4-22-2019

Self-Efficacy and STEM Career Interest in Black and Latino Middle School Students: A Study on the Next Generation Science Standards

Whitney McCormick
Loyola Marymount University, whitney.mccormick@gmail.com

LOYOLA MARYMOUNT UNIVERSITY

Self-Efficacy and STEM Career Interest in Black and Latino Middle School Students: A Study on the Next Generation Science Standards

by

Whitney McCormick

A dissertation presented to the Faculty of the School of Education,

Loyola Marymount University,

in partial satisfaction of the requirement for the degree

Doctor of Education

2019

Self-Efficacy and STEM Career Interest Interest in Black and Latino Middle School Students: A Study on the Next Generation Science Standards

By

Whitney McCormick

Loyola Marymount University
School of Education
Los Angeles, CA 90045

This dissertation written by Whitney McCormick, under the direction of the Dissertation Committee, is approved and accepted by all committee members, in partial fulfillment of requirements for the degree of Doctor of Education.

2/24/19
Date

Dissertation Committee

[redacted]
Martha McCarthy, Ph.D., Committee Member

[redacted]
Rebecca Herr Stephenson, Ph.D., Committee Member

[redacted]
Anita Kreide, Ed.D., Committee Member

ACKNOWLEDGEMENTS

Thank you to the student participants and the teachers that elected to become apart of this study to change science education for all. Thank you to the Friday Institute for Educational Innovation for granting me permission to use the S-STEM.

I could not have done this dissertation without the support of my fearless chair, Dr. Martha McCarthy, and my phenomenal committee, Dr. Becky Stephenson and Dr. Anita Kreide. Your continued encouragement has made me see that my dissertation is only the starting point of what is to come for me.

A heartfelt thank you to Dr. Karie Huchting for helping me find the path in my study. Your patience, continued support, and belief in my research has helped me recognize my potential for the future.

Thank you to to all the individuals who supported me in the dissertation work: Dr. Jill Bickett, Michaela Cooper, Diana Hernandez, Dr. Frances Kellar, Kathleen Mautner, and Dr. Lacey Westphal.

Thank you to all the incredible women that have supported my journey in education: Claire Hackett, Judith de Nuño, Dr. Carolyn Viviano, Ena LaVan, Dr. Candace Poindexter, Jocelyn Castro, Meghan Van Pelt, Sheena Velasquez, Jenni MacLean, and Cassia Sonderleiter.

Last, but definitely not least, thank you to my kids who have changed my heart and perspective on the world: Franklin, Martha, and Natalie.

DEDICATION

I dedicate this work to my family, whose words have propelled me beyond worlds I could ever have imagined for myself.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS .... **iii**
DEDICATION .... **iv**
LIST OF TABLES .... **ix**
LIST OF FIGURES .... **x**
ABSTRACT .... **xi**

CHAPTER 1: BACKGROUND OF THE STUDY **1**
Introduction 1
Goals of Science Education 1
Reform 2
Next Generation Science Standards 3
Access for All 6
Problem Background 7
Statement of the Problem 7
Purpose of the Study 9
Research Questions 9
Hypotheses 9
Significance of the Study 10
Conceptual Framework 10
Three-Dimensional Learning 11
Constructivism 11
Self-Efficacy 14
Research Design and Methodology 15
Procedure 15
Identification of Groups 16
Participants 16
Measures 16
STEM attitudes 17
STEM career interest 17
Analytical Plan 17
Limitations and Delimitations 18
Limitations 18
Delimitations 19
Assumptions 19
Definitions of Terms and Acronyms 20
Organization of Dissertation 21

CHAPTER 2: REVIEW OF THE LITERATURE **22**
Introduction 22
Goals and Reforms of Science Education 22
Goals for Science Education 22
Scientific Knowledge 22
Application of Scientific Methods 23
Responsible Decision Making for Society. 23

Development of Personal Understanding 24
Increase Career Awareness 24
Reform 24
National Defense Education Act (1958). 26
Nation at Risk (1983) 26
Project 2061(1985) 27
Educate America Act, Goals 2000 (1994). 27
No Child Left Behind (1983) 27
Every Student Succeeds Act (2015) 28
Current State of Science Education 29
Changing World, Changing Standards 29
Diversity in Science Education 29
Lagging Achievement of U.S. Students 29
Leaky K-12 STEM Pipeline 31
Next Generation Science Standards (NGSS) 32
Access for All 32
Step 1: Get the Science Right 34
Step 2: State Developed 34
Framework for K-12 Science Education 35
Conceptual Shifts of the Next Generation Science Standards 36
Shift 1: Interconnected Nature of Science 38
Shift 2: NGSS Are Performance Expectations—NOT Curriculum 39
Shift 3: NGSS Build Coherently from K-12 40
Shift 4: Focus on Deeper Understanding and Application of Content 40
Shift 5: Science and Engineering Are Integrated through K-12 42
Shift 6: Prepare Students for College, Career and Citizenship 42
Shift 7: NGSS and Common Core State Standards Are Aligned 43
Three-Dimensional Learning 44
Science and Engineering Practices. 47
Crosscutting Concepts 48
Disciplinary Core Ideas 48
Recommended Learning Cycle for NGSS 49
Traditional Versus Next Generation Science Standards Classrooms 52
STEM Interest 54
Scientific Identity 54
Individual Sense of Self (Self-Efficacy) 55
Recognition of Self and by Others 56
Underrepresented Populations in Science 58
Ethnicity and Culture 59
Gender 61
Summary 62

CHAPTER 3: METHODOLOGY 63
Research Questions 63
Method 64

Context ... 64
Procedures ... 64
Determination of Groups ... 65
Recruitment of Teachers ... 65
Lesson Plans ... 66
Expert Group ... 67
Student Participants ... 71
Measures ... 72
Student Attitudes Toward STEM Survey ... 72
Math Attitudes ... 74
Science Attitudes ... 75
Engineering and Technology Attitudes ... 75
Attitudes toward Learning Skills ... 76
STEM Career Interest ... 77
Data Collection ... 78
Analytical Plan ... 80
Descriptive Statistics ... 81
Correlations ... 81
Debrief ... 82
Summary ... 83

CHAPTER 4: FINDINGS ... 84
Study Background ... 84
Results ... 87
Research Question 1 Analysis ... 97
Research Question 1 Conclusion. ... 99
Research Question 2 and 3 Analysis ... 99
Survey Results ... 100
Research Question 2 and 3 Conclusion ... 101
Conclusion ... 101

CHAPTER 5: DISCUSSION ... 102
Introduction ... 102
Discussion of Findings ... 103
Finding 1 ... 103
Finding 2 ... 105
Transition Time ... 105
Measurement Error. ... 106
Definitions of Variables ... 107
Lesson Plan Alignment ... 108
Finding 3 ... 109
Limitations ... 110
Future Research ... 110
Implications ... 112
Theoretical Implications ... 112
Implications for Practice ... 113

Policy Implications 115
Recommendations 115
District and School Level 116
State and Higher Education Level 118
Conclusion 119

APPENDIX A 120
APPENDIX B 121
APPENDIX C 124
REFERENCES 135

LIST OF TABLES

Table Page

1. Intent and Impact of Political Events that Occurred from 1950 to Present 25

2. Trends in International Mathematics and Science Study (TIMSS) Average Eighth Grade Science Results Over Time 30

3. Educational Shifts Based on NGSS and their Implications for Science Teacher Education (Bybee, 2014) 37

4. The Three Dimensions of the Framework 46

5. Summary of the BSCS 5E Instructional Model 51

6. Student Narratives and the Vision for NGSS K-12 Education 60

7. Charter Network Demographic Data 71

8. Respondant Demographics (N= 580) 72

9. S-STEM Reliability 74

10. Lesson Plan Evaluations Based on EQuIP Rubric to Determine Comparison Groups ... 86

11. Percentage Responses, Mean, and Standard Deviation for Math Attitudes (N= 580) 88

12. Percentage Responses, Mean, and Standard Deviation for Science Attitudes (N= 580) 89

13. Percentage Responses, Means, and Standard Deviations for Students Attitude Towards Engineering and Technology (N= 580) 91

14. Percentage Responses, Mean, and Standard Deviation for Attitudes Towards Learning Skills (N= 580) 93

15. Percentage Responses, Mean, and Standard Deviation for Career Interests (N=580) 94

16. Mean Scores and Standard Deviation for Each Composite Variable Measuring Self-efficacy in STEM 96

17. Correlation between Four Variables of STEM Attitudes and Your Future in STEM Careers (N= 580) 98

18. Independent t-Test Results Comparing NGSS-Aligned and Non-NGSS-Aligned Student Groups 100

LIST OF FIGURES

Figure Page

1. Three dimensions of NGSS: Science and Engineering Practices, Crosscutting, Concepts and Disciplinary Core Ideas 5

2. Conceptual framework illustrating the need for three dimensions as the pillars to an NGSS-aligned classroom 12

3. Proposed workflow 65

4. EQuIP rubric phases to determine lesson alignment to NGSS 69

ABSTRACT

Self-Efficacy and STEM Career Interest in Black and Latino Middle School Students:
A Study on the Next Generation Science Standards

By

Whitney McCormick

With only 11% of the current Science, Technology, Engineering, and Math (STEM) workforce being Black and Latino men and women, there is a crisis of underrepresented individuals in STEM fields. The construction of the Next Generation Science Standards (NGSS), and the mantra "all standards, all students," represents an attempt to increase access to science for more students, and increase their self-efficacy about STEM subjects, as low self-efficacy is cited as one of the main causes of disinterest in STEM subjects. This study examined the relationship between students' self-efficacy in STEM fields and their career interests, specifically in a population of Black and Latino youth. The study further analyzed self-efficacy and STEM interest between two groups of middle school students, those engaged with the Next Generation Science Standards (NGSS) and those with traditional instruction. The Student Attitudes Towards STEM survey was distributed to 580 students to collect quantitative data on student self-efficacy in STEM and their attitudes towards varied STEM careers. Statistical analysis (correlation) determined a significant ($p < 0.01$) moderate correlation between students' self-efficacy and STEM career interest. Statistical analysis (independent samples t-test) also determined there was no statistical difference between the two student groups. This study offers insights into the implementation of the standards, suggestions for future research around science programs in schools, and a call to action for all schools to offer science courses to all students from kindergarten to 12th grade to increase interest in STEM fields for future careers and life outside the classroom.

CHAPTER 1

BACKGROUND OF THE STUDY

Introduction

Since the launch of Sputnik in 1957, the United States has placed greater emphasis on educational reform to prepare students to be leading scientists. Although this single scientific event, through multiple decades and Presidents, was the catalyst to scientific reform, U.S. students are still not becoming the leading scientists in the world. The lack of engagement in the science classroom is a major contributing factor to the low percentage of scientists emerging from the United States. Archer et al. (2010) found "that the majority of young children have positive attitudes towards science at age ten but that this interest then declines sharply and by age 14, their attitude and interest in the study of science has been largely formed" (p. 617). Fewer middle school students are interested in science and, therefore, do not choose to go on to study advanced science in high school, college, and beyond. In 2006 alone, "the United States graduated 70,000 engineers, but China graduated 300,000 and India, 150,000" (Pantic, 2007, p. 25). Besides the lack of interest, students of color and girls are not receiving the quality education and opportunity to become successful scientists and sustain their interest in STEM careers during middle school (Beasley & Fischer, 2012; Brickhouse & Potter, 2001; Licona, 2013).

Goals of Science Education

There are five categories of goals for science education: scientific knowledge, application of scientific methods, responsible decision-making for society, development of personal understanding, and career awareness (Bybee & Pruitt, 2017). These goals became common practice in the early 1800s and have stayed the same; however, their prioritization has changed based on the social, economic, and world conditions throughout the decades. Scientific knowledge and application of methods, goals one and two, aim for students to learn how to question the natural systems around them and understand how different fields of science are interconnected to each other (Bybee & Pruitt, 2017). The decision-making for society goal aims for students to interact with "grand challenges such as climate change, resource use, environmental quality, emerging and reemerging infectious diseases and a variety of natural hazards" (Bybee & Pruitt, 2017, p. 74), all of which have political, ethical, and societal implications. The personal goal asks for students to understand themselves and the decisions they make for healthier lives and communities. Finally, students should be aware of their options for working in Science, Technology, Engineering, and Math (STEM) fields; therefore, a career focus was added. At the heart of science reform are the five goals of science education.

Reform

Post Sputnik, there have been six major educational reforms that have impacted science education and brought to light a specific population of citizens. First, the *National Defense Education Act* (1958) determined that the United States was behind in science, and the focus was placed on elevating the importance of scientists' roles and the number of people going into science careers (Jolly, 2009). The target population, however, was primarily White men. The next reform, *Nation at Risk* (1983), called for tougher math and science courses, which would increase the number of graduates entering STEM fields (Rodriguez, 2015). The third reform, the *Educate America Act* (1994), promised to eliminate the gap between White students and students of color, increasing the United States' international testing scores to the number one position (Rodriguez, 2015). The fourth reform, the 1985 *Project 2061*, Science for all Americans, determined that science should not be limited to White males, and in fact science should be offered and encouraged for all (Riechard, 1994). Fifth, *No Child Left Behind* (NCLB) in 2001 implemented high-stakes testing with the intention of increasing math and English scores; however, science instruction was not encouraged (Judson, 2012). Finally, the *Every Student Succeeds Act* (ESSA) of 2015 highlighted that underrepresented populations need access to high quality instruction (U.S. Department of Education, 2015).

Each reform has placed an emphasis on a different goal in science education. The Next Generation Science Standards (NGSS) link the goals of science education with those of reform efforts aimed to increase access to science (NGSS Lead States, 2013a). Through this connection, the NGSS provide not only standards but also a framework for science instruction that develops students' abilities to thrive in an ever-changing world.

Next Generation Science Standards

The Next Generation Science Standards, which will also be referred to as the standards or performance expectations, were adopted by the state of California in 2013. The standards focus on preparing "all students to learn academically rigorous science, become college and career ready, and take part in the global community" (Januszyk, Miller, & Lee, 2016, p. 47). This change gives an opportunity for all students to be scientists and interact with the natural systems on a daily basis and with their community. The standards were written by a group of educators, content experts, and policymakers from 26 lead states, who used the National Research Council's (NRC) *The Framework for K-12 Science Education,* as a guide to promote equity and access, and three-dimensional learning (NGSS Lead States, 2013a). The new standards promised a more engaging curriculum for all students. The NGSS "Diversity and Equity Team takes the stance that the standards must be made accessible to all students, especially those who have traditionally been underserved in science classrooms" (Lee, Miller, & Januszyk, 2014, p. 224).

Hence, the principle phrase behind the NGSS is “all standards, all students” (NGSS Lead States, 2013a). For the first time in science education reform, diversity, equity, and access were placed at the forefront during the inception of the standards, which were written to engage all students in science to understand their own lives and become global science citizens.

To engage all students in active participation with science, the standards are structured with the three dimensions of learning, identified as science and engineering practices, disciplinary core ideas, and crosscutting concepts. The dimensions emphasize that science is not just a body of knowledge; rather, it includes a set of practices to help establish and deepen understanding of the world (National Research Council [NRC], 2012). The first dimension is science and engineering practices, which include skills that scientists employ to investigate the world. Students are expected to use these practices during class to learn that science is not just about inquiry hands-on learning, but it also involves cognitive and communication skills.

The second dimension is crosscutting concepts, encouraging students to use scientific ways of thinking across all domains of science. These concepts “help provide students with an organization framework for connecting knowledge from the various disciplines into a coherent and scientifically based view of the world” (NRC, 2012, p. 83). Often, science in traditional classrooms is taught independent of other disciplines, which makes connecting science class content difficult for students. Crosscutting concepts ensure students are making connections between these disciplines to increase their depth of understanding of the world around them (Konicek-Moran & Keeley, 2015).

The third dimension is disciplinary core idea. Next Generation Science Standards encourage the interconnectedness of science disciplines, and the core ideas ground the foundation in these disciplines. They are split up into four disciplines: earth and space science, life science, physical science, and engineering, technology, and application of science. Science in the workforce is becoming more interdisciplinary, and the standards have made strides to incorporate this aspect of science early in students' educational careers to increase their understanding across all disciplines and in a deeper way than ever before (Bybee & Pruitt, 2017). Figure 1, entitled "Three Dimensions of NGSS," depicts the importance of the interrelatedness of these three dimensions in an NGSS-aligned classroom. They are intended to be taught together to increase students' use of the practices to access the content with a specific scientific lens.

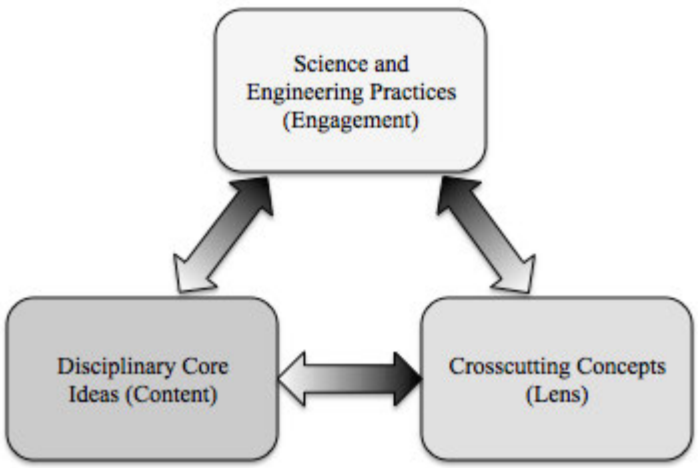

Figure 1. Three dimensions of NGSS: Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas. These dimensions are represented in every performance expectation and must be taught together to ensure increased connectivity between content and application. Adapted from "A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas," by National Research Council, 2012. Copyright 2012 by the National Academies Press.

In Figure 1, content, which is now known as disciplinary core ideas in NGSS, is only one-third of the expectation in science classrooms. Traditionally, teachers felt most comfortable with their content, which took the primary role in the classroom. The standards include the integration of the crosscutting concepts and the science and engineering practices to engage students within the content and increase the scientific lens held by students.

