruction practices over inquiry practices. For example, the highest mean of 3.3 (1-4 scale) is for teacher lectures, a direct instruction practice, whereas the lowest mean of 2.38 is for having authentic science experiences, an inquiry practice. Hence, the national emphasis on shifting instruction with the transition to the Next Generation Science Standards, that support a more authentic approach to instruction, is necessary since students mostly experience traditional and non-realistic science practices.

Many direct instruction practices were significantly correlated with other direct instruction practices, and same for inquiry practices, which means when participants experienced a practice falling in direct instruction style, they experienced other direct instruction style practices as well. This could mean that teachers who typically teach traditional direct instruction, stay with direct instruction practices and vice versa with inquiry. Although a weak relationship, this is reaffirmed be a few significant negative correlations between an inquiry practice and a direct instruction practice, such as guided discovery and students copying notes. Students tended to experience one instructional style over another from their teachers. One interesting significant moderate correlation was traditional labs with students investigate and explore concepts, an inquiry and a direct instruction practice. However, if participants haven't had many experiences with inquiry, given most experienced one practice over another, then they could easily see traditional labs as exploring, even though it's very directed. Students might also see traditional labs as an authentic science practice, because that presents a stereotypical image as well as provides students with opportunities for "doing" science activities as opposed to passively learning it.

Sub Question 3: Are instructional strategies such as collaboration, relevant experiences, scaffolded scientific thinking, personal experiences, and exposure to scientific processes predictive of achievement or interest in science?

Sub question 3 ties in the theoretical framework that guided the literature review with the predictions of achievement and interest. The instructional practices listed were designed based on the *The Scaffolded Knowledge Integration Framework for Instruction* by Linn, Davis, & Eylon (2004), as the framework includes both aspects of inquiry and direct instruction, as well as personal and relevant experiences and exposure to scientific processes in general. For sub question 3, the survey included measures beyond the classroom such as family experiences, general interest, and demographic information.

A path analysis incorporated some of the major components of the framework as exogenous and endogenous variables, leading to the ultimate endogenous variable of achievement. The achievement variable used was "I have been successful in my prior science classes." I recognize that this is self-reported achievement and that, in theory, there could be a discrepancy between this variable and actual academic success. Ultimately, the predictions are about whether the students saw themselves as achieving success or not in their high school classes.

In the before diagram, survey items such as having supportive peers, family and teachers for science studies, experiencing investigative/hands on learning, having positive prior experiences, being provided explicit and direct explanations of concepts, confidence in science abilities, and interest were all variables leading to student achievement. Background and personal experiences like having family and peer support were removed in the after diagram. Most surprisingly, interest was also removed. Though weak, positive prior experiences had a direct relationship to achievement, but a moderate relationship to science self-efficacy. Since self-efficacy and growth mindset both served as predictors of achievement, and positive prior experiences predicted both of those, it seems that participants did not have to find science interesting for the experience to be positive. It could be that the experience was positive because of feelings of success in science. Thus, teachers not only need to spark interest in students in the classroom, but also ensure that students have the proper supports to feel successful. Thus, the purpose of the *Scaffolded Knowledge Integration Framework* is to provide appropriate explicit scaffolds for scientific thinking, as well as expose students to authentic scientific practices through an inquiry approach with scientific experiences relevant to students' lives.

While interest was not in the after diagram, other data analysis further supported the theoretical framework. For interest regressions, only one specific teacher practice was significant and made it into the step-wise model which was students investigate and explore science concepts through hands on engagement with materials, but the Beta was very low (.130). Otherwise, feelings of confidence such as "science comes easy to me" had higher Betas in each regression for interest. For achievement, a few practices such as "direct and explicit explanations of concepts" and "teacher poses open ended questions" made it at a significant level into the regression model; however, they had weak Betas. Thus, specific instructional practices were not a strong predictor for achievement or interest in science. However, having supportive teachers repeatedly was significant in the models. It is clear that the experiences teachers create in their classrooms have an impact on student attitudes toward science, and their feelings of success.

A great percentage of participants noted that they had peers/friend support (83.4%) and a general interest in science (85.3%). The significant positive correlation between having friend/peer support and interest in science provides a reason for incorporating purposeful collaboration as part of teaching instructional practices. It also is validated by the body of literature on peer effects and the impact peers can have on each other's academic performance and interest (Sacerdote, 2011).

Some inquiry instructional practices such as open-ended questions and investigating concepts, as well as direct instruction practices such as explicit and direct instruction and teacher lectures were found to predict achievement. Direct instruction practices seemed to have a larger influence overall, however. This could reflect tests students were taking, as many are based on direct instruction practices, having fact recall type questions. It could also be lack of the shift in instruction and exposure to inquiry, and thus there weren't any significant results for inquiry practices to report.

Ultimately, this reaffirms the idea that teachers have an opportunity to play a major role with student achievement and interest. It was the most reoccurring theme throughout all the analyses, including being the most important predictor in several interest and achievement regressions. Interest is vital for student pursuit, and teachers can initiate it. This is reflected by the number of students who mentioned specific teachers or courses as influencing their decision to choose a science major. While specific teacher practices did not have major results in terms of strength of predictions and correlations, many aspects of the *The Scaffolded Knowledge Integration Framework for Instruction* did have positive results in both the quantitative and qualitative analyses. Having peer support and teacher support all have significant correlations for achievement and success.

Themes from the short response demonstrate that scientific thinking processes, personal experiences, and exposure are important for students to gain interest. Relevant experiences could include exposure to specific jobs in the science field students might find interesting. Some districts have moved to this by offering courses as a pathway to a specific field, such as a medical school pathway.

Overarching Question: What are college students' high school science experiences that contributed to their achievement and/or interest in science?

Several different analyses were run to get a comprehensive response to this question. Each one contributed a different piece to the puzzle. Ultimately, prior research was confirmed that positive prior experiences and prior achievement predict interest and achievement in science. Furthering this, however, the role of teachers was highlighted in several analyses in this paper. Interestingly, interest as a predictor of achievement was deleted as a variable in the after diagram for the path analysis, yet positive prior experiences remained as a direct and indirect predictor. Despite this discrepancy, there is other evidence in this study supporting the idea that interest and achievement are related. According to the discriminant function results, enjoying science and finding science interesting were the top predictors of choice of science majors. This is not surprising, but it demonstrates that interest is related to achievement, since choosing to be a science major was also correlated moderately to interest, and interest was moderately correlated to achievement.

The regressions and short responses highlighted the point that teacher support strongly influences student interest in science. There weren't many strong findings related to specific teacher practices in the classroom; however, participants felt that courses could impact their interest and ultimately their decision to enter the science field. The only evidence about specific instructional practices was reported in the regression tables that revealed that a mixture of certain inquiry and direct instruction practices predicted interest and achievement measures. One reason more teacher practices may not have entered significantly or strongly into most analyses could be because participants haven't experienced many of them. In the descriptive statistics, it was clear that fewer students had exposure to inquiry practices than direct instruction. This could be due to the fact that many districts are still in transition to the Next Generation Science Standards, and that when these participants were in high school, teachers might not have transitioned at all yet.

Despite the limited findings on specific teacher practices, there are several other experiences that are important findings from the study, that teachers can practice in the classroom. Other experiences include having family support and having a growth mindset. Teachers can create home-school connections with families and the community, and provide students with culturally relevant experiences in science. A second finding was related to gender. In the growth mindset and science self-efficacy regressions, females reported more negative feelings. It is interesting that despite the increased focus on women in STEM and the increased enrollment of women over men in colleges, the females still tended to lack the confidence and the growth mindset related to science.

People can tend to categorize themselves as a "science person" or "not a science person." This just reflects their belief that people were either born with the skillset to do it or not. That belief system reflects a fixed mindset. Contrastingly, in the discriminant function analysis, having a growth mindset was one of the more important variables for predicting science majors. Science majors did not necessarily feel they were born a scientist, but rather, they knew that hard work could help them achieve success with science. Ultimately, that belief was one of the factors that enabled them to have the confidence to pursue the field. Teachers can support students in developing a growth mindset as mindsets are not static. Teachers can ensure students learn to persevere and provide students with rigorous experiences with the proper supports for students to achieve success.

Conclusions

Ultimately, teachers create the experiences for their students, so it can be concluded that a variety of purposeful exposure and interactions are necessary for student success. One specific instructional style over another, especially using only a traditional direct instruction approach, is not sufficient for increasing interest and achievement. As students get more and more exposure to authentic practices, this research might produce stronger results one way or another.