Access for All

In the past, there have been "low learning expectations and biases stereotypical views about the interests and abilities of particular students or demographic groups" (NRC, 2012, p. 279), which have contributed to inequitable learning opportunities decreasing the educational experience of those students. With a new emphasis on multiple ways of learning and connecting concepts, the NGSS increase the engagement of underrepresented groups in science classrooms. Increasing the engagement and encouragement of dialogue between students can increase a student's self-efficacy, which has been supported in the research to also increase their achievement and interest in science (Bandura, Barbaranelli, Caprara, & Pastorelli, 2001; Fong & Krause, 2014).

To move towards the guiding principle of "all standards, all students," the classroom is now a place of discovery for students to ask questions, to research phenomena, and to talk about real issues happening in their community. The NGSS allow teachers the freedom to keep the curriculum fluid and changing based on the student's needs and interests (Ladson-Billings, 2016). The focus shifts to making science more personal, connecting content through learning progressions and engaging in practices that scientists use in the field. The standards highlight that science is the nexus of English, math, and history. The NGSS create an opportunity to engage students with a self-actualizing and socially-reconstructed curriculum focused on not only learning the science behind their inquiries, but also developing their responsibility to the earth and community as well as social inequities that occur around them (Ladson-Billings, 2016). The conceptual shifts in the standards move away from memorization and isolation of facts and figures and toward science skills that build connections between the different fields of science, engaging more students in problem solving.

Problem Background

Science education is important for multiple reasons. First, science knowledge increases understanding of everyday occurrences and improves everyday ways of life. Second, science education can be a pathway to STEM careers. Science education is doing a disservice by not educating students to understand their world, whether or not they are interested in excelling in a STEM career. The NGSS Lead States (2013b) articulated that "fewer than one in three college graduates can perform tasks such as interpreting a data table about blood pressure and physical activity" (para 6). Students deserve to understand their health and make informed decisions. Science does not just reach the medical field, it also impacts the political climate. In 2016, California had one of the longest ballots in the country, including 17 propositions, 10 of which included scientific principles ranging from plastic bag and condom usage to the legalization of marijuana (Secretary of State California General Election, 2016). Without having access to engaging inclusive science education, allowing for dialogue about important issues impacting the community and the world, students will not be prepared to make these decisions.

Finally, the NGSS create an opportunity to engage all students in science, embracing and connecting with students of all backgrounds and bringing their voices to the table. For the first time, the science standards address diversity and equity, and it is crucial that students have access to this quality science education to increase their interest in STEM careers, to impact their decisions in society, and to lead a healthier life.

Statement of the Problem

Underrepresented populations, people of color, and women have not had access to quality inclusive science instruction to achieve the goals of science education: increasing scientific knowledge, application of scientific methods, responsible decision making for society, increasing personal development, and awareness of STEM careers (Banks et al., 2007). Students in underserved communities are less likely to have access to highly qualified teachers, quality curriculum, and appropriate funding to have an inclusive interactive experience with science (Darling-Hammond, 2004). Beyond institutional discrimination through access to resources and course offerings, stereotyping and stereotype threat greatly impact students' decisions to go into STEM fields (Beasley & Fischer, 2012). In 2015, there were 8.6 million STEM jobs in the United States, with 45% in computer technology and 19% in engineering (Fayer, Lacey, & Watson, 2017), yet only 11% of the total STEM workforce is Black and Latino men and women (National Science Foundation [NSF], 2017).

Jackson and Rich (2014) found that "the historical descriptions of scientists gathered by Mead and Metraux (1957) and Chambers (1983) reveal that the perceived image of how scientists look and what a scientist does has remained reasonably constant for decades" (p. 78). High school students of all backgrounds drew a scientist essentially the same way: White, male, lab coat, glasses, and bubbly liquids. This single image does not represent most of the population, and it does not represent a scientist's job. This image results in lower self-efficacy in minority students and girls as they see themselves as not a fit for a science career (Archer et al., 2010). The leaky STEM pipeline partially occurs because of this stereotypical single image of a scientist (Beasley & Fischer, 2012). Stereotype threat also has a significant impact on whether or not students persist in STEM fields. The anxiety that students have that their behavior will confirm a negative stereotype placed on their group is high and can have serious implications for their own self-efficacy (Beasley & Fischer, 2012).

Purpose of the Study

The purpose of this study was to examine the correlation between middle school students' self-efficacy in STEM and their interest in STEM careers. It also examined how students' self-efficacy in STEM in NGSS-aligned classrooms differed from those in traditional classrooms that have not adopted the conceptual shifts outlined by the NGSS. Due to the disproportionality of underrepresented groups in STEM fields, the study focused on Black and Latino subgroups of students to gain an understanding of their self-efficacy.

Research Questions

This study was limited to Black and Latino youth in underserved communities as they are illustrative of the underrepresented populations in STEM fields. To better understand their levels of self-efficacy in STEM and their interests in STEM fields, the following research questions guided the study:

1. What is the relationship between students' self-efficacy in STEM and career interest in STEM fields?
2. How does student interest in STEM careers differ between students who engage with NGSS instruction and students who engage with traditional instruction?
3. How does students' self-efficacy in STEM differ between students who engage with NGSS instruction and students who engage with traditional instruction?

Hypotheses

1. Students who have a greater self-efficacy in STEM will also have a higher interest in STEM careers.
2. Students engaged in NGSS-aligned classrooms will have a higher interest in STEM careers than those who do not participate in an NGSS-aligned classroom.

3. Students engaged in NGSS-aligned classrooms will have a higher self-efficacy in STEM than those who do not participate in an NGSS-aligned classroom.

Significance of the Study

This study first and foremost gave a voice to students who were underrepresented in STEM fields. Although quantitative in nature, this study gave a voice to students through the large number of responses to the survey. All districts in California are beginning their transition to NGSS; however, most literature is focused on teacher feedback and not rooted within the views of the students. With only 11% of the STEM workforce composed of Black and Latino individuals, the NGSS implementation might be the key to increasing passion for science and interest in STEM careers (NSF, 2017). The exposure to a science education that is connected to their community and world, which fulfills the goals of science education, could influence their self-efficacy in STEM.

It is important that "we are preparing students for a world we have yet to experience [and] that world is not for the few or the privileged—it is for all" (Bybee & Pruitt, 2017, p. 368). The NGSS offer the disruption needed to change the equilibrium in science education and make sure that every student has the opportunity to learn and change the world around them. Hearing from the students is a powerful way to collect their interests in STEM field and determine how to encourage more attributes of STEM in the classroom.

Conceptual Framework

The foundation of NGSS throughout K-12 science education is the integration of the three dimensions of learning: (a) science and engineering practices (SEP); (b) crosscutting concepts (CCC); and (c) disciplinary core ideas (DCI). These three dimensions of learning serve as pillars supporting a NGSS-aligned classroom, as seen in Figure 2. As students progress through their K-12 educational experiences, their understanding and application of the three dimensions progress to prepare them for college, career, and citizenship. These learning progressions are intended to increase the construction of knowledge at the appropriate grade level, increase the attainability of the standard, and amplify the feeling of accomplishment by the learner.

Three-Dimensional Learning

The three dimensions of learning (science and engineering practices (SEP), crosscutting concepts (CCC), and disciplinary core ideas (DCI)), are the foundation to any NGSS-aligned classroom. All three dimensions are woven into every performance expectation from kindergarten to 12th grade, and every year, students increase their knowledge and application of science leading to mastery. The SEP are the skills that are necessary to access the content and represent what scientists do in the field. The CCC are the themes or lenses with which scientists approach the world. These lenses reach across disciplines and encourage students to make connections between domains. Finally, DCI are the science-specific content for each course. To create a stable foundation for learning, all three of the pillars need to be taught together.

Constructivism

The standards move away from a more behaviorist method to a constructivist approach, using inquiry learning to increase students' understanding and reconceptualization of the world around them starting in kindergarten (Crowther, 2017). In Figure 2, constructivism continues throughout the K-12 educational system to build deeper understanding of concepts .

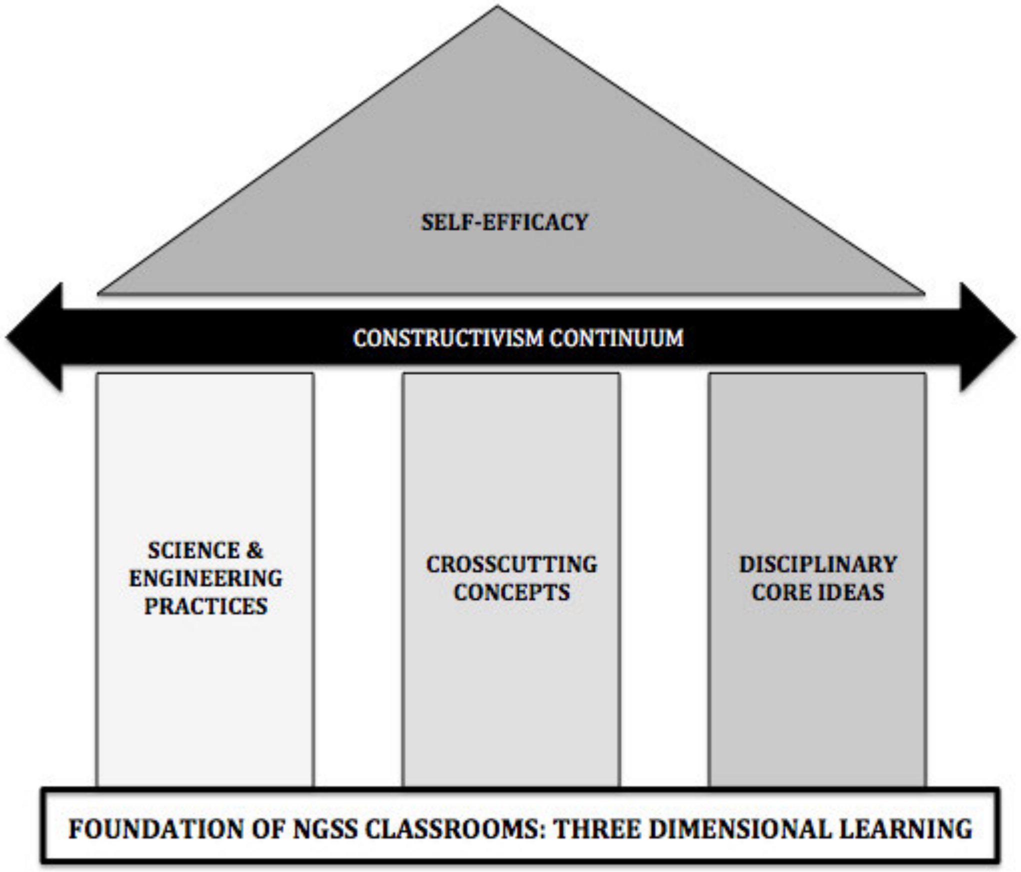

Figure 2. Conceptual framework illustrating the need for three dimensions as the pillars to an NGSS-aligned classroom.

Constructivism suggests “knowledge as temporary and non-objective, internally constructed, and socially and culturally mediated” (Fosnot, 1993, p. 69). Learning from this perspective means that students must negotiate conflicts between their current conceptions of the world and the new insights they hear about from others or experience in the classroom (Bybee & Pruitt, 2017; Fosnot, 1993, Konicek-Moran & Keeley, 2015). Students then create new “representations and models of reality as a human meaning-making venture, and further negotiat[e] such meaning through socially cooperative activity, discourse, and debate” (Fosnot, 1993, p. 69). Students co-construct meaning in an active process facilitated by the teacher rather than passively experiencing factual knowledge presented by the teacher (Juvova, Chudy, Neumeister, Plischke, & Kvintova, 2015; Wright & Greiner, 2009).

As Ash (2004) discussed,

> Vygotsky (1978) emphasized the inherently social nature of learning through his construct of the zone of proximal development (ZPD) which can be described as the zone in which an individual is able to achieve more with assistance than he or she can manage alone. (p. 858)

It is through this collaborative spirit that scientific dialogue increased understanding over time and works hand in hand with the doing of science (Ash, 2003). This active learning increases the students' ability to challenge their own preconceptions of a phenomenon and seek answers with others (Konicek-Moran & Keeley, 2015); therefore, constructivism "represents a multiplicity of ways to think" (Kroll, 2004, p. 200).

The theoretical perspective of constructivism is challenging because there are several different constructivist identities that lie on a continuum. This continuum has the extremes of individual constructivism and social constructivism, and these "constructivist perspectives [act as the] foreground and background for one another" (Kroll, 2004, p. 200). In science classrooms utilizing NGSS, students initially may struggle through a task on their own in order to construct an understanding of the phenomenon. Then, to increase depth of understanding or to challenge current conceptions, students may be placed in groups to discuss the phenomenon. Through dialogue, students have the opportunity to explore any preconceptions they may have. Preconceptions based on students' everyday lives are not unusual. However, "instruction in any subject matter that does not explicitly address students' everyday conceptions typically fails to help them refine or replace these conceptions with others that are scientifically more accurate"

(Donovan & Bransford, 2005, p. 400). Students need the space in classrooms to individually challenge their own thinking about science and then to discuss scientific concepts and phenomena with others (Konicek-Moran & Keeley, 2015).

Self-Efficacy

Self-efficacy is the belief that one can “successfully execute the behavior required to produce the outcomes” (Bandura, 1977, p. 193). Self-efficacy theory came from expectancy theory, which defines expectancy as figuring out the right behavior to lead to an outcome. After individuals’ figure out the correct behavior to reach the outcome, the individuals’ analyze their belief in their ability to accomplish that behavior successfully (Bandura, 1977). Self-efficacy theory identifies four sources of information important to people’s confidence in their abilities: (a) mastery experience; (b) verbal persuasion; (c) vicarious feedback; and (d) physiological feedback (Sanders & Sanders, 2006). These four sources of information can increase a student’s self-efficacy throughout their K-12 science education, as seen in Figure 2.

Mastery experience is more heavily weighted in that if the outcome of the task is positive, there will be an increase in self-efficacy. Verbal persuasion and vicarious feedback are both social aspects of the construction of an individual’s efficacy. If the individuals’ have role models who are accomplishing tasks similar to them and has also been encouraged by others to work through the task, their self-efficacy could increase. An individual's own physiological responses also factor into self-efficacy. For example, if there is anxiety associated with a particular behavior to accomplish a task, that can contribute to lower self-efficacy. In a classroom, “students of high efficacy attribute failure to insufficient effort, whereas those of low efficacy ascribe it to deficient ability” (Zimmerman, 1995, p. 214). The NGSS are specifically written to engage every student in learning science, but self-efficacy is key to success because students need to have the belief that they can learn science.

The integration of the three dimensions in the classroom gives students the opportunity to develop knowledge along the constructivism continuum and increase their own self-efficacy. Through the internal struggle between preconceptions and new knowledge and continual work with others, students can begin to see success in their learning.

Research Design and Methodology

This study was a quasi-experimental quantitative study to evaluate the relationship between students' self-efficacy in STEM and their interest in STEM careers. The study also compared NGSS and non-NGSS classrooms to see if there was a significant difference between students' self-efficacy in STEM as well as their career interest. A quantitative approach was used to gather data from a large population and gain insight into many students' self-efficacy and interest. The setting of this study was at multiple schools within one large charter network in California, located in an urban center.

Procedure

All teachers within the network were asked to submit five lesson plans to participate in the study. Eight teachers chose to participate. The lesson plans came from any of their units but demonstrated their typical teaching cycle. The lesson plans were evaluated by a committee of NGSS experts using the Educators Evaluating the Quality of Instructional Products (EQuIP) rubric (Achieve, 2016). Three experts were selected based on years of experience with the standards. Based on the evaluation of the lesson plans, two groups, NGSS-aligned and non-NGSS-aligned, were identified. Following the identification of groups, parent consents were sent out by the school to allow for student participation in the surveys. Administration of the survey occurred during the students' advisory period to reduce the amount of content time taken for the survey or during the class period if the schools preferred that option. Finally, debrief sessions occurred with the chief academic officer, the principals of the schools participating, and the teachers following the conclusion of the published study.

Identification of Groups

There were two primary data sources used to identify the two student groups: (a) the lesson plan and (b) the EQuIP rubric. The lesson plans submitted by the teachers reflected their common lesson structure. The EQuIP rubric was used by the expert committee to determine alignment to NGSS. This alignment identified the two student groups who participated in the study. For example, there were three teachers at a school site participating, and one of the three was aligned to NGSS, identifying those students into the NGSS group, which is why grouping occurred by teacher rather than school site. The students selected their teacher's name on the survey, but prior to data analysis, teacher names were given a code to eliminate their identity during the analysis portion of the study.

Participants

Middle school students were the focus because research suggests many students start to lose interest in science at the age of ten, and it continues to decrease until age 14 (Archer et al., 2010). This study included 580 students in grades six through eight. Across the network of schools, 98% of students were Latino or African American, 17% were English Language Learners, and 94% were eligible for free or reduced-price lunch.

Measures

The quantitative Student Attitudes Towards STEM Survey (S-STEM), developed by the Friday Institute for Educational Innovation, was administered via Qualtrics on an iPad or computer to all students enrolled in the selected teachers' classes. The survey gathered demographic information and contained five sections measuring attitudes toward STEM and interest in STEM careers. The key variables included math attitudes, science attitudes, engineering and technology attitudes, 21st century learning, and interest in STEM careers. Attitudes were defined as the variables in the measure and were used to measure self-efficacy related to the subject and "expectations for future value gained for success" in that subject (Friday Institute for Educational Innovation, 2012a, p. 1). For this study, self-efficacy was measured using the attitutinal construct variables.

STEM attitudes. There were four main variables to measure the construct of attitudes towards STEM: math attitudes, science attitudes, engineering and technology attitudes, and 21st century learning. For all four variables, students responded on a Likert scale of 1 (*Strongly Disagree*) to 5 (*Strongly Agree*). These items were anticipated to have strong reliability and validity because they had been tested previously by the Friday Institute for Educational Innovation (2012a) with all constructs having a Cronbach alpha above .89.

STEM career interest. The "Your Future" survey section measured student interest in 12 broad categories of STEM career fields. For each item, students responded on a Likert scale of 1 (*Not at all Interested*) to 5 (*Extremely Interested*). In this section, students read a description of subject areas that involved science, technology, engineering, and math.

Analytical Plan

Descriptive statistics were used to report frequencies of demographic information in the study, including grade, gender, and ethnicity. This data validated the population as being underrepresented populations in STEM fields. Mean scores and standard deviation were calculated for each variable: math attitudes, science attitudes, engineering and technology attitudes, and 21st century learning. Mean scores and standard deviations were also used to report the career interests.

To answer the research question—*What is the relationship between students' self-efficacy in STEM and career interest in STEM fields?*—a Pearson correlation was calculated to examine the relationship between students' self-efficacy in STEM and career interest in STEM fields. The Pearson correlation showed there was a positive relationship between the two variables, such that an increase in students' self-efficacy in STEM also showed an increase in career interest in STEM fields.

Next, to answer the research question—*How does student interest in STEM careers differ between students who engage with NGSS instruction and students who engage with traditional instruction?*—an independent samples *t*-test was run between the two groups of students for the STEM career interest variable, showing there was no significant difference between groups.

To answer the research question—*How does students' self-efficacy in STEM differ between students who engage with NGSS instruction and students who engage in traditional instruction?*—an independent samples *t*-test was run between the two groups of students for each variable, showing that there was no significant difference between groups.

Limitations and Delimitations

Limitations

There are seven major limitations in this study. First, the study was quasi-experimental with predetermined groups and causality can only be implied from the results. Second, student interest in STEM careers was a complex variable, and many other factors could have influenced the student's attitudes towards STEM. For example, mentorship, ability, and self-determination are other variables that could have had an influence. Third, there was natural variability among teacher styles, especially as teachers transitioned to new state standards. This variability might not have shown up in the lesson plan, but it might have shown up in the implementation of the plan in the classroom. Fourth, measurement error may have occurred because of lack of clarity around variables and reverse-scored items. Fifth, self-reporting data are a limitation of the survey design. Sixth, I had a dual role as researcher and network-wide science administrator. As a district administrator, I was asked to transition the entire network to the NGSS, which I viewed as a promising standards reform. Due to my role, I also offered professional development to teachers in the early years of the transition from 2013 to 2016, which could have impacted their implementation of lesson plans during this study. Lastly, self-efficacy takes many years to develop and with it still being early in the transition to NGSS, students and teachers need time to develop the pedagogy that comes along with the expectations of the standards.

Delimitations

This study was limited to only one charter network of schools and groups of students were formed based on their teachers' alignment to the NGSS. Therefore, the findings might not be generalizable beyond this particular network of schools. This study was also quantitative in nature, which has its own limitations, especially surrounding data collection with regards to student attitudes.

Assumptions

One assumption was that teacher lesson plans mirrored their classroom instruction; even if timing needed to be changed, the activities and tasks that existed in the lesson plans existed in the classroom. It was also assumed that NGSS-aligned instruction does embed math, engineering, and technology instruction.

Definitions of Terms and Acronyms

NGSS: Next Generation Science Standards

STEM: Science, Technology, Engineering and Mathematics

S-STEM: Student Attitudes Towards STEM survey

Attitudes: Attitudes encompass the "feelings, beliefs, and values about an object" (Lisciandro, Jones, & Geerlings, 2018, p. 16), which in this study were used to measure self-efficacy.

Engagement: Classroom engagement "provides opportunities for students to participate in scientific and engineering practices, engages them in tasks that require social interaction, the use of scientific discourse (that leverages community discourse when possible), and the application of scientific representations and tools" (NRC, 2012, p. 283).

Engineering: Engineering requires the application of "understanding of the natural world and of human behavior to design ways to satisfy human needs and wants" (NRC, 2012, p. 11).

EQuIP rubric: Educators Evaluating the Quality of Instructional Products rubric is used to identify high-quality materials aligned to the NGSS (Achieve, 2017).

Leaky STEM pipeline: The leaky pipeline "refers to the loss of students from STEM fields who are often disproportionally racial or ethnic minorities" (Ball, Huang, Cotton, & Rikard 2017, p. 373)

Phenomenon: "Scientific phenomena are occurrences in the natural or human-made world that cause one to wonder and ask questions" (Spiegel, 2017, para. 1).

Technology: "Any engagement in a systematic practice of design to achieve solutions to particular human problems" (NRC, 2012, p. 11).

Three-dimensional learning: Three-dimensional learning is the vision of NGSS in which "students, over multiple years of school, actively engage in scientific and engineering practices and apply crosscutting concepts to deepen their understanding of the core ideas in these [science and engineering] fields" (NRC, 2012, p. 10).

Traditional instruction: "Students put all of their focus on the teacher. The teacher talks, while the students exclusively listen" ("Which is best", 2016, p. 1).

Self-efficacy: Self-efficacy is the belief that one can "successfully execute the behavior required to produce the outcomes" (Bandura, 1977, p. 193).

*Underrepresented: "*Women and three racial and ethnic groups—Blacks, Hispanics, and American Indians or Alaska Natives—are marginalized in Science and Engineering" (NSF, 2017).

Organization of Dissertation

Chapter 1 identifies the problem with science education and discussed the significance of the study focusing on students' self-efficacy in STEM and their interests in STEM careers. Chapter 2 outlines the essential literature discussing previous science reform, the current state of STEM education, and the intent of the NGSS. Chapter 3 discusses the methodology and the research design. Chapter 4 provides an in-depth analysis of the findings from the study. Finally, Chapter 5 includes a summary of the problem and the study's significance with suggestions for change in the implementation of the NGSS in the classroom and future research.

CHAPTER 2

REVIEW OF THE LITERATURE

Introduction

The purpose of this study was twofold: to examine the correlation between students' self-efficacy in STEM and their interest in STEM careers, as well as to examine how students who engage in NGSS-aligned classrooms differ from those in traditional classrooms that have not adopted the conceptual shifts outlined by the NGSS. The review of the literature contextualizes the importance of STEM education for all students and lends insight into the need for this research. First, this chapter reviews the history of educational reform that has impacted science education through a policy review. Second, this chapter provides an overview of the inadequacies that are present in current science education. Next, this chapter gives a detailed overview of the development of the NGSS, the intention behind the standards, and what NGSS implementation looks like in a classroom compared to traditional instruction. Lastly, this chapter focuses on the need for this research to increase STEM interest, especially for populations who have lacked access to quality science education.

Goals and Reforms of Science Education

Goals for Science Education

The goals of science education, which became common practice in the early 1800s, have remained the same although their emphasis has changed based on the social, economic, and world conditions throughout the decades.

Scientific knowledge. The first goal of science, which has been established for over 200 years, is the fundamental understanding of the natural world (Bybee & Pruitt, 2017). This fundamental understanding comes from students using facts and conceptual schemes to develop an interconnectedness of knowledge. In the standards, fundamental science knowledge is known as the disciplinary core ideas.

Application of scientific methods. The second goal of science education is for students to use the methods and practices of scientific inquiry to gain a deeper understanding of the world. Application of scientific methods is highlighted in the NGSS as the science and engineering practices, linking scientific knowledge from the disciplinary core ideas to the crosscutting concepts (Bybee & Pruitt, 2017). This goal has changed over time from using "the scientific method" to "a scientific method," opening the boundaries of inquiry for all students (Konicek-Moran & Keeley, 2015, p. 41). This change is crucial to understanding NGSS because there are no fixed steps to follow, and students need to engage in their own discovery to construct meaning of concepts through multiple scientific methods. One problem that still exists with solely focusing on only knowledge and skills is the irrelevancy to students' future careers or everyday life (Aikenhead, 2006; Brickhouse, Lowry, & Schultz, 2000; Calabrese Barton, Tan, & Rivet, 2008; Carlone, Huan-Frank, & Webb, 2011).

Responsible decision making for society. The third goal of science education promotes the connection to students' lives with a focus on the relevance of science in society. This goal aims for students to interact with "grand challenges such as climate change, resource use, environmental quality, emerging and reemerging infectious diseases, and a variety of natural hazards" (Bybee & Pruitt, 2017, p. 74), all of which have political, ethical, and societal implications to make informed decisions. There has been research on teachers using communities as the basis of their curriculum to increase engagement with students and to show the real-life connection of science in the community to become STEM literate and shape developments in society (Archer, DeWitt, & Osborne, 2015; Ladson-Billings, 1995).

Development of personal understanding. The personal goal requires students to understand themselves and the decisions they make for a healthier life and community. To address students on a personal level, science instruction needs to "change pedagogy so that it includes the experiences, worldviews, learning styles, funds of knowledge, and/or interests of students from diverse backgrounds" (Carlone et al., 2011, p. 479). To personally develop and make scientific decisions outside of school, students must see how their worlds combine and connect. Instead of science being merely a class they take, they must see science as a way of thinking about and affecting their world (Archer et al., 2010; Barman, 1997; Christensen, Knezek, & Tyler-Wood, 2015; Hughes, 2001).

Increase career awareness. Finally, the career goal has been emphasized and deemphasized at different times of history, but ultimately students should be aware of their options for working in the STEM field. It is essential that students engage in the previous four goals in order to be prepared for the 21st century workforce (Bybee & Pruitt, 2017). At the heart of science reform are these five goals of science education.

Reform

Six different political acts, outlined in Table 1, have stirred controversy in science education and reform since the launch of Sputnik in 1957. Each reform had a different agenda of what was expected in the science classroom; however, the general theme was the same: create science-literate citizens who were productive in our society and the world economy.

Table 1

Intent and Impact of Political Events that Occurred from 1950 to Present

Year	Event	Intent	Impact
1958	*National Defense Education Act* (NDEA)	Develop curriculum based on the conceptually fundamental ideas and the modes of scientific inquiry and mathematical problem solving (NRC, 2012)	"Overall, NDEA impacted the educational landscape with 'general upward trends' with more rigorous science and mathematics courses along with greater opportunity to explore STEM careers" (Jolly, 2009, p. 52).
	Summary: A rigorous curriculum did increase the interest in STEM careers to address national security.		
1983	*Nation at Risk* Report	Reagan "commissioned *Nation At Risk (1983)* Report, which demanded more and tougher math and science courses if the US economy was to survive the takeover of foreign economies" (Rodriguez, 2015, p. 1032).	"Support for high standards was embraced with some enthusiasm as states worked to raise academic bars and increase graduation requirements, and in the 1990s many professional organizations, often with federal support, got involved in developing standards. But progress also stalled with objections to federal involvement in setting standards, a perceived violation of the traditional state and local control of education" (Birman, 2013, p. 5).
	Summary: Although federal funding contributed to an increase in math and science curriculum, should the federal government be determining what is taught in schools?		
1985	*Project 2061: Science for all Americans*	"Science education reform cannot be legislated from the top; reform takes much collaboration among many constituencies; science cannot be isolated or fragmented by structure of the discipline's, subject matter, or grade level; and, there must be a central, equitable and universally beneficial outcome toward which the national effort is directed" (Riechard, 1994, p. 135).	"Project 2061 has brought into the mainstream of education discourse some core ideas about science education reform: that science is a subject to be learned by all students; that science programs must be coherent, not just a collection of random facts and activities; and that the natural and social sciences, mathematics and technology are interrelated" (American Association for the Advancement of Science, 2013)
	Summary: *Project 2061* (1985) is still alive within the NGSS, focusing on science application to real life and science for all.		
1994	*Educate America Act*	This act "promised to eliminate the achievement gap between Anglo and culturally diverse students and to raise US student's achievement to the number one spot on international testing by the year 2000" (Rodriguez, 2015, p. 1032).	"The nation has not met any of the eight educational goals for the year 2000 set a decade ago by President Bush and the governors of all 50 states, although measurable progress has been made toward the goals pertaining to preschoolers and student achievement in math and reading" (Homeschool Legal Defense Association, 2002, p. 1)
	Summary: Although the *Educate America Act* (1994) promised to close the achievement gap, the United States has not met any of the goals.		

Table 1 (continued)

Year	Event	Intent	Impact
2001	*No Child Left Behind Act*	Brought about by George W. Bush, this act focused on the accountability of standards that were implemented from the Clinton administration through Annual Yearly Progress, AYP. (Judson, 2012).	"The act resulted in a narrowed curriculum with "an over concentration on the content areas of mathematics and reading and the diminished focus on other subjects, such as science and social studies" (Judson, 2012, p. 2) "Science is only required to be tested once in elementary schools [... and therefore] teachers are instructed not to teach science until grade 4 or 5 (when it is usually tested)" (Rodriguez, 2015, p. 1032).
2015	*Every Student Succeeds Act* (ESSA)	"Requires—for the first time—that all students in America be taught to high academic standards that will prepare them to succeed in college and careers" (U.S. Department of Education, 2015, para. 10).	Monitoring and implementation are happening in 2017-2018 school year (U.S. Department of Education, 2015)
	Summary: *ESSA* (2015) intended to increase access to the rigorous standards to ensure all students are prepared for college and careers. Schools transitioned during the 2016-2017 school year, and implementation monitoring was in place in the 2017-2018 school year.		

***National Defense Education Act* (1958).** Following the launch of Sputnik, the United States placed an emphasis on rigorous science and mathematics instruction in classrooms to increase STEM interest. The national security of the United States had been threatened, and in order to regain power in the world and in the space race, the United States needed to increase its recruitment and training of STEM individuals (Jolly, 2009). Up to this point in 1958, science education was focused on memorization of information and terms; but after this reform, science instruction shifted its emphasis to the structures and procedures of science to increase the number of individuals capable of dominating the space race (Bybee & Pruitt, 2017).

***A Nation at Risk* (1983).** After 26 years of rigorous math and science curriculum in classrooms with the passage of NDEA, the National Commission on Excellence in Education (NCEE) published *A Nation at Risk* in 1983. The report stated that the U.S. educational system needed to improve to survive in the global economy (Rodriguez, 2015). The report presented a dismal view of the U.S. educational system and warned "of a generation of scientifically and technologically illiterate Americans, a growing chasm between scientific and technological elites, and citizenry both ill-informed and uninformed in scientific matters" (Bybee & Pruitt, 2017, p. 63). A few years later, Project 2061 was created to increase scientific literacy for all.

***Project 2061* (1985).** Since the early 1800s, the goal of science education was to increase the scientific literacy of citizens, but often this was applied only to certain individuals who were adept at science or who represented a particular social status (Bybee & Pruitt, 2017). In 1985, Project 2061 focused on achieving scientific literacy for all by the year 2061, debunking the Sputnik-era belief that science was a "specialized subject to be taught to special students for some specialized purpose" (Riechard, 1994, p. 136). This belief in increasing scientific literacy is very prominent in today's version of the NGSS.

***Educate America Act, Goals 2000* (1994).** Although Project 2061 intended scientific literacy for all, underrepresented groups were still denied access to quality science education. In 1994, the *Educate America Act* "promised to eliminate the achievement gap between Anglo and culturally diverse students, and to raise US students' achievement to the number one spot on international testing by the year 2000" (Rodriguez, 2015, p. 1032). However, none of the goals were met by the year 2000, and although there was an increase in math scores, there was no significant increase in science scores on international testing.

***No Child Left Behind* (2001).** In 2001, George W. Bush proposed *No Child Left Behind* (NCLB). This reform brought about accountability measures for schools to ensure all students were pursuing rigorous standards. Due to increased pressure on testing, classroom instruction suffered, resulting "in a narrowed curriculum, [meaning] an over concentration on the content areas of mathematics and reading and a diminished focus on other subjects, such as science and social studies" (Judson, 2012, p. 2). *No Child Left Behind* (2001) mandated achievement results in math and English by ensuring all students had access to qualified teachers and appropriate assessments to measure progress (Haag & Megowan, 2015). Therefore, NCLB gave states the responsibility to set standards, support classroom instruction, and ensure qualified teachers could teach toward the progress assessments (Haag & Megowan, 2015). This reform had a caveat:

> It is possible that the need to create standards that can be measured by high-stakes testing, drives states toward producing standards that focus on facts rather than on difficult-to-measure skills such as deep thinking and conceptual understanding of the underlying processes of science and STEM subjects. (Haag & Megowan, 2015, p. 417)

The science standards are the latest standards movement that places emphasis on these “difficult-to-measure skills” and is less focused on assessments. Currently, the California Department of Education is building a platform to test students using the three dimensions of learning. Although this is a difficult task, the California Department of Education supports the attempt of the standards to place emphasis on deep thinking and conceptual understanding rather than straightforward memorization of factual information and the aim to incorporate all three dimensions into state accountability assessments (Boyd & Gregson, 2017).

***Every Student Succeeds Act* (2015).** *The Every Student Succeeds Act* (ESSA) was signed by Barack Obama in 2015 and was a rejuvenated version of *The Elementary and Secondary Education Act* (ESEA), which was signed by Lyndon Johnson in 1965. The new law offers more opportunities for low-income students, supported by rigorous standards, to have access to adequate preparation for college and career. The law provides an accountability measure, but unlike NCLB, assessments are used to track student progress towards the goals of the rigorous standards (U.S. Department Education, 2015). The 2017-2018 school year was the first year in which monitoring of implementation occurred.

Current State of Science Education

Changing World, Changing Standards

To keep up with the ever-changing world, education must change. By the time students in today's high schools move into the workforce, many of the facts they have learned and programs in which they have been involved will be obsolete. To prepare students for a world that they have yet to experience, it is important that students develop creativity, are collaborative, and possess a mindset of change (Quinn, 2015).