Teachers enter the classroom and their instructional strategies are influenced not only by the teacher education programs, but also by their experiences as students themselves. In science, much of what they learned was by direct instruction and not through inquiry based instruction, so it is understandable that an inquiry approach is unfamiliar and even uncomfortable to them. By breaking down these specific practices, teachers can get a more comprehensive view of what inquiry and direct instruction encompass. Specifically, the synthesis of the analyses demonstrates the importance of shifting to a less traditional approach, to a more authentic approach as the NGSS calls for. When students are interested in what they are learning, and it is purposeful to them, they will be more likely to pursue that concept and have stronger beliefs in their abilities. With teachers supporting and ensuring successful experiences, students' self-efficacy ultimately predicts their achievement; especially given the finding that students do not necessarily have to take interest in science to do well in it, or to have positive prior experiences.

In order to support classroom teachers in meeting the demands of current science reform, they must be provided multiple professional learning opportunities where they experience authentic inquiry-based instruction as learners themselves (Lederman & Lederman, 2012; McLaughlin & McFadden). Because the role of the teacher is significant for students as demonstrated by the analysis, it is essential to provide opportunities for teachers to build their content knowledge and pedagogical skills through authentic experiences facilitating inquiry science. This way, teachers feel confident to facilitate a variety of practices and incorporate key practices that motivate and support student learning.

Limitations

Limitations include participant availability and sample size since participation was optional. I had hoped to do a special regression using English Language Learners, but my analysis of the responses was that there were very few of them and it appeared that some respondents did not understand the question. It was not clear to me that I had a good valid sample of English Language Learners. Another limitation is maturation, as the participants are being asked to reflect on experience that occurred several years prior. An external threat is demand characteristics, as participants might try to give examples of instruction that they feel the researcher is seeking or that seems logical to be impactful or meaningful, rather than what they truly experienced. Finally, the sample size was attained from two colleges that were very different demographically. At one college, more science majors took the survey than the other. Also, the majority of participants who were non-science majors were education majors.

Implications

Implications are to train teachers to practice a more guided inquiry approach, especially for teachers transitioning to an inquiry approach as opposed to unstructured inquiry. It is also ideal to incorporate relevant experiences of students, and expose them to possible future opportunities in the science field. Conderman and Woods (2012) recommend more experience for preservice teachers, more staff development, choosing a comprehensive curriculum, prioritizing budgets for science equipment, integrating concepts into other curricular areas, addressing management issues with science equipment, sharing expertise of science specialists, and developing a long-range plan for implementing science curriculum. Science instruction needs to be purposeful and provide students with multiple opportunities for authentic experiences coupled with the appropriate supports to limit confusion and misconceptions. Research needs to be more focused on the positive aspects from each instructional strategy, to determine what combination may be most effective to promote both interest and achievement in science.

Another implication is to extend results to higher education. Once students enter college as science majors, retention in the major has been noted as an issue for colleges. This could be for several reasons worth investigating. However, the instructional practices and experiences in this study were reported on by current college students. It could be beneficial to not only use the ideas and results from this study in the K-12 system, but to also implement at the college level. Instruction at the college level could be a factor in science major attrition, and enhancing instructor practices could further support students pursuing the field.

Recommendations

Teachers need to provide students with opportunities for investigation and critical thinking (students need to be taught explicitly how to think scientifically). Thus, the combination of inquiry instructional strategies with appropriate direct instruction strategies to scaffold scientific thinking is necessary to promote scientific skills and engagement in science. Professional development needs to be directed at science instructional practices that incorporate relevant experiences and exposure to scientific processes, especially as this study produces results that teachers had strong influences on their science learning and motivation. A continued focus on females, specifically in their science self-efficacy and growth mindset, is important to continue initiatives on increasing females in STEM fields.

Future Research

Despite increased attention to science education through STEM initiatives and the adoption of the Next Generation Science Standards (NGSS), science teaching in elementary schools remains an area of concern (Center for Research, Evaluation, and Assessment, Lawrence Hall of Science, 2007). Reform efforts focus on a singular practice over another, despite warnings from research that inquiry might not always be effective for achievement, and direct instruction can be ineffective for student engagement. Given the knowledge that student self-efficacy predicts achievement (Caprara, Barbaranelli, Steca & Malone 2006) and the results of this study, it is important that students feel successful as well as engaged, and effective strategies that promote interest and achievements need to be explored in order to help reform efforts continue in the most effective direction. Because of mixed feelings regarding traditional tests as a form of achievement measurement and the difficulty of correlating interest and practices with young students, college students who found success in science and pursued the science field can be useful in determining effective and memorable instructional practices.