Diversity in Science Education

It is the role of science education to prepare students for a world that has yet to be seen, and "this world is not for the few or privileged—it is for all" (Bybee & Pruitt, 2017, p. 368). The more minds and diverse perspectives that are included in the conversation, the more stimulating the solutions become. The "culturally and ethnically diverse elementary school children in our current classrooms are the scientists of the future" (Jackson & Rich, 2014, p. 75). To open up the doors of opportunity, science education must not only excite these students but also actively engage them in the practices of science, engage them in thinking like scientists, and change identity perceptions of who scientists are and what they do (NGSS Lead States, 2013a).

Lagging Achievement of U.S. Students

The Trends in International Mathematics and Science Study (TIMSS) is an assessment given to fourth and eighth graders to compare students' achievement in math and science from various countries. Table 2 shows the TIMSS average results over time from 1995 to 2011.

Table 2

Trends in International Mathematics and Science Study (TIMSS) Average Eighth Grade Science Results Over Time

Year	Number of Nations	U.S. Average Score	International Average	Rank Compared to other Nations
1995	41	513	500	28
1999	38	515	488	18
2003	45	527	473	9
2007	48	520	500	11
2011	56	525	500	10

Note. Adapted from "Trends in International Mathematics and Science Study," by U.S. Department of Education, 2011. Copyright 2011 by the National Center for Education Statistics.

Although the United States has increased the national average of achievement by 12 points from 1995 through 2011, there was no measurable difference between 2007 and 2011 with a gain of only five points. On the 2011 test in California, "White, Asian, and multiracial students' average scores were higher than the TIMSS scale average, while Black and Hispanic students scored lower, on average, than the TIMSS scale average" ("Trends in International Mathematics and Science Study Results," 2011, p. 1). For the majority of students to be successful on the TIMSS assessment, the NGSS needed to address the culturally and ethnically diverse population that is growing larger every year in the United States.

Between "increased global competition, lackluster performance in mathematics and science education, and a lack of national focus on renewing its science and technology infrastructure, [the U.S.] has created a new economic and technological vulnerability as serious as any military or terrorist threat" (Business-Higher Education Forum, 2005, p. 3). This sentiment existed in a previous attempt at reform with *Nation at Risk,* and the decline in science educational outcomes has continued until the present NGSS recommendation for adoption.

Leaky K-12 STEM Pipeline

It is well documented that in the United States there is a leaky K-12 STEM pipeline (Bybee & Pruitt, 2017; Pruitt, 2015). Between 2009 and 2015, 800,000 net STEM jobs were added in United States, with 160,950 of those being in California. With an increase of 10-12.5% projected between 2014 and 2024, there are few individuals that can fill these open STEM positions due to the leaky STEM pipeline (Fayer et al., 2017). With the large number of jobs available, there are not enough college graduates able to meet the demand, and with a lack of prepared workers, the United States has begun to recruit qualified candidates in other countries. In 2017, it was reported that China was graduating 4.7 million STEM professionals; India, 2.6 million; and the United States, 568,000 (McCarthy, 2017). This STEM workforce, which is essential for the economy, can be described in many different ways, but "whether it is researchers, science and mathematics teachers, the aerospace industry, or the construction industry, they all have one thing in common: It is about moving forward, solving problems, learning, and pushing innovation to the next level" (Gerlach, 2012, p. 1). Due to the considerable number of workforce opportunities that need to be filled, the National Research Council investigated factors that contribute to persistence in STEM education throughout high school and into college. One of the key factors they found was exposure to rigorous science throughout K-12 education (Bybee & Pruitt, 2017), which historically did not occur due to emphasis on accountability assessments following *No Child Left Behind* (2001). The new standards are reinvigorating the movement for rigorous science instruction in all grade levels to increase the depth of understanding in science.

Students are not prepared to enter STEM fields, but students in underserved communities have less access to highly qualified teachers, quality curriculum, and access to funds for inquiry learning, which places students of color at a larger disadvantage in science (Beasley & Fischer, 2012; Darling-Hammond, 2004). Adding to the problem is the student tracking system, which can "exacerbate these inequalities by segregating many minority students within the schools, allocating still fewer educational opportunities to them at the classroom level" (Darling-Hammond, 2004, p. 216). There is still a persistent narrative that these "advanced" classes are only for a few students who can handle a demanding course load, which still today does not include students of color. Students in higher-tracked classes are exposed to rigorous active learning opportunities, while students enrolled in lower tracks have access to instruction that focuses on rote memorization, thus preparing them for a different life and career (Darling-Hammond, 2004; Wenglinsky, 2002). Therefore, the STEM pipeline for students of color is not just leaky, but is broken wide open.

Next Generation Science Standards (NGSS)

Access for All

Teaching science for all means teaching science for the diverse populations that schools service. The traditional minority student is now becoming the numerical majority, which means that the students who are in our classrooms today will make a large contribution to science and society (Januszyk et al., 2016; Lee et al., 2014; Wong, 2015). For all students to feel prepared, they must have access to "equitable opportunities to engage with scientific practices and construct meaning in science classrooms" (Lee et al., 2014, p. 225). Conditions need to be changed in science instruction to make NGSS accessible to all students. First, biases and stereotypes against any demographic group or individual should cease. In addition, science instruction should use students' previous knowledge to link their cultures and personal lives with what they study in science classrooms. Finally, there should be ample resources for students to gain access to science knowledge. These resources may include physical lab space with appropriate lab materials or human capital with access to STEM mentors (Lee et al., 2014). The term "student diversity" in the NGSS refers to the four groups identified by NCLB that have often been limited in their access to science courses:

1. economically disadvantaged students;
2. students from major racial and ethnic groups;
3. students with disabilities; and
4. students with limited English proficiency.

Also, the definition of student diversity is extended in the NGSS documents to include other groups that have often been underserved:

1. girls;
2. students in alternative education programs; and
3. gifted and talented students. (Lee et al., 2014, p. 230)

These groups, which historically have been underserved in science, have demonstrated that they can perform well on achievement tests when offered opportunities to engage in quality science instruction that encourages them to use their funds of knowledge and pursue investigations that are linguistically and socioculturally relevant to their lives (Lee, Deaktor, Enders, & Lambert, 2008; Rodriguez, 2015).

The NGSS have led states to adopt the phrase "all standards, all students," affirming that all students have the right to have access to all science courses, as well as access to the content within the classroom. To achieve the goal of "all standards, all students," the National Research

Council (NRC) developed a two-step implementation plan to get the science right and to analyze the standards from a standpoint of assuring diversity and equity.

Step 1: Get the science right. The NRC led the first phase of the implementation plan by partnering with the American Association for the Advancement of Science (AAAS), National Science Teachers Association, and Achieve to develop *A Framework for K-12 Science Education* (Pruitt, 2014). During the initial round, the Diversity and Equity Team conducted reviews of the standards to check for biases and the consistency of language. The team reported there were no instances of negative or positive biases or stereotypes present, but they recommended that there be more "inclusive language, relevance of science to students' lives, and low-cost science supplies in consideration of districts or schools with limited resources" (Lee et al., 2014, p. 227). In order to achieve "all standards, all students," it was important to increase the inclusive language to include more student identities and also to connect to students' lives more often in the document.

Step 2: State developed. During the second phase, Achieve and NRC invited all states to become the lead states in the NGSS development process (Pruitt, 2014). The writing team of 41 writers included stakeholders that NGSS could affect, including "teachers, administrators, higher education faculty, state science supervisors, practicing scientists and engineers, and researchers" (Pruitt, 2014, p. 147). This writing group incorporated more stakeholders than in previous standards and stretched from schools to higher education to industry. To plug the leaky STEM pipeline, it was important to increase the cohesion between all aspects of the scientific community.

In total, 26 lead states participated in the development of the NGSS; hundreds of experts did confidential reviews, and there were two public comment periods to make these standards the most integrated and comprehensive ones in science education (Lee et al., 2014). Public comment periods were crucial for the development to increase awareness of the state of the standards, to increase the stakeholder participation in the development of relevant content, and to increase the coherence of the three dimensions in the vision for science education.

Framework for K-12 Science Education

The *Framework for K-12 Science Education,* which was published in 2012 by the NRC, articulated "the vision for science education in the twenty first century and what students need to know in their K-12 experience to be considered scientifically literate" (Pruitt, 2014, p. 146). The new vision for science education hinged on coherence. The K-12 Framework articulates the connections not only between different sciences but also between math and engineering. It also lays out a spiraled sequence of the three dimensions over the K-12 grade span, which increase in rigor and depth every year (NRC, 2012).

There are six main principles of the framework:

1. the belief that children are born investigators;
2. the focus on core ideas and practices;
3. the belief that understanding develops over time;
4. the understanding that science and engineering require both knowledge and practice;
5. the importance of connecting to students interests and experiences; and
6. the promotion of equity. (NRC, 2012)

The research findings in *Taking Science to School* revealed that children are born investigators who naturally come to school with curiosity about the world (NRC, 2007). The findings also indicated that even at a young age and regardless of background or socioeconomic status, children reason in a very sophisticated way (NRC, 2012). Second, the framework focuses on core ideas and practices that ensure cohesion throughout all 13 years of schooling. Every year, the student is exposed to the same core ideas and practices but in a progressively rigorous way to increase their understanding of the content. Fourth, "science is not just a body of knowledge that reflects current understanding of the world; it is also a set of practices used to establish, extend and refine that knowledge" (NRC, 2012 p. 26). For students to be successful in a STEM field, they must have ample opportunities to combine this knowledge with practice. Fifth, in order to increase students' curiosity and interest in science, which could play a role in their selection of higher science courses or career interest, science instruction must incorporate students' interests and experiences. Finally, promoting equity is at the forefront of the framework. It is important to recognize that different cultural contexts "are assets on which to build—both for the benefit of the student and science itself" (NRC, 2012, p. 28). Increasing the value of what students bring to class is important to solve complex problems.

Conceptual Shifts of the Next Generation Science Standards

Based on the *Framework for K-12 Science Education,* the NGSS, adopted in 2013, were written to be different from the previous 1998 science standards. As seen in Table 3, science education will now contain less of "traditional" science instruction, including memorization, worksheets, and teacher-led activities, and become more progressive science instruction, full of application, real-world tasks, and student-facilitated activities (Quinn, 2015).

Table 3

Educational Shifts Based on NGSS and their Implications for Science Teacher Education

From	To	Implications	Alignment to Conceptual Shift (CS)
Learning facts (e.g., parts of the cell)	Explaining natural phenomena (e.g., how cell structures relate to cell functions)	Students develop models and make sense of natural world by using evidence to develop explanations.	CS 2, CS 4, CS 6
Single dimensions of science (e.g., disciplinary core ideas for physical science)	Interconnections of three dimensions of science (e.g., science and engineering practices, crosscutting concepts, disciplinary core ideas)	Students use the practices to gather data and form explanations using crosscutting concepts and disciplinary core ideas.	CS 1, CS 6
Grade-level content (e.g., middle school life science)	Progression of core ideas and practices across K-12 (e.g., coherent horizontal and vertical development of concepts and practices)	Students learn concepts below and above grade-level.	CS 3, CS, 6
Science as a single discipline (e.g., biology)	Science and engineering (e.g., practice of engineering design incorporated with science)	Students learn and apply the practices of engineering design.	CS 5, CS 6
Science as a body of knowledge (e.g., conceptual structure of a discipline)	Science as a way of knowing (e.g., nature of science as an extension of practices and crosscutting concepts)	Students understand the nature of scientific knowledge.	CS 4, CS 6
Science as a stand-alone discipline (e.g., separate time or course in curriculum)	Science connected with common core (e.g., English language arts and mathematics incorporated with science)	Students' science education program includes experiences that incorporate reading, writing, and mathematics.	CS 6, CS 7

Note. Adapted from "NGSS and the Next Generation of Science Teachers," by R. W. Bybee, 2014, *Journal of Science Teacher Education, 25,* p. 217. Copyright 2014 by the Association for Science Teacher Education.

These key educational shifts alter the environment of a science classroom from a teacher-centered to a student-centered one. These six educational shifts are linked to the seven conceptual shifts outlined by the NGSS lead states to impact how teachers plan for instruction and how students interact with the science curriculum (NGSS Lead States, Appendix A, 2013a). These shifts provide a noticeable difference in classroom climate and separate NGSS from previous standard reform efforts.

Shift 1: Interconnected nature of science. The interconnected nature of science means that students are able to connect different science disciplines coherently. This shift also focuses on students' possessing a feeling of connection to science personally. As stated previously, "science is a human endeavour" (Lee et al., 2014, p. 229). The NGSS offer the connection between humans, science, and our interaction in the world, in which all students can participate. Students should not be seen as outside society; rather, they should be included and valued in the interconnectedness of the world (Bybee & Pruitt, 2017; Carlone et al., 2011). In the past, science has been broken up into many disciplines, and students have lacked the ability to see the interconnectedness of the disciplines within their contexts.

The NGSS engage students in a vision for connecting the different fields by using the three dimensions throughout the standards: Science and Engineering Practices (SEPs), Crosscutting Concepts (CCCs), and Disciplinary Core Ideas (DCIs). Using the three dimensions, students are able to access the content (disciplinary core idea) through a science and engineering practice in order to understand the bigger themes in science (crosscutting concept). Therefore, "performance expectations focus on understanding and application as opposed to memorization of facts devoid of context" (NGSS Lead States, Appendix A, 2013a, p. 1). Teachers must make science relevant to students' experiences, cultures, and interests, encouraging a connection between science in the classroom and the application of science in the real world (Crowther, 2017; Miller & Januszyk, 2014). In the traditional mindset, "Our mainstream science education does not support the outbound trajectory toward a broad field of possible identities in a wider range of possible activities that use science" (Lemke, 2001, p. 308). The science standards offer the interconnectedness of science, which encourages students to make connections across disciplines and see science in all parts of everyday life. This is a departure from what was previously described as "science" in the classroom.

Shift 2: NGSS are performance expectations—NOT curriculum. Traditionally, science reform has supplied standards that are accompanied by a scripted curriculum to be delivered to students. Standards are now called "performance expectations," a term which describes how students should demonstrate their knowledge of the disciplinary core ideas. The NGSS are not a scripted curriculum, and the performance expectations are written to identify the levels of mastery of learning that students are expected to demonstrate by the end of the learning sequences. Therefore, teachers should not feel restricted by the performance expectation. Rather, they should feel empowered to teach to and beyond the assessment boundaries (NGSS Lead States, Appendix A, 2013a).

The changes in the standards have increased the need to address students at their current level of understanding and include them in the development of their own knowledge. Science is no longer a prescribed curriculum for all students because a "sociocultural perspective tells us that we should be doing research to discover the best ways to integrate science teaching that is responsive to different needs with teaching that addresses the challenges of a heterogeneous and diverse classroom community" (Lemke, 2001, p. 308). To support this tailoring to diverse classrooms, the NGSS Lead States have developed case studies to serve as a model for implementing the NGSS. Teachers are expected to tailor their instruction to respond to the learning needs of specific student groups in local contexts. Using the case studies as a guide, teachers can begin to alter their planning of instructional blocks (Lee et al., 2014). It is imperative that teachers take the performance expectations and adapt them to their local context. For example, if teachers are teaching in Brooklyn, NY, they should not choose an experiment based on water quality of a freshwater pond in the middle of Oregon. Instead, they should choose a local water source to engage students in the same science principle but in a local and familiar context.

Shift 3: NGSS build coherently from K-12. Unlike previous reform, such as NCLB, in which science was not addressed until it was tested, often in the fourth or fifth grade, NGSS build coherently beginning in kindergarten. In order “to develop a thorough understanding of scientific explanations of the world, students need sustained opportunities to work with and develop the underlying ideas and to appreciate those ideas’ interconnections over a period of years rather than weeks or months” (NRC, 2012, p. 26). Traditionally, science in the younger grades is only taught if the teacher has some extra time in class. Due to accountability measures, the emphasis on reading and math took precedence over science. The NGSS call for more science in younger grades, and the lead states have developed learning progressions that lay out the depth to which students should be engaging in the science. Each year, their knowledge, application, and thinking like a scientist should increase in magnitude, leading to a deeper understanding of science.

Shift 4: Focus on deeper understanding and application of content. The standards are written to focus on core ideas rather than tiny facts and definitions. Traditionally, science education meant covering all content, which required the memorization of 1,000 or more vocabulary terms and allowed for very little application. The content now is not something "to cover." Instead, science instruction focuses on the journey, not the destination. For example, students engaging with NGSS are now investigating new science discoveries that promise to end cancer while learning about how cells mutate. There is no longer an emphasis on a linear method to teach through the content. Instead, the methodology focuses on integrating the content within the application of science. This "engagement [with crosscutting concepts] promises to lead to deeper understanding of science for students who have traditionally not had such access" (Lee et al., 2014, p. 229). The standards are designed to prepare students to become experts and to engage in deeper understanding of scientific ideas in high school, college, and beyond. The difference between experts and novices is that "experts understand the core principles and theoretical constructs of their field, and they use them to make sense of new information or tackle novel problems" (NRC, 2012, p. 27). If students are to increase their ability to perform on the TIMSS assessment and ultimately become productive citizens, they must be taught how to become experts engaging in work that requires them to take knowledge and apply it to new situations or problems.

Successful implementation of the standards relies on "students and teachers [understanding] how science and science education are always a part of larger communities and their cultures, including the sense in which they take sides in social and cultural conflicts that extend far beyond the classroom" (Lemke, 2001, p. 301). If students and teachers are able to bring their culture into the classroom, contributing to a safe dialogue, students will be able to bring what they have learned into the real world, beyond the four walls of the classroom where "science" has historically lived.