Future research needs to focus around mixed methods of science instruction to get a more complete picture of student experiences, especially as districts continue the transition to Next Generation Science Standards. It would be helpful to capture instructional practices that influenced student interest and achievement through interviews, as opposed to a snapshot short response. This could provide a more accurate picture of effective instructional practices, since the researcher can probe deeper for specific examples in order to align the researcher's definitions of the practices. A further survey could find out which practices were more effective for promoting interest and achievement by asking participants specifically which practices they felt supported their learning and interest. Analysis by ethnicity and gender would also provide valuable data in order to differentiate practices within schools. Finally, it would be interesting to see how confident students became confident in their abilities with science, considering there weren't any strong and significant correlations or predictions using specific teacher practices. Confidence was correlated with interest, but it was unclear how students became confident in the first place. Focusing on these questions can help generate further understanding of important practices schools can be incorporating into their science programs.

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Appendices

Appendix A: Survey

Check one for each statement.

Q 1. To what extent do you currently agree or disagree with the following statements?	Strongly Disagree	Disagree	Agree	Strongly Agree
I enjoy participating in science related activities.	☐	☐	☐	☐
I have enjoyed my prior experiences with science.	☐	☐	☐	☐
I find science interesting.	☐	☐	☐	☐
Science comes easy to me.	☐	☐	☐	☐
If I try hard, I can do well in science.	☐	☐	☐	☐
I have been successful in my prior science classes.	☐	☐	☐	☐

Q 2. Reflect on your high school (grades 9-12) experiences with science. To what frequency do the following teacher practices describe your experiences in high school science classes?	Never	Occasionally	Frequently	Always
Teacher lectures	☐	☐	☐	☐

Reading about science concepts through textbooks or other reputable sources	☐	☐	☐	☐
Students investigate and explore science concepts through hands on engagement with materials	☐	☐	☐	☐
Traditional labs (teacher provides specific step by step instructions for completing the experiment)	☐	☐	☐	☐
Guided discovery (teacher provides hints and prompts while students seek explanation to a scientific phenomenon)	☐	☐	☐	☐
Explicit and direct explanations of concepts.	☐	☐	☐	☐
Students copy notes from the teacher or textbook about a scientific concept.	☐	☐	☐	☐
Teacher poses open ended questions about scientific concepts.	☐	☐	☐	☐
Teacher demonstrations (teacher models an experiment for class to watch)	☐	☐	☐	☐
Students ask and answer their own questions with teacher guidance.	☐	☐	☐	☐
Videos that show or explain scientific concepts.	☐	☐	☐	☐
Collaborating with peers to understand a concept.	☐	☐	☐	☐

Read and respond to questions in a textbook or on a worksheet.	☐	☐	☐	☐
Teacher poses a problem or phenomena, and students seek ways to solve it through provided resources and materials.	☐	☐	☐	☐
Students conduct an investigation and record data.	☐	☐	☐	☐
Teacher models scientific thinking and reasoning.	☐	☐	☐	☐
Students are provided opportunities to engage in authentic (real life) scientific experiences.	☐	☐	☐	☐

Q 3. Reflecting on your prior experiences, how strongly do you agree or disagree with the following statements.

	Strongly Disagree	Disagree	Agree	Strongly Agree
I had family support for my science studies.	☐	☐	☐	☐
My teachers were supportive and helpful with my science studies.	☐	☐	☐	☐
My peers and/or friends were supportive and helpful with my science studies.	☐	☐	☐	☐
I had peers and/or friends that were interested in or enjoyed science.	☐	☐	☐	☐
My science classes have contributed to how I feel about science today.	☐	☐	☐	☐

Q 4. Reflecting on your prior experiences, select whether you agree or disagree with the following statements.

	Agree	Disagree
I had science tutoring.	☐	☐
I went to science camps when I was younger.	☐	☐
My family went on science related outings when I was younger (visits to scientific museums, centers, activities, etc.)	☐	☐
I had family members that modeled the work of a scientist for me.	☐	☐

Q 5. What is your current major? (Specify if undeclared).

Q 6. If undeclared, list the major(s) you are considering declaring. Otherwise, leave blank.

Q 7. To the best of your memory, what was your high school G.P.A.?

☐ above 3.9
☐ 3.5-3.9
☐ 3.0-3.4
☐ 2.5-2.9
☐ 2.0-2.4
☐ below 2.0

Q 8. Are you the first person in your family to go to college? (besides a sibling)

☐ Yes
☐ No

Q 9. While you were in grades 6-12, were you in the English Language Learner program?