Shift 5: Science and engineering are integrated through K-12. Although engineering and technology have been part of previous standard reforms, they are placed within the NGSS to call attention to the belief that core ideas in engineering and technology are on the same level of importance as science disciplines. According to Cunningham and Carlsen (2014),

> Engineering and technology provide a context in which students can test their own developing scientific knowledge and apply it to practical problems; doing so enhances their understanding of science--and, for many, their interest in science--as they recognize the interplay among science, engineering and technology. (p. 207)

The NGSS encourage the application of science through engineering projects, which are embedded within every unit of study. This "vision of science learning and teaching, seamlessly blend[s] science and engineering practices, crosscutting concepts, and disciplinary core ideas to form a portrait of comprehensive science knowledge" (Lee et al., 2014, p. 229). Students engage in this work and start to understand the connections between all aspects of STEM education. Lee et al. (2014) stated:

> Engineering is a field that is critical to undertaking the world's challenges, and exposure to engineering activities can spark interest in engineering majors in college or engineering careers for females and students from multiple languages and cultures in this global community. (p. 229)

Engineering performance expectations, which are embedded into every course and encourage the connection between engineering and science fields, could peak STEM interest by students engaging in these expectations.

Shift 6: Prepare students for college, career and citizenship. Strengthening of the content and science and engineering practices throughout grades K-12 is in preparation for college, career, and citizenship in which students are expected use science in a meaningful way. With this in mind and "in an effort to reduce disparities in outcomes among diverse student groups, the NGSS draw from how students learn science,[and] the factors that will lead to achievement in science and possibility a STEM career" (Miller & Januszyk, 2014, p. 10). This is a major departure from previous standards outlined in other reforms. By embracing this cognitive approach, the NGSS have moved away from memorizing and following procedures to actually applying scientific knowledge within the K-12 setting.

The cognitive approach piques students' interest in college and careers, and in addition, when "comprehending current events, choosing and using technology, or making informed decisions about one's health care, understanding science is key" (NGSS Lead States, 2013a, Appendix A, p. 5). The mission for implementation of the NGSS is to make sure that everyone has the knowledge to make those decisions. Not only is science important for medical or life decisions, but also it is imperative that the NGSS implementation connects science classrooms to communities and homes for students to understand that science lives outside the classroom. This connection increases students' application of science to the community and the understanding that change can come from scientific actions (Lee et al., 2014).

Shift 7: NGSS and Common Core State Standards are aligned. The NGSS were written in connection to the Common Core State Standards (CCSS) for students to see the interconnectedness of science with math and English. This connection contributes to the child's comprehensive education and allows for meaningful opportunities to learn across all disciplines. The integration of the CCSS mathematics and English language arts within the science context "is particularly important for students from nondominant groups who may be allotted fewer instructional hours in science due to these accountability practices" (Lee et al., 2014, p. 228).

The more cross-curricular teachers make their classrooms, the more students will start to connect ideas between disciplines and engage in a deeper understanding of science with the ability to communicate their ideas and make connections to others.

Three-Dimensional Learning

After almost two decades of research on how students learn science, *The Framework for K-12 Science Education,* published in 2012, concluded that students must have opportunities to continually build and restructure their understanding of science. In order to do this, they must be able to engage in authentic active learning experiences that encourage the integration of knowledge and scientific practices (Bybee & Pruitt, 2017; Christensen et al., 2015). This integration of knowledge and practice over multiple years allows the students to internalize the learning of science and apply their learning to real-world situations. This integration of knowledge, practice, and metacognition contributes to the three dimensions of learning in the NGSS.

The three dimensions of the NGSS, science and engineering practices (SEP), crosscutting concepts (CCC), and disciplinary core ideas (DCI), listed in Table 4, are expected in instruction, curriculum, and assessments (NGSS Lead States, 2013a). The SEP are the practices students are expected to engage with to gain understanding of the DCI, which is the content of the science course. In Table 4, the DCI are delineated into four categories:

1. physical science;
2. life science;
3. earth and space; and
4. engineering, technology, and application of science.

Finally, the CCC are the metacognitive tasks or ways of thinking about science that mimic how scientists think in the field. The three dimensions are not to be taught independently of each other, as it is crucial that students understand the interplay of all the dimensions. Alongside the dimensions and embedded in all courses implementing the NGSS are engineering and technology standards that support the understanding of the human-built world and increase the interconnectedness of STEM fields.

Table 4

The Three Dimensions of the Framework

Scientific and Engineering Practices
Asking questions (for science) and defining problems (for engineering)
Developing and using models
Planning and carrying out investigations
Analyzing and interpreting data
Using mathematics and computational thinking
Constructing explanations (for science) and designing solutions (for engineering)
Engaging in argument from evidence
Obtaining, evaluating, and communication information
Crosscutting Concepts
Patterns
Cause and effect: Mechanism and explanation
Scale, proportion, and quantity
Systems and system models
Energy and matter: Flows, cycles, and conservation
Structure and Function
Stability and change
Disciplinary Core Ideas
Physical Sciences
PS1: Matter and its interactions
PS2: Motion and stability: Forces and interactions
PS3: Energy
PS4: Waves and their applications in technologies for information transfer
Life Sciences
LS1: From molecules to organisms: Structures and processes
LS2: Ecosystems: Interactions, energy, and dynamics
LS3: Heredity: Inheritance and variation of traits
LS4: Biological evolution: Unity and diversity
Earth and Space Science
ESS1: Earth's place in the universe
ESS2: Earth's systems
ESS3: Earth and human activity
Engineering, Technology, and Application of Science
ETS1: Engineering design
ETS2: Links among engineering, technology, science, and society

Note. Adapted from *Perspectives on Science Education* (p 107),by R.W. Bybee & S.L. Pruitt, 2017, Arlington, VA: National Science Teachers Association. Copyright 2017 by the National Science Teachers Association.

Science and engineering practices. As seen in Table 4, a total of eight science and engineering practices help students access the content. The term "practices" is used rather than "skills" to "emphasize that engaging in scientific investigation requires not only skill but also knowledge that is specific to each practice" (Pruitt, 2014, p. 150). This application of practice and knowledge is the linchpin between "doing" science and "being" scientific. Students' abilities to demonstrate a deeper understanding of the content by utilizing science and engineering practices is critical and has been recognized by many as the most important step for students reaching true mastery of the content. Due to this emphasis on application of science, these practices have become a part of the content of the courses.

It is important to note that the science and engineering practices in Table 4 also incorporate math and technology, using investigations to link multiple subjects together. Another aspect of the practices is the fact that many involve students interacting with each other. The "acknowledgement of the socially constructed nature of science, combined with understanding of constructivist learning theories, has led to proposals that students learn science most productively by undertaking open-ended investigative work rather than soaking up pre-digested facts" (Hughes, 2001, p. 277). This social integration is key for students to feel like they are not only engaging in scientific work but also using the language of scientists. Because these practices are language intensive, students are encouraged to learn science and scientific language simultaneously (Lee et al., 2014). The writers of the NGSS hope that the "new kinds of learning experiences [through] modeling, simulation, remote-sensor data, data visualization, etc., are sufficient to increase widespread interest in and success at science learning" (Lemke, 2001, p. 306). These practices create opportunities to change the way that students view science class and science learning.

Crosscutting concepts. Crosscutting concepts have been described as both the themes within science and the mindset of scientists to stress the importance that students need to think across the galaxies of all the sciences. The crosscutting concepts are a schema for students to use when engaging in scientific thinking, which can increase their ability to build on concepts from other classes and life experiences. This idea of students connecting their current understanding of the world and the new ideas of the classroom is called "conceptual ecology" (Lemke, 2001, p. 312). Concepts or themes intertwine to create a network of ideas to increase the depth of knowledge and interconnectedness between the different domains in science.

Building schemas is an important aspect of learning for all students, but it is especially important because it leads to a deeper understanding for students who have traditionally not had access to quality science education, whether the barrier be linguistic, cultural, or social (Lee et al., 2014). These schemas developed throughout K-12 education with NGSS become more sophisticated throughout continued years in science instruction. In the long term, students retain the ability to reorganize their thinking across many contexts. Using the crosscutting concepts to develop these sophisticated schemas, students attach scientific concepts and ideas across many disciplines (Lemke, 2001). What students learn in school should not be separate from the rest of their lives because they should be able to apply what they take with them from the classroom to their lives to increase their success as human beings (Bybee & Pruitt, 2017).

Disciplinary core ideas. Two insights from high-achieving countries, gleaned from the TIMSS results, were a more coherent science progression and a reduced number of science topics students are expected to master by the end of their K-12 science education (Bybee & Pruitt, 2017). To make science more coherent, the NGSS writers identified four DCI: physical science; life science; earth and space science; and engineering, technology, and application of science. Refer to Table 4 for subcategories for each DCI. The Lead States have developed learning progressions that outline the level of rigor for each grade level band for each DCI. Every year, a student's understanding of a core idea increases in depth and increases in the interdisciplinary language required by the rigor of the NGSS. Students' schema of science grows throughout their continuous years of science instruction because the coherence as they move from one science class to the next is sound.

Recommended Learning Cycle for NGSS

The most frequently proposed learning cycle that is recommended for NGSS instruction, to increase engagement between all students three dimensionally, is the Biological Sciences Curriculum Study (BSCS) 5E instructional model. The 5E instructional model, developed by Rodger Bybee in 1989, was supported by the findings in the seminal work *How People Learn* by Bransford, Brown, and Cocking in 2000. Engaging students in a task immediately at the start of a lesson to elicit their current understanding is essential before confirming or deepening their understanding of the concept throughout the lesson (Konicek-Moran & Keeley, 2015). Bransford et al. (2000) concluded that "ideas are best introduced when students see a need or a reason for their use—this helps them see relevant uses of knowledge to make sense of what they are learning" (p. 127). This method aligns with the NGSS writers' decision to replace the memorization of facts with the application of new knowledge to gain deeper understanding of concepts that are relevant to students.

In the 1980s, substantial evidence supported a learning cycle in which students would engage with a new concept first before gaining deeper understanding of the concept (Atkins & Karplus, 1962; Lawson, Abraham, & Renner, 1989; Renner, Abraham, & Birnie, 1988). The Biological Sciences Curriculum Study added a component of cooperative learning and re-emphasized the importance of a constructivist view in which students challenge their own preconceptions when they enter the science classroom (Bybee & Pruitt, 2017; Konicek-Moran & Keeley, 2015). This learning cycle incorporates inquiry learning, combining experience with thinking, which has been around since Dewey in the 1900s. Dewey's work, *Democracy and Education* (1916), suggested an "instructional approach that is based on experience and requires reflective thinking" (Bybee et al., 2006, p. 5). This cycle of learning places importance on the student making sense of information in collaboration with others. Table 5 delineates the phases of the 5E model, engagement, exploration, explanation, elaboration, and evaluation, and provides a brief summary of each phase.

Table 5

Summary of the BSCS 5E Instructional Model

Phase	Summary
Engagement	The teacher or a curriculum task assesses the learners' prior knowledge and helps them become engaged in a new concept through the use of short activities that promote curiosity and elicit prior knowledge. The activity should make connections between past and present learning experiences, expose prior conceptions, and organize students' thinking toward the learning outcomes of current activities.
Exploration	Exploration experiences provide students' with a common base of activities within which current concepts (i.e., misconceptions), processes, and skills are identified and conceptual change is facilitated. Learners may complete lab activities that help them use prior knowledge to generate new ideas, explore questions and possibilities, and design and conduct a preliminary investigation.
Explanation	The explanation phase focuses student's attention on a particular aspect of their engagement and exploration experiences and provides opportunities to demonstrate their conceptual understanding, process skills, or behaviors. This phase also provides opportunities for teachers to directly introduce a concept, process, or skill. Learners explain their understanding of the concept. An explanation from the teacher or the curriculum may guide them toward a deeper understanding, which is a critical part of this phase.
Elaboration	Teachers challenge and extend students' conceptual understanding and skills. Through new experiences, the students develop deeper and broader understanding, more information, and adequate skills. Students apply their understanding of the concept by conducting additional activities.
Evaluation	The evaluative phase encourages students to assess their understanding and abilities and provides opportunities for teachers to evaluate student progress toward achieving the educational objectives.

Note. Adapted from "The BSCS 5E Instructional Model: Origins and Effectiveness," (p. 2) by R.W. Bybee, J.A. Taylor, A. Gardner, P. Van Scotter, A. Westbrook, and N. Landes, 2006. Copyright 2006 by BSCS.

In the 5E model, the first two stages, engagement and exploration, encourage students to engage with their preconception of a phenomenon. During these stages, students share with each other their ideas, and they use a metacognitive approach to help them discern what they do not know and what they still need to discover to understand the phenomenon completely (Bransford, Brown, & Cocking, 2000). These two stages allow for a leveling of the playing field for all students regardless of background. Most phenomena will be new to all students, who will be able to learn through a common experience (NGSS Lead States, Appendix D, 2013a).

The explanation phase is the first time when students are exposed to proper language and new concepts are introduced into the classroom. The teacher directs the students to specific areas of engagement or exploration and helps them develop a shared language to attach to their experience. Because students have engaged in a meaningful activity from the start of class and have used their metacognitive skills to determine what they still need to learn, they are more invested in learning the content because there is a need to understand the phenomenon (Bybee, 2009; Bybee et al., 2006).

The final two stages, elaboration and evaluation, are used to determine whether students are able to transfer their knowledge from the original concept to a new situation. During the elaboration phase, students should be in cooperative learning groups in order to learn from each other and apply their new common scientific language to understand a larger phenomenon (Bybee, 2009; Bybee et al., 2006). Then during the evaluation phase, after having multiple opportunities to gather information, develop understanding from their peers and their explorations, and practice using scientific terminology throughout all the phases, students are asked to express their understanding of the concept of the lesson on their own. Although this five-stage process is described as linear, formative evaluation frequently occurs during all phases to provide feedback and stimulate student growth (Duran & Duran, 2004).

Traditional Versus Next Generation Science Standards Classrooms

Traditional science teaching practices emphasized the memorization of facts, yet NGSS emphasize the active construction of knowledge through doing science with the use of models, mathematics, and investigations (Haag & Megowan, 2015). These practices integrate the knowledge with a practical application. Although the 5E instructional model, which strives for these connections, was first articulated in the 1980s, schools have continued to teach traditionally, keeping "inquiry and content standards separate [resulting] in a focus solely on content" (Pruitt, 2014, p. 146). A focus solely on content is a disservice to students because they do not have the opportunity to apply the learned knowledge to issues beyond the classroom (Lemke, 2001). In fact, "it is a falsification of the nature of science to teach concepts outside of their social, economic, historical, and technological contexts" (Lemke, 2001, p. 300). Students need to understand how the academic content lives outside of the classroom and translates to scientific activities and careers (Lemke, 2001).

Although there are various definitions of STEM education, integrated STEM "includes approaches that explore teaching and learning between/among any two or more of the STEM subject areas, and/or between a STEM subject and one or more other school subjects" (Sanders, 2009, p. 21). In the NGSS, science is intertwined with engineering and technology in every academic course as well as linked to Common Core mathematics standards, beginning in kindergarten. The NRC (2012) stated that "engaging in the practice of science and engineering during their K-12 schooling should help students see how science and engineering are instrumental in addressing major challenges that confront society today (p. 9). Guzey, Harwell, and Moore (2014) determined that an integrated STEM education approach had a positive effect on students' attitudes towards STEM.

STEM Interest

Interest in science is established by age 14 (Archer, DeWitt, & Willis, 2014), and "students who have positive attitudes towards science at the middle school level are more likely to pursue a STEM career" (Christensen et al., 2015, p. 899). Some research has found that students have a natural curiosity about science until age 10 when interest begins to decrease throughout middle school (Archer et al., 2014). Recent research has documented a positive change in attitudes towards science, especially with inquiry learning (Petrinkjak & Shapiro, 2017). However, gender inequalities still persist, ingrained in our current educational culture (Haste, 2004; Petrinkjak & Shapiro, 2017; Plucker, 1996; Scantlebury & Baker, 2007).

Scientific Identity

Several factors affect students' interest in STEM fields, including being good at school science, interest in a science career, seeing themselves as scientists, believing they have the capacity to do real science, and experiencing positive reinforcement from others. All of these factors can be categorized under developing and having a science identity, which is central to learning (Lemke, 2001). Science identity is "both an individual's sense of self and the extent to which a student sees him/herself as interested in and/or competent at science and the extent to which a student is recognised by others" (Archer, DeWitt, & Osborne, 2015, p. 203). Identity is a complex variable. Even students who are high achievers still struggle to identify with a career in science (Archer et al., 2010; Archer et al., 2014; Jenkins & Nelson, 2005; Wong, 2015). Although a student might enjoy and succeed in science class, it does not necessarily follow that the individual will adopt a science identity.

Identities are understood as "discursively and contextually produced (i.e., produced through practices, relationships, and interaction within specific sites and spaces)—and as profoundly relational" (Archer et al., 2010, p. 619). Due to the nature of identity as relational, it is important to encourage the environmental conditions that build students' identities instead of using pedagogy that conceals individual identities in the classroom. Scientific identity produced through students' developing a sense of self-efficacy can contribute to increased self-motivation and positive attitudes towards STEM.

> Student interest in, attitudes towards, and motivation toward science, and student willingness to entertain particular conceptual accounts of phenomena depend on community beliefs, acceptable identities, and the consequences for a student's' life outside the classroom of how they respond to our well-intentioned but often unified effort at directing their learning. (Lemke, 2001, p. 301)

Shifts in the NGSS encourage the use of these funds of knowledge to build science identities and increase motivation to pursue a career in STEM fields (Christensen et al., 2015). Building identities within a student community, where students encourage the sharing of information using their funds of knowledge, helps shape others' way of "talking, knowing, doing, and being of that community" (Wong, 2015, p. 982). A student community can build strong schemas in science and increase self-motivation and interest in STEM.

Individual sense of self (self-efficacy). Self-efficacy can be described using three factors, "environmental, behavioral, and internal factors (Bandura et al., 2001). Environmental factors are the messages and stereotypes communicated by peers, teachers or parents that can contribute to students' self-evaluation of their competency in science (Fong & Krause, 2014). Behavioral factors are the previous experiences that can cause an individual to question her competence in science (Fong & Krause, 2014; Jones, Howe, & Rue, 2000). If previous experiences have increased anxiety or caused difficulty, students are less likely to repeat the activity because "unless people believe they can produce desired outcomes by their actions, they have little incentive to act or to persevere in the face of difficulties" (Bandura et al., 2001, p. 185). When Miller and Januszyk (2014) studied the NGSS in classroom environments, they observed students engaged in the three dimensions and "most gratifyingly, witnessed their confidence and self-efficacy as student scientists soar" (p.13). NGSS instruction is trying to change the environmental, behavioral and internal factors that influence self-efficacy in a positive and more integrated manner.