☐ Yes ☐ No ☐ I don't know

Q 10. *If yes*, to the best of your memory, which year did you exit the English Language Learner program?

☐ 6th ☐ 7th ☐ 8th ☐ 9th ☐ 10th ☐ 11th

☐ 12th ☐ I was not exited ☐ I am not sure

Q 11. What is your gender?

☐ Male ☐ Female ☐ Other: ____________

Q 12. What is your age?

☐ 18 ☐ 19 ☐ 20 ☐ 21 +

Q 13. What year are you in college?

☐ 1st year
☐ 2nd year
☐ 3rd year
☐ 4th year
☐ More than 4th year

Q 14. What is your ethnicity? (Check all that apply)

☐ American Indian or Native American or Pacific Islander
☐ Asian or Asian American
☐ Black or African American

☐ Hispanic or Latina/o
☐ White
☐ Other

15. If you are a science major, please describe how you became interested in science.

Appendix B: Correlations Matrix

	Enjoy participating in science related activities	Enjoy prior experiences in science	Find science interesting	Science comes easy to me	If I try hard, I can do well	I have been successful in prior classes	Teacher lectures	Reading about science concepts through textbooks	Students investigate and explore concepts	Traditional Labs	Guided discovery
Enjoy participating in science related activities	1	.616**	.648**	.589**	.414**	.407**	.068	.037	.199**	.103	.063
Enjoy prior experiences in science	.616**	1	.555**	.572	.432**	.445**	.149*	.102	.260**	.194**	.159*
Find science interesting	.648**	.555**	1	.499	.520**	.385**	.084	.018	.176**	.061	.091
Science comes easy to me	.589**	.572**	.499**	1	.444**	.501**	.152*	.000	.204**	.158*	.123*
If I try hard, I can do well	.414**	.432**	.520**	.444*	1	.569**	.162**	.124	.135*	.217**	.125*
I have been successful in prior classes	.407**	.445**	.385**	.501*	.569**	1	.236**	.118	.152*	.189**	.119
Teacher lectures	.068	.149*	.084	.152*	.162**	.236**	1	.472**	.169**	.218**	.124*
Reading about science concepts through textbooks	.037	.102	.018	.000	.124	.118	.472**	1	.113	.159*	.122

Students investigate and explore concepts	.199**	.260**	.176**	.204**	.135*	.152*	.169**	.113	1	.450**	.428**
Traditional Labs	.103	.194**	.061	.158*	.217**	.189**	.218**	.159*	.450**	1	.443**
Guided discovery	.063	.159*	.091	.123*	.125*	.119	.124*	.122	.428**	.443**	1
Explicit and direct explanations	.227**	.232**	.269**	.290**	.319**	.309**	.344**	.251**	.269**	.279**	.236**
Students copy notes from teacher	.091	.085	.145*	.006	.172**	.187**	.372**	.323**	-.031	.108	-.137*
Teacher poses open ended questions	.086	.162**	.160*	.165**	.193**	,187**	.135*	.063	.242**	.217**	.297**
Teacher demonstrations	.019	.090	.141*	.056	.170**	.006	.019	-.076	.296**	.259**	.328**
Students ask and answer own questions	.037	.128*	.075	.082	.176**	.053	.103	-.059	.246**	.148	.365**
Videos that show or explain	-.025	.007	.058	-.053	.202**	.096	-.008	.131*	.077	.098	.127*
Collaborating with peers	.103	.162**	.087	.003	.142*	.107	.081	.013	.296**	.254**	.257**
Read and respond to questions in textbook	-.002	.072	.087	-.040	.101	.131*	.163**	.315**	.005	.064	.019

Teacher poses problem/phenomena	-.045	.124*	.081	.014	.042	.032	.127*	.129*	.257**	.167**	.419**
Students conduct investigation	.113	.205**	.148*	.135*	.147*	.153*	.234**	.090	.443**	.394**	.394**
Teacher models scientific thinking	.077	.218**	.180**	.126*	.211**	.223**	.193**	.103	.357**	.361**	.415**
Students provided authentic experiences	.091	.183**	.113	.137*	.069	.182**	.145*	.059	.418**	.305**	.527
Family support for science	.335**	.384**	.244**	.395**	.305**	.235**	.112	.014	.142*	.138*	.173**
Teachers supportive and helpful	.218**	.401**	.282**	.276**	.413**	.320**	.070	.015	.146*	.237**	.182**
Peers/friends supportive and helpful	.256**	.318**	.225**	.188**	.248**	.244**	.039	.046	.239**	.181**	.173**
Peers/friends interested in science	.184**	.110	.160*	.163**	.175**	.052	.075	.102	.114	.137*	.077
Science classes contributed to attitudes	.266**	.147*	.315**	.180**	.245**	.190**	.134*	.030	.086	.070	.031
Major	-.320**	-.332**	-.350**	-217**	-.184**	-.164**	-.063	.058	-.013	-.034	-.127*
G.P.A	.046	.077	.084	-.018	-.008	-.027	-.110	-.067	-.028	.016	-.035

Gender	-.156*	-.109	-.094	-.179**	-.070	-.170**	.084	.026	.059	-.020	-.091

	Explicit and direct explanations	**Students copy notes from teacher**	**Teacher poses open ended questions**	**Teacher demonstrations**	**Students ask and answer own questions**	**Videos that show or explain**	**Collaborating with peers**	**Read and respond to questions in textbook**	**Teacher poses problem/phenomena**	**Students conduct investigation**	**Teacher models scientific thinking**
Enjoy participating in science related activities	.227**	.091	.086	.019	.037	-.025	.103	-.002	-.045	.113	.077
Enjoy prior experiences in science	.232**	.085	.162**	.090	.128*	.007	.162**	.072	.124*	.205**	.218**
Find science interesting	.269**	.145*	.160*	.141*	.075	.058	.087	.087	.081	.148*	.180**
Science comes easy to me	.290**	.006	.165**	.056	.082	-.053	.003	-.040	.014	.135*	.126*
If I try hard, I can do well	.319**	.172**	.193**	.170**	.176**	.202**	.142*	.101	.042	.147*	.211**
I have been successful in prior classes	.309**	.187**	,187**	.006	.053	.096	.107	.131	.032	.153	.223**
Teacher lectures	.344**	.372**	.135*	.019	.103	-.008	.081	.163**	.127*	.234**	.193**
Reading about science concepts through textbooks	.251**	.323**	.063	-.076	-.059	.131*	.013	.315**	.129*	.090	.103

Students investigate and explore concepts	.269**	-.031	.242**	.296**	.246**	.077	.296**	.005	.257**	.443**	.357**
Traditional Labs	.279**	.108	.217**	.259**	.148*	.098	.254**	.064	.167**	.394**	.361**
Guided discovery	.236**	-.137*	.297**	.328**	.365**	.127*	.257**	.019	.419**	.394**	.415**
Explicit and direct explanations	1	.263**	.167**	.212**	.147*	.101	.160*	.166	.175**	.203**	.254**
Students copy notes from teacher	.263**	1	.048	-.020	-.070	.060	.046	.368	.027	.032	.017
Teacher poses open ended questions	.167**	.048	1	.317**	.377**	.147*	.296**	.088	.376**	.359**	.317**
Teacher demonstrations	.212**	-.020	.317**	1	.352**	.132*	.259**	.091	.346**	.245**	.253**
Students ask and answer own questions	.147*	-.070	.377**	.352**	1	.172**	.124*	-.038	.293**	.257**	.225**
Videos that show or explain	.101	.060	.147*	.132*	.172**	1	.259**	.152*	.224**	.224**	.186**
Collaborating with peers	.160*	.046	.296**	.259**	.124*	.259**	1	.126*	.242**	.314**	.401**
Read and respond to questions in textbook	.166**	.368**	.088	.091	-.038	.152*	.126*	1	.199**	.148*	.119