Recognition of self and by others. Science identity expresses the extent to which a persons' see themselves as a science person and the extent to which they are recognized by others as being capable of doing science (Archer et al., 2014). As research has shown, tensions between student and institutional and/or disciplinary identities (Brickhouse et al., 2000; Carlone, 2004) can impact a student's ability to successfully learn science. Successful participation in school science "can be facilitated when students have a science-related identity they can fall back on" (Calabrese Barton & Tan, 2010, p. 194). Since identity is socially constructed, if students' do not have a strong perception of scientists or recognition by others, they may not have the science related identity to participate in school science successfully.

Perception of scientists. For over 50 years, research has documented that students typically portray a scientist as a White male, working in a laboratory with dangerous chemicals (Barman, 1997; Chambers, 1983; Farland-Smith, 2012; Mead & Metraux, 1957). These perceptions of scientists held by students contribute "to their attitudes toward science, locus of control, and self-efficacy" (Finson, 2002, p. 335). Students who view science as a field dominated by White males might become discouraged from being interested in science (Bayri, Koksal, & Ertekin, 2016). Science stereotypes are not limited to White males; they are also heavily influenced by certain cultures in science fields. In 2017, Petrinkjak and Shapiro published an article for the National Science Teachers Association, stating that the scientist stereotype is eroding and that “60% more students are aware that scientists can come from any demographic group” (p. 6). The article suggests that students recognizing people from all backgrounds can be scientists is an improvement from past polls. However, 25% of the students still “do not connect those opportunities with their own demographic group” (Petrinkjak & Shapiro, 2017, p. 6). This view of scientists has a negative impact on a student’s self-efficacy in science.

Recognition by others. Archer, DeWitt, and Willis (2014) described the importance of recognition by others that contributes to an increase in self-efficacy. Acknowledgement of a student’s skills, grasp, and success in science can increase motivation to do well, build confidence in communication, and lead to a deeper understanding of content knowledge. Although recognition can contribute to positive results, there is also a stereotype threat for underrepresented groups in science. In addition, recognition by peers, teachers, and parents can be elusive.

Stereotype threat. Stereotype threat is “the anxiety individuals from stigmatized groups have that their behavior might confirm—to others or even to themselves—the negative stereotypes imposed upon their group” (Beasley & Fischer, 2012, p. 428). Many of the stereotypes come from students’ thinking there are science people with a science mind, and they do not see themselves in that category (Archer et al., 2010). These stereotypes frequently are expressed by peers. But teachers also have a way of stereotyping students in science, encouraging some students to study the biological sciences over the physical sciences because students are not good at math or science (Finson, 2002). Teachers and counselors recurrently track students into certain classes and limit underrepresented students' access to rigorous science classes.

Finally, there is stereotype threat placed on the student by a parent who discourages access to integrated science due to cultural norms and expectations of being in a female role at home. Finson (2002) suggested that "evidence exists that such a stereotypical perception is persistent and pervasive across grade levels, gender, racial groups, and national borders" (p. 335). These stereotypical perceptions can persist even after students enter STEM careers and can deter individuals from full membership in the STEM community (Teo, 2014). These stereotypes, which exacerbate racism and sexism in science classrooms, create hostile environments for underrepresented groups in science (Archer et al., 2014; Malcom, Van Horne, Gaddy, & George, 1998).

Underrepresented Populations in Science

Although there are millions of STEM jobs available in the United States, only 11% of the STEM workforce is Black and Latino men and women (NSF, 2017). The NGSS provide a framework to prepare all students to fill these millions of positions if they are given the opportunity. With the growing population of minorities in the United States, which is predicted to reach 56% by the year 2060, there needs to be a focus in science education to address the gap in these occupation numbers (Landivar, 2013; NGSS Lead States, 2013b; NSF, 2017). Participation in science varies considerably by social class and ethnicity because many do not see themselves or know someone in the STEM field (Archer et al., 2014; Archer et al., 2015; Gorard & See, 2009).

The development of self-efficacy and recognition by others is more difficult for underrepresented groups in science education. Research suggests that even minority students who perform well in science still do not identify with science or aspire for a science career because science is perceived as not for “people like us” (Archer, DeWitt, & Osborne, 2015; Carlone et al., 2011; Wong, 2015, p. 992). Along with not seeing themselves or others like them as scientists, the “general disregard for students' lived experiences contributes to the silencing of expression of women and underrepresented groups” (Martin, 2016, p. 96). Although there has been an increase in STEM programs for girls to combat the traditional view of women in STEM careers, little attention has been given to improving experiences for underrepresented minority groups in STEM fields (Archer et al., 2014).

Ethnicity and culture. There has been significant research on student narratives regarding STEM interest, especially among students of color and girls ranging in age from second to twelfth grade. These narratives confirm the aforementioned factors that contribute to students’ attitudes toward STEM. Table 6 contains a few of the narratives and ways in which NGSS address the narratives in order to engage all learners.

Table 6

Student Narratives and the Vision for NGSS K-12 Education

Student Narrative	NGSS' Vision
Language	
"I am not like them. I don't use big words… 'cause I don't know what they mean most of the time... I use the words I know" (Carlone et al., 2011, p. 461). "When you're doing science, they have like lots of word that you don't know" (Carlone et al., 2011, p. 462).	The emphasis in the NGSS is placed on the role of encouraging and accepting informal and native language to make sense of phenomenon. Then throughout the activities in the classroom and interaction with others, students start to attach academic language for a deeper understanding of the content (Crowther, 2017; NRC, 2012).
Interest and Self-perception	
"I'd find it boring. Wearing a white coat, walking around with glasses. I don't find that interesting" (Archer et al., 2015, p. 213). "Physics is horrible, difficult, and nasty" (Hughes, 2001, p. 280). "People are smarter than me" (Archer et al., 2015, p. 216). "No, I'm not like them. I'm not that smart" (Carlone et al., 2011, p. 461).	With a focus on integrating engineering, social construction of knowledge, and phenomena-driven instruction, NGSS classrooms are more collaborative, involving more voices than ever before. This encourages students to develop a science identity, so that even if the subject is hard, they are still interested (Konicek-Moran & Keeley, 2015; NRC, 2012). The NGSS also promote a coherence to the K-12 educational experience, increasing students' attractiveness to the storylines of science (Quinn, 2015).
Usefulness	
"I think it's different because English and Math are used more widely but Science is like a thing that you...like unless you want to be a scientist, isn't relevant to you" (Archer et al., 2015, p. 214). In science, "you have to remember all the theories and stuff like that and like your dates and things...i'm not very good at remembering a lot of stuff" (Archer et al., 2015, p. 215). "I'll understand sort of the basic principles that doesn't really fit anything that I will ever encounter in my entire life" (Hughes, 2001, p. 281).	The integration of the three dimensions of NGSS, SEP, CCC, and DCI, encourages students to practice science and 21st century skills within the content that interconnects different forms of science in real-world applications. There is less memorization of theories and facts and more attention to collaborating and communicating information, which can be applied to everyday life situations (Bybee & Pruitt, 2017; Corcoran, Mosher, & Rogat, 2009; Miller, Slawinski-Blessing, & Schwartz, 2006; NRC, 2012).

Three themes emerge in the narratives: language, interest and self-perception, and usefulness. Although these narratives are prevalent in previous research, the intention of NGSS is to address these narratives with a desire to increase students' application of their language and funds of knowledge to access content, to increase their interest and scientific identity through phenomenon-driven instruction, and to employ three-dimensional learning progressions to increase the amount of time students are exposed to content that links to their everyday life. There is very little research currently about NGSS implementation on these intentions. These narratives describe the experiences of underrepresented minority individuals in science. However, the narratives are even more intense when the variable of gender is added.

Gender. Women in science fields face many challenges that have been well documented in the literature (Archer et al., 2014; Atwater, 2000; Brickhouse & Potter, 2001; Carlone & Johnson, 2007; Carlone et al., 2011; Rascoe & Atwater, 2005). Currently, women account for "only 20% of the bachelor's degrees in engineering, computer science and physics even though high school boys and girls perform equally well on mathematics and science courses" (Christensen et al., 2015, p. 891). Many women enter college declaring a STEM major but drop out or change majors due to a myriad of reasons, including stereotype threat and self-identity (Hughes, 2001; Miller et al., 2006). Even if women succeed in the educational system, they still face challenges in the workplace. One African American teacher, "despite having earned a doctoral degree in chemistry and a teaching position in a STEM school, was cognizant of how gender and race had marginalized her and her minority female students, making them feel like border members of the STEM community" (Teo, 2014, p. 48). She questioned her identity as a scientist and developed a science club to encourage science identity development with her female students. Even the "perceived risk of confirming a negative stereotype of an individual's identity group acts as a physiological burden that negatively impacts performance" and self-efficacy (Sunny, Taasoobshirazi, Clark, & Marchand, 2017, p. 157).

Stereotype threat can impact identity: "Reconstructing dominant versions of science generates more comfortable female scientist identities" (Hughes, 2001, p. 281). There needs to be a departure from the stereotype of a scientist as a Caucasian male with crazy hair (Barman, 1997). Perceptions are directly related to students' attitudes toward science, and if girls' only perceptions of scientists are as Caucasian males in a lab, there is going to be little change in increasing the number of minority women in STEM fields (Barman, 1997; Finson, 2002; Finson, Pedersen, & Thomas, 2006).

Summary

This chapter provided an outline of science education goals and reforms that have hindered the advancement of these goals. Chapter 2 also described the current inadequacies of science education, especially for underrepresented groups in science, the development of the NGSS to address these inadequacies, and the need for research on this population to increase attitudes towards STEM fields. The next chapter describes the methodology for this study.

CHAPTER 3

METHODOLOGY

Within the context of an ever-changing world and U.S. job market, science education must be on the cutting edge in order to engage students to be scientifically literate and capable of navigating challenges in the world (NGSS Lead States, 2013b). In 2015, there were 8.6 million jobs available, with 64% in computer technology and engineering (NSF, 2017). Students need scientific literacy not only to access opportunities to join this type of workforce but also to understand issues important to their lives, such as medical conditions or voting measures (NSF, 2012). Underrepresented groups in science often have negative perceptions of themselves in science careers as well as negative experiences with science education, which contributes to a lack of self-efficacy (Archer et al., 2014). This study examined the correlation between middle school students' self-efficacy in STEM and their interest in STEM careers. It also examined how students who engaged in NGSS-aligned classrooms differed from those in traditional classrooms that have not adopted the conceptual shifts outlined by the NGSS.

Research Questions

This study was limited to Black and Latino youth as they represented the disporportionate extent to which Black and Latino men and women are represented in STEM fields. To better understand the perspectives of underrepresented students regarding STEM careers and their self-efficacy in STEM, the following research questions guided the study:

1. What is the relationship between students' self-efficacy in STEM and career interest in STEM fields?
2. How does student interest in STEM careers differ between students who engage with NGSS instruction and students who engage with traditional instruction?

3. How does students' self-efficacy in STEM differ between students who engage with NGSS instruction and students who engage in traditional instruction?

In this study, students' self-efficacy was measured using the Student Attitudes Toward STEM Survey (S-STEM), focusing on four variables, including: (a) math attitudes; (b) science attitudes; (c) engineering and technology attitudes; and (d) attitudes towards 21st century learning.

Method

Context

The setting of this study was multiple middle school sites within one large charter school network located in an urban center in California. The middle school focus aligned with research suggesting many students start to lose interest in science at the age of 10 and the decline continues until 14 years of age (Archer et al., 2010). Prior to middle school, students are curious about the world and are excited about science class; however, in high school fewer students choose to take more than the required two years of science (Morgan, Farkas, Hillemeier, & Maczuga, 2016).

Procedures

This was a quasi-experimental quantitative study to evaluate the relationship between students' self-efficacy in STEM and their interest in STEM careers and the differences in these interests based on whether students have participated in NGSS-aligned instruction. Although the primary focus and participants were students, teachers were involved to identify the two student groups that took the S-STEM survey via evaluation of teacher lesson plans. Figure 3 outlines the scope of the research. Determining the two student groups during the teacher alignment phase took the largest amount of time due to the complexity of evaluating the teachers' lesson plans for alignment to NGSS. Alignment was determined by an NGSS expert group using the Educators Evaluating the Quality of Instructional Products (EQuIP) rubric.

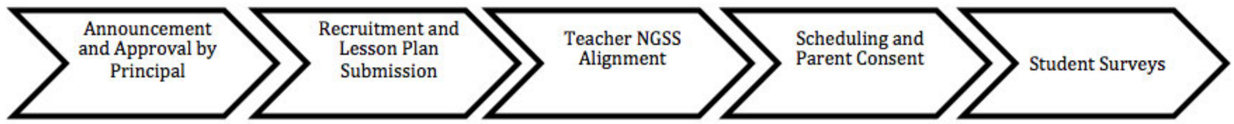

Figure 3. Proposed workflow.

Every effort was made to follow the workflow as designed. However, some steps were more challenging and took more time than expected. Due to the wave of submissions of lesson plans over several weeks, the workflow was linear for each teacher at different rates. As one school was on step two, antoher was on step four, depending on how quickly teachers submitted their lesson plans and consent forms. There were also several rounds of consent forms and reminder emails to gain a larger sample size for the study.

Determination of Groups

Recruitment of teachers. All of the teacher participants in the sample were employed at one of ten middle schools in a large charter school network in California, which served approximately 12,500 students in grades 6-12. Prior to the start of teacher recruitment, a description of the upcoming study was announced during a principal meeting to all middle school principals with a session opportunity following for questions. One week following the announcement, principals received a summary follow-up email with a one-page description of the study and a request for an approval letter for their site participation. See Appendix A for a sample principal approval letter.

Once principals approved their site for participation, the teacher recruitment phase began with purposeful sampling of teachers. All 30 middle school science teachers were contacted via email to be informed of the topic of the study, that the project was voluntary, the expectations for participation, and the potential outcomes that could come from the study. They were also informed that the data gathered during this study would be reported in the aggregate if they selected to participate and their identity would be kept confidential.

Lesson plans. Teachers were asked to submit five lesson plans that reflected their everyday teaching. In this network of schools, lesson plans were expected on a regular basis, therefore, they did not have to be created for this study. Teachers had the option of submitting any of their lessons that reflected their typical teaching cadence, and any of the school lesson plan templates were accepted. As an incentive for participation, all teachers who submitted the five lesson plans were given a Starbucks gift card. One week following the initial email, reminder emails were sent out to all teachers as a last call for lesson plans.

Eight middle school science teachers were selected from all the middle school teachers in the network. All lesson plans were reviewed by a committee of NGSS experts. This lesson plan data determined if each teacher was considered NGSS-aligned or non-NGSS-aligned based on EQuIP rubric ratings. Once teachers were placed in one of the two categories, this determined the two student groups. Because lesson plans were gathered on an ongoing basis, identifying equal groups based on teacher lesson plans was going to be difficult, and due to a limited time window in the school year, schools were scheduled without initially forming equal groups. A total of three teachers were NGSS-aligned, and five were not NGSS-aligned. Although I intended to review lesson plans until I had four teachers aligned to NGSS and four not aligned to NGSS, equal student groups were still able to be formed with NGSS-aligned (n=290) and non-NGSS-aligned (n=290).

At one school site, three teachers participated, one who was NGSS-aligned and two who were not. Therefore, the analysis was grouped by teacher and not by school. After the conclusion of the study, teachers received a copy of the EQuIP ratings for their lesson plans as feedback and support for participating in this study.

Expert group. A small committee of three NGSS experts reviewed the lesson plans as they were received using the EQuIP rubric to determine alignment to NGSS. These scores determined the two student groups, NGSS-aligned and non-NGSS-aligned, who took the S-STEM survey.

The NGSS experts were selected based on their years of experience with the standards. Three years of experience planning with NGSS and developing curriculum with NGSS was a prerequisite for becoming an expert panelist. Interrater reliability was achieved by engaging in an EQuIP calibration session using example lesson plans. Each lesson plan was graded individually and then discussed to come to consensus about the overall score for the lesson. Criteria for scoring was discussed among the panel to determine which cut-off score was considered NGSS-aligned. In order to be considered NGSS-aligned, an average score of lessons had to exceed a score of a “2.0-adequate” in “Category I: NGSS 3D Design.” Each lesson was scored by each expert individually, then averaged together for an average score on that particular teacher lesson. After all five lessons were scored, an average of those scores were reported to determine which group the teacher would be placed in. If the average of the lessons scored above a 2.0, teachers and therefore students were placed in the NGSS-aligned group.

Educators Evaluating the Quality of Instructional Products rubric. The EQuIP rubric was designed to evaluate lessons for alignment to NGSS. The rubric does not require a specific lesson plan template and is not intended to evaluate a single task. It was developed by Achieve

(2017), an “independent, nonpartisan, nonprofit education reform organization dedicated to working with states to raise academic standards and graduation requirements, improve assessments and strengthen accountability” (p. 1). The rubric is a feedback form that is intended to be used with a group of people evaluating a lesson plan to look for three-dimensional teaching and components of NGSS, described in the next section. The overall score of the lesson determined the two student groups.

Rubric design. The rubric is broken into three categories, NGSS 3D design, NGSS instructional supports, and monitoring NGSS student progress (Achieve, 2016). In Figure 4, the main focus for category one, “alignment to NGSS” or “NGSS 3D Design,” is student engagement in making sense of phenomena through the three dimensions of NGSS: science and engineering practices, disciplinary core ideas, and crosscutting concepts. There are three sections within in this category: explaining phenomenon, three dimensions, and integrating three dimensions. An example from the first section, explaining phenomena, reads “ student questions and prior experiences related to the phenomenon or problem motivate sense-making and/or problem solving” (Achieve, 2016, p. 6). This phase is represented as a rope because it is important that all three dimensions are intertwined and taught together.

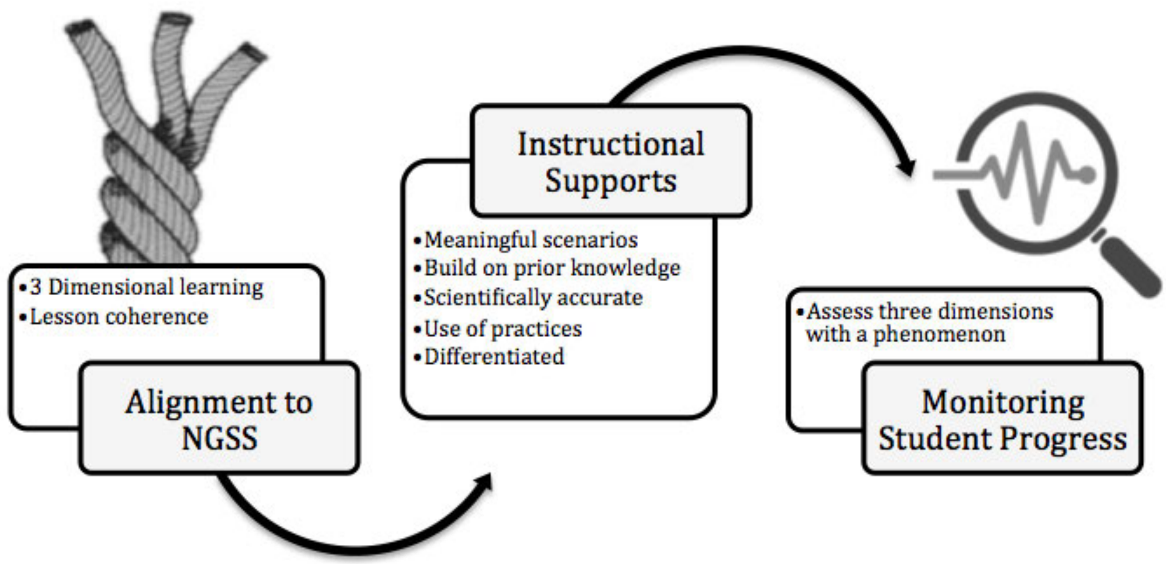

Figure 4. EQuIP rubric phases to determine lesson alignment to NGSS. Adapted from "EQuIP Rubric for Lessons and Units: Science, Version 3.0," by Achieve, 2016. Copyright 2016 by Achieve.

The second category, NGSS instructional supports, focuses on "three-dimensional teaching and learning for ALL students by placing the lesson in a sequence of learning for all three dimensions and providing support for teachers to engage all students" (Achieve, 2016, p. 1). There are five sections in this category: relevance and authenticity, student ideas, building progressions, scientific accuracy, and differentiated instruction. An example item under the section "student ideas" reads, "provides opportunities for students to express, clarify, justify, interpret and represent their ideas and respond to peer and teacher feedback orally and/or in written forms as appropriate" (Achieve, 2016, p. 1).

The final category is monitoring student progress, which contains four sections, including monitoring 3D student performances, formative, scoring guidance, and unbiased tasks/items. An example from the unbiased tasks sections reads, "assesses student proficiency using methods, vocabulary, representation, and examples that are accessible and unbiased for all students" (Achieve, 2016, p. 1). In Figure 4, this phase is presented with a magnifying glass to data because it is important make clear when students will be evaluating their own progress and when the teacher will be evaluating their understanding of the concepts.

Each category requires specific evidence pulled from the lesson plan to inform a score of quality. There are four options for quality: none, inadequate, adequate, and extensive. Finally, there is a section devoted to suggested improvement to increase the alignment. Although each category contains lesson- and unit-guiding sections, this study only used the lesson components of the rubric. Following the three ratings on each category, an overall rating was selected. There are four options for overall ratings: example of high-quality NGSS design, example of high-quality NGSS design if improved, revision needed, and not ready to review.

Using the Educators Evaluating the Quality of Instructional Products rubric. All evaluators were required to go through a training using the EQuIP facilitator's guide in order to effectively evaluate lessons. There are five main steps to accurately using the EQuIP rubric. First, review the materials to understand the performance expectations that are being addressed in the lesson. Read any key materials to understand the lesson as whole. Second, apply the criteria for category one of NGSS 3D design. Collect evidence from the lesson and place it in the appropriate box in category one. If the lesson plan "does not score at least a '2' in Category I: NGSS 3D Designed, the review should stop and feedback should be provided to the lesson developer" (Achieve, 2016, p. 5). Third, if the lesson passes the first category, repeat the process of evidence collection for categories two and three, instructional supports and monitoring student progress. Fourth, review the rating from each category and assign an overall score. This should be done prior to conversation with the group. Fifth, compare overall ratings and recommended next steps. For this study, the next steps were to determine the student groups based on the overall teacher performance on the lesson plan analysis.

Student Participants

Five hundred and eighty students were surveyed, with parent or guardian consent, within the teachers' classrooms from the different middle schools in the network. See Appendix B for a sample parental consent form. Table 7 provides the demographic data across the charter network. The survey was administered on students' one-to-one device during one of their advisory class periods or during class time, depending on the school's request, and took up to 30 minutes to complete.

Table 7

Charter Network Demographic Data (percentages)

Latino & African American	English Language Learners	Students with Disabilities	Free & Reduced Lunch
98%	17%	10%	94%

Note. Demographic data come from network website and therefore cannot be cited to keep the context confidential.

Descriptive statistics were used to report frequency of demographic information in the study, including grade, gender, and identity, to verify the population as mirroring the underrepresented groups in STEM fields. These frequencies substantiated the population of this study as comprised of underrepresented students, but also this data may be used in future studies to look at students by gender in science.

Table 8

Respondent Demographics (N= 580)

Characteristic	*n*	%
Grade		
Sixth	181	31.2
Seventh	161	27.8
Eighth	238	41.0
Gender		
Male	232	40.0
Female	333	57.4
Prefer not to say	13	2.2
Missing	2	.3
Identity		
American Indian/Alaska Native	5	.9
Asian	4	.7
Black/African American	28	4.8
White/Caucasian	3	.5
Hispanic/Latino	498	85.9
Multiracial	19	3.3
Other	22	3.8
Missing	1	.2

Measures

A quantitative survey was taken by all middle school students enrolled in the selected teachers' classrooms (N = 580). The survey gathered demographic information, including grade, gender, and identity. Other questions assessed the key variables: attitudes towards STEM and STEM career interest.

Student Attitudes Toward STEM Survey. The Friday Institute for Educational Innovation at North Carolina State University (2012a; 2012b), in partnership with the National Science Foundation (NSF), developed both the upper-elementary and the middle/high school S-STEM surveys. Each attitudinal section measures students' self-efficacy related to a topic and "expectations for future value gained with success" in that topic area (Friday Institute for

Educational Innovation, 2012a, p. 1). The surveys have been administered to 10,000 fourth through 12th grade students in North Carolina who were enrolled in various science and STEM classes.

To use the survey, permission was granted by the Friday Institute for Educational Innovation through a submission of an intent email. The Institute allows reproduction of the survey and modifications if necessary to allow for educational use and evaluation purposes. It asks that publications and de-identified data are shared with the Institute to continue contributing to the relability and validity of the measure.

There are four main variables to measure attitudes towards STEM in the survey: math attitudes, science attitudes, engineering and technology attitudes, and 21st century learning. For all four variables, students responded on a Likert scale of 1 (*Strongly Disagree*) to 5 (*Strongly Agree)*. These items were anticipated to have strong reliability and validity because they had been tested previously by the Friday Institute for Educational Innovation (2012a). The four constructs that make up the attitudes variable help measure "the impact of various interventions on student interest and confidence in STEM subjects, including programs that implement new curricula, use new instructional strategies, or provide new learning opportunities" (Friday Institute for Educational Innovation, 2012b, p. 1). This survey also has a comprehensive section measuring student career interest and can "help schools, organizations or researchers determine the degree in which a program has influenced student-interest in 12 STEM career pathways ranging from physics to medicine" (Friday Institute of Educational Innovation, 2012b, p. 10). In this study, implementation of NGSS could influence student interest in STEM careers and their persistence in STEM fields. See Appendix C for the entire survey.

Table 9

S-STEM Reliability

Construct	Number of Items	Cronbach Alpha
Math Attitudes	5	.87
Science Attitudes	8	.79
Engineering and Technology Attitudes	9	.87
21st Century Learning	11	.90
Your Future	12	.89

Math attitudes. Student attitudes towards math were measured by asking them to respond to statements on a Likert scale of 1 (*Strongly Disagree*) to 5 (*Strongly Agree*). Items included all of the following:

1. Math has been my worst subject.
2. I would consider choosing a career that uses math.
3. Math is hard for me.
4. I am the type of student to do well in math.
5. I can handle most subjects well, but I cannot do a good job in math.
6. I am sure I could do advanced work in math.
7. I can get good grades in math.
8. I am good at math. (Friday Institute for Educational Innovation, 2012b)

The survey items and data analysis procedure produced by the Friday Institute for Educational Innovation (2012a) showed a strong construct reliability of Cronbach's $\alpha = .90$. This construct however, included three reverse-coded items, which decreased the reliability of the measure in this study. When reverse items were included in the analysis, Cronbach $\alpha = .004$, showing low reliability was produced; however, when reverse items were not included, there was an improved Cronbach $\alpha = .87$. Therefore, for this study the math attitude composite variable consisted of five items, none of which were reverse coded.

Science attitudes. Student attitudes towards science were measured by asking them to respond to statements on a Likert scale of 1 (*Strongly Disagree*) to 5 (*Strongly Agree*). Items included all of the following:

1. I am sure of myself when I do science.
2. I would consider a career in science.
3. I expect to use science when I get out of school.
4. Knowing science will help me earn a living.
5. I will need science for my future work.
6. I know I can do well in science.
7. Science will be important to me in my life's work.
8. I can handle most subjects well, but I cannot do a good job with science.
9. I am sure I could do advanced work in science. (Friday Institute for Educational Innovation, 2012b)

Nine items comprised the science attitudes construct with a reported strong reliability, Cronbach $\alpha = .89$. There was one reverse-coded item; however, there was still a strong reliability reported in this study, with a Cronbach $\alpha = .79$ with the reverse-coded item included. All composites were created with items that tested above .75.

Engineering and technology attitudes. Student attitudes toward engineering and technology were measured by asking them to respond to statements on a Likert scale of 1 (*Strongly Disagree*) to 5 (*Strongly Agree*). Items included all of the following:

1. I like to imagine creating new products.
2. If I learn engineering, then I can improve things that people use every day.
3. I am good at building and fixing things.
4. I am interested in what makes machines work.
5. Describing products or structures will be important for my future work.
6. I am curious about how electronics work.
7. I would like to use creativity and innovation in my future work.
8. Knowing how to use math and science together will allow me to invent useful things.
9. I believe I can be successful in a career in engineering. (Friday Institute for Educational Innovation, 2012b)

The engineering and technology attitudes construct consisted of nine items with a strong reported reliability, Cronbach $\alpha = .89$. In this study, the reported Cronbach α was .87 for the engineering and technology composite. The composite did not include any reverse-coded items.

Attitudes toward learning skills. Attitudes towards 21st century learning skills were measured by asking students to respond to statements on a Likert scale of 1 (*Strongly Disagree*) to 5 (*Strongly Agree*). Items included all of the following:

1. I am confident I can lead others to accomplish a goal.
2. I am confident I can encourage others to do their best.
3. I am confident I can produce high-quality work.
4. I am confident I can respect the difference of my peers.
5. I am confident I can help my peers.
6. I am confident I can include others' perspectives when making decisions.
7. I am confident I can make changes when things do not go as planned.

8. I am confident I can set my own learning goals.
9. I am confident I can manage my time wisely on my own.
10. When I have many assignments, I can choose which ones need to be done first.
11. I am confident I can work well with students from different backgrounds. (Friday Institute for Educational Innovation, 2012b)

Finally, the 21st century learning attitudes construct contained 11 items with a reported strong reliability, Cronbach $\alpha = .91$. In this study, it was confirmed that this composite had strong reliability, Cronbach $\alpha = .90$. The composite did not include any reverse-coded items.

STEM career interest. The career interest section of the survey, which was called "Your Future," contained 12 broad categories of STEM career fields (Friday Institute for Educational Innovation, 2012b). For each item, students responded on a Likert scale of 1 (*Not at all Interested*) to 5 (*Extremely Interested*). In this section, students read a description of subject areas that involved science, technology, engineering, and math, as well as a list of topics connected to that particular subject. Items included all of the following:

1. Physics: is the study of basic laws governing the motion, energy, structure, and interactions of matter. This can include studying the nature of the universe.
2. Environmental work: involves learning about physical and biological processes that govern nature and working to improve the environment. This includes finding and designing solutions to problems like pollution, reusing waste and recycling.
3. Biology and Zoology: involve the study of living organisms and the processes of life. This includes working with farm animals and in areas like nutrition and breeding.
4. Veterinary Work: involves the science of preventing or treating disease in animals.

5. Mathematics: is the science of numbers and their operations. It involves computation, algorithms and theory used to solve problems and summarize data.
6. Medicine: involves maintaining health and preventing and treating disease.
7. Earth Science: is the study of earth, including the air, land, and ocean.
8. Computer Science: consists of the development and testing of computer systems, designing new programs and helping others to use computers.
9. Medical Science: involves researching human disease and working to find solutions to human health problems.
10. Chemistry: uses math and experiments to search for new chemicals, and to study the structure of matter and how it behaves.
11. Energy: involves the study of generation of power, such as heat or electricity.
12. Engineering: involves designing, testing, and manufacturing new products (like machines, bridges, and electronics) through use of math, science, and computers. (Friday Institute for Educational Innovation, 2012b).

There was no Cronbach α reported by the Friday Institute for Educational Innovation; however, in this study there was a strong reliability among items, Cronbach $\alpha = .89$, to create a composite called "Your Future."

Data Collection

Prior to survey administration, Institutional Review Board approval was received from Loyola Marymount University and parent consent letters in English and Spanish were given to all students enrolled in the participating teachers' classes. The letters indicated that all surveys were confidential and discussion of the data would be in the aggregate. The packet included a cover letter, overview of the study, research participants' bill of rights, and a parental consent form, all of which were in English and Spanish. This packet was also coupled with an introductory video that showed the purpose of the study and background of the researcher. The signed consent forms were collected by the teachers and turned in to me on the day of the survey administration. Students without parental consent were not given the survey and were asked to do a citizen science web interactive instead.

The survey was built in Qualtrics, an online survey software program (Qualtrics, Provo, UT), but an external link was created via tinyurl for easy distribution to students via their computer or iPad. During the confidential student survey phase, teachers were asked to write out the tinyurl for the survey on the board or their class website prior to administration. They were also asked to ensure that all iPads or computers were charged prior to the administration. On the administration day, I arrived 30 minutes prior to the start of the advisory period or class period, depending on the school, to set up in the teacher's classroom. As per IRB protocol, I administered the survey to ensure consistency and check off names of consent forms as students entered the room. I also had a research assistant with a NIH certificate to help out during administration when there were multiple teachers at one school who were participating in the study. The students who did not have a parent consent letter continued with their advisory duties or worked on the citizen science interactive, supervised by their teacher.

All data collected in Qualtrics were exported to Statistical Package in the Social Sciences program (SPSS),version 24, to be analyzed. During this phase, teacher names were coded for NGSS and non-NGSS in order to protect their identity during the analysis. A one was assigned to NGSS-aligned teachers, and a two was given to non-NGSS-aligned teachers in SPSS, which determined the two groups of student participants. The coded names and data reports from SPSS were exported onto an external hard drive and placed in a locked cabinet in my home office, where they will remain for five years. Following the five-year period, the hard drive will be erased. The consent letters were filed also in a locked cabinet in my home office until the end of three years, at which time they will be shredded and disposed of in the trash. All data were reported in the aggregate, and nothing personally identifiable was released. The aggregate data were also shared with the Friday Institute for Educational Innovation and kept confidential, per their agreement to use their measurement.

Analytical Plan

After exporting the data from Qualtrics into SPSS, I cleaned the data, filling in missing questions with the code 999. I also deleted students who did not complete the survey. If students answered three of the five sections of the survey, they were included within the analysis. I reverse coded the four items that were identified by the Friday Institute for Educational Innovation (2012c) to be negatively worded within the survey, meaning that a positive response would be the opposite of agreement with the other items in that section of the survey. Next, I checked for reliability of the measure, which revealed that the reverse-scored items in the math attitudes portion of the survey were not reliable. I threw out all three items that were reverse scored, which produced a more reliable sample for the construct variable of math attitudes. The four other sections of the survey had Cronbach alphas that were above .75, thus creating construct variables.

To answer research question number one—*What is the relationship between students' self-efficacy in STEM and career interest in STEM fields?*—a Pearson's *r* correlation was calculated to examine the relationship between student self-efficacy in STEM and career interest in STEM fields.

To begin data analysis for the second and third research questions, I separated the data into two groups, NGSS-aligned and non-NGSS-aligned, based on teacher name and their EQuIP rubric score. A "one" was coded for all teachers who were NGSS-aligned, and a "two" was assigned for non-NGSS-aligned teachers. To answer research question number two—*How does student interest in STEM careers differ between students who engage with NGSS instruction and students who engage with traditional instruction?*—an independent samples *t*-test was run between the two groups of students for the composite variable and STEM careers. Finally, to answer the research question—*How does students' self-efficacy in STEM differ between students who engage with NGSS instruction and students who engage in traditional instruction?*—an independent samples *t*-test was run between the two groups of students for each variable.