Teacher poses problem/phenomena	.175**	.027	.376**	.346**	.293**	.224**	.242**	.199**	1	.324**	.348**
Students conduct investigation	.203**	.032	.359**	.245**	.257**	.091	.314**	.148*	.324**	1	.458**
Teacher models scientific thinking	.254**	.017	.317**	.253**	.225**	.186**	.401**	.119	.348**	.458**	1
Students provided authentic experiences	.184**	-.171**	.279**	.297**	.289**	.184**	.286**	-.036	.388**	.515*	.472**
Family support for science	.213**	.037	.132*	.234**	.186**	-.070	.077	.001	.016	.070	.045
Teachers supportive and helpful	.231**	.017	.092	.121	.154*	.019	.235**	.032	.082	.148*	.220**
Peers/friends supportive and helpful	.155*	.052	.093	.105	.021	-.061	.272**	-.013	.053	.120	.223**
Peers/friends interested in science	.020	.034	-.088	-.001	.011	.012	.123	-.039	.018	.049	.081
Science classes contributed to attitudes	.195**	.152	.076	.115	-.008	.045	.089	.068	.034	.128*	.168**
Major	-.161**	-.065	-.033	-.014	-.105	.026	-.087	-.129	.006	-.066	-.059
G.P.A	.069	-.003	.003	.104	.007	-.005	-.018	.049	.029	-.058	-.016
Gender	-.044	.069	.043	-.035	-.060	.016	.079	-.042	-.078	.063	.033

	Students provided authentic experiences	Family support for science	Teachers supportive and helpful	Peers/friends supportive and helpful	Peers/friends interested in science	Science classes contributed to attitudes	Major	G.P.A.	Gender
Enjoy participating in science related activities	.091	.335**	.218**	.256**	.184**	.266**	-.320**	.046	-.156*
Enjoy prior experiences in science	.183**	.384**	.401**	.318**	.110	.147*	-.332**	.077	-.109
Find science interesting	.113	.244**	.282**	.225**	.160*	.315**	-.350**	.084	-.094
Science comes easy to me	.137*	.395**	.276**	.188**	.163**	.180**	-217**	-.018	-.179**
If I try hard, I can do well	.069	.305**	.413**	.248**	.175**	.245**	-.184**	-.008	-.070
I have been successful in prior classes	.182**	.235**	.320**	.244**	.052	.190**	-.164**	-.027	-.170**
Teacher lectures	.145*	.112	.070	.039	.075	.134*	-.063	-.110	.084
Reading about science concepts through textbooks	.059	.014	.015	.046	.102	.030	.058	-.067	.026

Students investigate and explore concepts	.418**	.142*	.146*	.239**	.114	.086	-.013	-.028	.059
Traditional Labs	.305**	.138*	.237**	.181**	.137*	.070	-.034	.016	-.020
Guided discovery	.527*	.173**	.182**	.173**	.077	.031	-.127*	-.035	-.091
Explicit and direct explanations	.184**	.213**	.231**	.155*	.020	.195**	-.161**	.069	-.044
Students copy notes from teacher	-.171**	.037	.017	.052	.034	.152*	-.065	-.003	.069
Teacher poses open ended questions	.279**	.132*	.092	.093	-.088	.076	-.033	.003	.043
Teacher demonstratio ns	.297**	.234**	.121	.105	-.001	.115	-.014	.104	-.035
Students ask and answer own questions	.289**	.186**	.154*	.021	.011	-.008	-.105	.007	-.060
Videos that show or explain	.184**	-.070	.019	-.061	.012	.045	.026	-.005	.016
Collaborating with peers	.286**	.077	.235**	.272**	.123	.089	-.087	-.018	.079
Read and respond to	-.036	.001	.032	-.013	-.039	.068	-.129	.049	-.042

questions in textbook									
Teacher poses problem/phen omena	.388**	.016	.082	.053	.018	.034	.006	.029	-.078
Students conduct investigation	.515*	.070	.148*	.120	.049	.128*	-.066	-.058	.063
Teacher models scientific thinking	.472**	.045	.220**	.223**	.081	.168**	-.059	-.016	.033
Students provided authentic experiences	1	.163**	.155*	.118	.069	.090	-.062	-.001	-.019
Family support for science	.163**	1	.343**	.331**	.115	.215**	-.247**	.037	-.059
Teachers supportive and helpful	.155*	.343**	1	.477**	.275**	.279**	-.212**	.135*	-.068
Peers/friends supportive and helpful	.118	.331**	.477**	1	.413**	.215**	-.144*	-.007	-.037
Peers/friends interested in science	.069	.115	.275**	.413**	1	.173**	-.027	-.180**	-.134**
Science classes contributed to attitudes	.090	.215**	.279**	.215**	.173**	1	-.070	.091	-.039

Major	-.062	-.247**	-.212**	-.144*	-.027	-.070	1	-.097	.135*
G.P.A	-.001	.037	.135*	-.007	-.180**	.091	-.097	1	-.111
Gender	-.019	-.059	-.068	-.037	-.134**	-.039	.135*	-.111	1

* $p < 0.05$ ** $p < 0.01$