Descriptive Statistics

Descriptive statistics were used to report frequency of item responses. Mean scores and standard deviation were calculated for each variable: math attitudes, science attitudes, engineering and technology attitudes, and attitudes toward learning skills. Mean scores and standard deviations were used to report career interests.

Correlations

To answer the first research question—*What is the relationship between students' self-efficacy in STEM and career interest in STEM fields?*—Pearson's *r* correlations were used to determine the relationship between each of the variables and the composite student responses of the "Your Future" items, which measured STEM career interest. Table 17 shows all of the correlations that were run between variables. The first four variables, math attitudes, science attitudes, engineering and technology attitudes, and attitudes toward 21st century learning skills all contribute to overall STEM attitudes. A Pearson's *r* correlation was run between variable 1, math attitudes, and variable 2, science attitudes, to yield information about the relationship between math and science attitudes. Another correlation was run between math attitudes and the construct of "Your Future" to yield information regarding the relationship between math attitudes and career interest.

To answer the research question—How does student interest in STEM careers differ between students who engage with NGSS instruction and students who engage with traditional instruction?—an independent samples t-test was run between the two groups of students for the composite variable of STEM careers. A mean score and standard deviation were calculated for each of the student groups, NGSS-aligned and non-NGSS-aligned. For the STEM career composite variable of "Your Future," a *t* value, degrees of freedom, and *p* value were reported. To answer the research question—*How does students' self-efficacy in STEM differ between students who engage with NGSS instruction and students who engage in traditional instruction?*—an independent samples *t*-test was run between the two groups of students for each variable. A mean score and standard deviation were calculated for each of the student groups, NGSS-aligned and non-NGSS-aligned. For each variable, a *t* value, degrees of freedom, and *p* value were reported.

Debrief

Individual teacher debriefs occurred for all participating teachers in which the findings from the two student groups throughout the charter network were shared. They occurred during teacher prep periods following the study. These sessions were optional; therefore, teachers could have declined the meeting if they did not wish to discuss the findings. During a monthly principal meeting, I requested a middle school session with all principals who had students involved in the study. During that session, I reported the findings and implications for the future, as well as potential professional development for their teachers based on the student responses. Finally, a network office debrief meeting with the charter network's chief academic officer, chief executive officer, and vice president of curriculum and instruction was requested to share final findings, implications for instruction, and student data highlights.

Summary

This chapter has provided a detailed explanation of the methods used in this quasi-experimental study. The S-STEM was used to gather data on students' attitudes and self-efficacy in STEM, as well as their interest in STEM careers. Pearson correlations and independent samples *t*-tests were run to show the relationship between variables and difference between two groups, those engaged in NGSS-aligned instruction, and those who were not. The next chapter describes the results of this study.

CHAPTER 4

FINDINGS

Study Background

The emergence of the Next Generation Science Standards (NGSS) solidifies the normalization of "equity and access" in science for all students and for all standards, not a select few (California Department of Education, 2018, Chapter 10, p. 1432). To reach the standards of science for all students, NGSS set a path for student exposure to instruction that encourages co-construction of knowledge in a variety of ways relatable to them and their community, which in turn will prepare them to be knowledgeable citizens and possibly choose a STEM career. This co-construction of knowledge through real-world application could increase self-efficacy in students, a contributor to achievement and interest in science (Bandura et al., 2001). Self-efficacy is the belief oneself can "successfully execute the behavior required to produce the outcomes" (Bandura, 1977, p. 193). Although many studies have focused on the implementation of the NGSS through the teacher lens, very few exist from the student perspective, especially students of color.

The purpose of this study was to examine the relationship between students' self-efficacy in STEM and their interest in STEM careers. It also compared students who were taught in NGSS-aligned classrooms to those taught in traditional classrooms to examine differences in self-efficacy in STEM and career interest. It was of critical importance that research was done on the difference between these two groups, specifically with students of color, given that there is an underrepresentation of people of color in STEM fields. Little research exists comparing students' self-efficacy in a NGSS-aligned classroom versus a traditional science classroom, in particular with students of color. The research questions guiding this study were as follows:

1. What is the relationship between students' self-efficacy in STEM and career interest in STEM fields?
2. How does student interest in STEM careers differ between students who engage with NGSS instruction and students who engage with traditional instruction?
3. How does students' self-efficacy in STEM differ between students who engage with NGSS instruction and students who engage in traditional instruction?

To answer these research questions, a survey measuring self-efficacy in STEM and future career interests was distributed via Qualtrics to middle school students ranging from grades six through eight in one charter school network. Demographic data were collected to verify that the surveyed population was part of the underrepresented groups in STEM fields. Students identified primarily as Hispanic or Latino (85.9%), with the majority of the remainder of students identifying as Black/African American (4.75%), Multiracial (3.22%), and other (3.73%). Half of the students received NGSS instruction and half traditional instruction, as determined by teacher lesson plans.

To determine traditional versus NGSS-aligned instruction, a NGSS expert panel evaluated teacher lesson plans using the EQuIP rubric to determine two comparison groups. The overall average score above 2.00 on a 3.00 scale indicated a NGSS-aligned lesson on the EQuIP rubric. The table below indicates average scores per lesson and an averaged overall score used to determine the NGSS or non-NGSS groups.

Table 10

Lesson Plan Evaluations Based on EQuIP Rubric to Determine Comparison Groups

Teacher	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5	Average	Group
Teacher 1	2.00	2.67	1.00	1.33	2.00	1.80	Non-NGSS
Teacher 2	2.00	2.33	1.67	1.00	1.30	1.66	Non-NGSS
Teacher 3	2.33	2.33	2.00	2.00	2.33	2.20	NGSS
Teacher 4	1.30	1.00	1.00	1.00	0.66	0.99	Non-NGSS
Teacher 5	2.33	2.33	2.00	2.33	2.67	2.33	NGSS
Teacher 6	2.00	1.33	2.33	2.00	2.00	1.93	Non-NGSS
Teacher 7	2.33	2.67	2.67	1.67	2.00	2.70	NGSS
Teacher 8	1.00	1.00	1.33	1.00	1.00	1.07	Non-NGSS

Based on the overall average EQuIP rubric score, three teachers were NGSS-aligned and five did not align. Although equal numbers of teachers were not identified, the numbers of students represented by each teacher were identical when comparing the aligned and non-aligned groups for the math, science, and engineering and technology attitude variables (NGSS n = 290, Non-NGSS n = 290). Groups were almost identical comparing for 21st century learning (NGSS n= 289, Non-NGSS n = 287) and comparing the “Your Future” composite variable (NGSS n = 289, Non-NGSS n = 288). To answer the research questions, student data were analyzed using descriptive statistics, correlations, and independent samples *t*-test.

This chapter presents findings organized by research question, showcasing the appropriate statistical analysis corresponding to each research question. The first research question on the relationship between students’ self-efficacy in STEM and their career interests was interval in nature. As such, Pearson’s *r* correlations were utilized for analysis. The second question on student STEM career interest in NGSS-aligned versus non-NGSS-aligned was analyzed using independent *t*-test samples for mean differences among the groups. The third question on student self-efficacy in STEM in NGSS-aligned versus non-NGSS-aligned classrooms was reviewed via their attitudes towards, math, science, engineering and technology, and learning skills. Individual items were attitudinal in nature and were taken together as a construct variable to measure students' overall self-efficacy in a particular area. For example, an independent samples *t*-test was run comparing the two groups for each of the four variables listed above.

Results

To learn about students' self-efficacy in STEM and their interest in STEM careers, 46 items were asked on the survey to measure students' attitudes towards STEM subjects and careers. The original intent of the survey by the Friday Institute for Educational Innovation (2012b) was to "measure changes in students' confidence and efficacy in STEM subjects" (p. 1). For example, the math attitudes section of the survey "consists of items measuring self-efficacy related to math and expectations for future value gained by success in math" (Friday Institute for Educational Innovation, 2012a, p. 1). Therefore, for this survey self-efficacy was determined by students' attitudes towards a particular STEM area. Data from the five variables are described in the tables below.

Table 11 outlines the data collected for each item regarding student attitudes towards math.

Table 11

Percentage Responses, Mean, and Standard Deviation for Math Attitudes (N= 580)

Survey Item	Strongly Disagree (%)	Disagree (%)	Neither Agree nor Disagree (%)	Agree (%)	Strongly Agree (%)	M	SD
I would consider choosing a career that uses math (n=576)	12.50	24.13	28.99	26.39	7.99	2.93	1.15
I am the type of student to do well in math (n=568)	7.75	16.73	26.06	33.98	15.49	3.33	1.15
I am sure I could do advanced work in math (n=575)	10.61	18.78	24.87	31.48	14.26	3.20	1.21
I can get good grades in math (n=579)	5.70	10.02	17.96	40.76	25.56	3.70	1.12
I am good at math (n=579)	9.33	13.13	26.94	33.68	16.93	3.36	1.18

Note. Sample sizes differ by item due to skipped responses.

Table 11 illustrates the percentage students selected each response option for attitudes towards math with the corresponding mean and standard deviation per item. The highest response rate in this section was students indicating that they can get good grades in math (*M* = 3.70, *SD* = 1.12).

Table 12 outlines the data collected for each item indicating students' attitudes toward science. Percentage of responses, mean scores, and standard deviations are represented for all nine items composing the science attitudes variable.

Table 12

Percentage Responses, Mean, and Standard Deviation for Science Attitudes (N= 580)

Survey Item	Strongly Disagree (%)	Disagree (%)	Neither Agree nor Disagree (%)	Agree (%)	Strongly Agree (%)	M	SD
I am sure of myself when I do science (n=579)	2.42	6.91	17.96	55.96	16.75	3.78	.89
I would consider a career in science(n=577)	5.72	15.77	35.18	31.02	12.31	3.28	1.05
I expect to use science when I get out of school (n=580)	4.14	13.28	27.76	40.17	14.66	3.48	1.03
Knowing science will help me earn a living (n=579)	2.42	7.60	26.25	45.08	18.65	3.70	.94
I will need science for my future work (n=575)	3.65	13.57	32.52	34.26	16.00	3.45	1.03
I know I can do well in science (n=572)	1.92	4.20	11.36	56.47	26.05	4.01	.85
Science will be important to me in my life's work (n=577)	3.12	10.05	37.26	33.80	15.77	3.49	.98
I can handle most subjects well, but I cannot do a good job with science* (n=579)	20.90	46.46	19.34	11.74	1.55	2.27	.97
I am sure I could do advanced work in science (n=580)	5.69	13.62	25.86	35.00	19.83	3.50	1.12

Note. *Numbers reported are reverse scored because the item was negatively worded and the agreement to that question would be the opposite of the attitude agreement for the remainder of the items. Adapted from "Student Attitudes Toward STEM Survey: Tips, for Using Your Data," by Friday Institute for Educational Innovation, 2012. Copyright 2012 by the Friday Institute for Educationa Innovation..

The numbers in Table 12 indicate the percentage with which students selected each response option for science attitudes and displays the mean and standard deviation per item. The two items students selected the most pertaining to science attitudes were “I know I can do well in science” (*M* = 4.01, *SD* = 0.85) and “I am sure of myself when I do science” (*M* = 3.78, *SD* = .89).

Table 13 outlines the data collected for each item indicating students’ attitudes towards engineering and technology. Percentage response, mean score, and standard deviation are represented for all nine items composing the engineering and technology attitudes variable in the survey.

Table 13

Percentage Responses, Means, and Standard Deviations for Students Attitude towards Engineering and Technology (N= 580)

Survey Item	Strongly Disagree (%)	Disagree (%)	Neither Agree nor Disagree (%)	Agree (%)	Strongly Agree (%)	M	SD
I like to imagine creating new products (n=577)	2.08	8.67	20.80	47.31	21.14	3.77	.95
If I learn engineering, then I can improve things that people use every day (n=579)	1.21	5.01	17.10	53.20	23.49	3.93	.84
I am good at building and fixing things (n=577)	3.81	16.64	30.85	36.22	12.48	3.37	1.02
I am interested in what makes machines work (n=574)	4.88	17.42	21.25	37.28	19.16	3.48	1.13
Designing products or structures will be important in my future work (n=578)	3.46	16.26	31.83	32.70	15.74	3.41	1.05
I am curious about how electronics work (n=578)	2.25	8.30	15.05	47.92	26.47	3.88	.97
I would like to use creativity and innovation in my future work (n=580)	2.24	5.69	20.52	42.24	29.31	3.91	.96
Knowing how to use math and science together will allow me to invent useful things (n=578)	1.73	4.67	18.69	46.54	28.37	3.95	.90
I believe I can be successful in a career in engineering (n=580)	6.21	10.00	33.10	33.62	17.07	3.45	1.08

The numbers in Table 13 indicate the percentage of students who selected each response option for engineering and technology attitudes. Table 13 also displays the mean and standard deviation per item showing the average response per item. Three items were highly selected in this section, indicating that students know that if they learn engineering, they will be able to improve things that people use every day ($M = 3.93$, $SD = .84$); students would like to use their creativity and innovation in their future work ($M = 3.91$, $SD = .96$); and students know if they can use math and science together, it will allow them to invent useful things ($M = 3.95$, $SD = .90$).

Table 14 outlines the data for each item indicating the 21st century learning composite variable, which measures student confidence levels in skills related to STEM fields. Percentage of response, mean score, and standard deviation are represented for all 11 items that compose the 21st century learning variable.

Table 14

Percentage Responses, Mean, and Standard Deviation for Attitudes Towards Learning Skills (N= 580)

Survey Item	Strongly Disagree (%)	Disagree (%)	Neither Agree nor Disagree (%)	Agree (%)	Strongly Agree (%)	M	SD
I am confident I can lead others to accomplish a goal (n=574)	1.74	6.10	18.47	51.22	22.47	3.87	.89
I am confident I can encourage others to do their best (n=572)	.87	4.72	13.99	52.27	28.15	4.02	.83
I am confident I can produce high quality work (n=575)	.70	6.43	20.70	46.61	25.57	3.90	.88
I am confident I can respect the difference of my peers (n=573)	.70	.87	9.95	44.85	43.63	4.30	.74
I am confident I can help my peers (n=575)	1.04	2.43	13.04	54.43	29.04	4.08	.78
I am confident I can include others' perspectives when making decisions (n=573)	.70	2.27	16.58	52.71	27.75	4.05	.77
I am confident I can make changes when things do not go as planned (n=575)	1.39	3.83	17.91	49.91	26.96	3.97	.85
I am confident I can set my own learning goals (n=571)	1.40	4.03	14.54	45.01	35.03	4.08	.88
I am confident I can manage my time wisely when working on my own (n=573)	1.57	7.50	23.21	45.03	22.69	3.80	.93
When I have many assignments, I can choose which ones need to be done first (n=576)	1.74	3.99	15.28	45.66	33.33	4.05	.90
I am confident I can work well with students from different backgrounds (n=576)	1.39	1.91	15.45	41.67	39.58	4.16	.85

The numbers in Table 14 indicate the percentage selection for students' attitudes toward learning styles. Table 14 also displays the mean and standard deviation per item showing the average response per item. Two items had strong agreement in this section, indicating students were confident they could respect differences in their peers (*M* = 4.30, *SD* = .74), and they felt confident they could work well with students from different backgrounds (*M* = 4.16, *SD* = .85).

Table 15 outlines the data collected for each item indicating the "Your Future" composite variable. Percentage of response, mean score, and standard deviation are represented for all 12 items that compose the "Your Future" variable, which measures student interest in STEM careers.

Table 15

Percentage Responses, Mean, and Standard Deviation for Career Interests (N= 580)

Survey Item	Not at all Interested (%)	Not so interested (%)	Somewhat interested (%)	Very Interested (%)	Extremely Interested (%)	M	SD
Physics: is the study of basic laws governing the motion, energy, structure, and interactions of matter. This can include studying the nature of the universe (n=574)	11.85	24.39	40.59	15.85	7.32	2.82	1.07
Environmental Work: involves learning about physical and biological processes that govern nature and working to improve the environment. This includes finding and designing solutions to problems like pollution, reusing waste, and recycling (n=574)	9.41	24.22	35.54	22.13	8.71	2.97	1.09
Biology and Zoology: involve the study of living organism and the process of life. This includes working with farm animals and in areas like nutrition and breeding (n=575)	9.22	21.39	30.78	23.48	15.13	3.14	1.19

Table continued

Table 15 (continued)

Percentage Responses, Mean, and Standard Deviation for Career Interests (N= 580)

Veterinary Work: involves the science of preventing or treating disease in animals (n=574)	9.23	15.51	29.44	28.05	17.77	3.30	1.20
Mathematics: is the science of numbers and their operations. It involves computation, algorithms and theory used to solve problems and summarize data (n=574)	18.12	21.78	29.79	18.82	11.50	2.84	1.25
Medicine: involves maintaining health and preventing and treating disease (n=572)	7.52	15.56	28.67	27.97	20.28	3.38	1.19
Earth Science: is the study of earth, including the air, land, and ocean (n=572)	9.62	18.71	31.82	25.35	14.51	3.16	1.18
Computer Science: consists of the development and testing of computer systems, designing new programs and helping others to use computers (n=574)	10.80	17.42	29.44	22.30	20.03	3.23	1.26
Medical Science: involves researching human disease and working to find solutions to human health problems (n=575)	6.96	17.39	27.83	25.57	22.26	3.39	1.20
Chemistry: uses math and experiments to search for new chemicals, and to study the structure of matter and how it behaves (n=575)	12.87	21.22	25.57	25.39	14.96	3.08	1.26
Energy: involves the study and generation of power, such as heat or electricity (n=573)	12.04	24.61	31.41	20.59	11.34	2.95	1.18
Engineering: involves designing, testing, and manufacturing new products (like machines, bridges, buildings, and electronics) through use of math, science, and computers (n=577)	9.53	14.04	26.17	25.48	24.78	3.42	1.26

The numbers in Table 15 indicate the percentage students selected for each response option for interest in STEM careers. Table 15 also displays the mean and standard deviation per item showing the average response per item. Students indicated that engineering was their preferred career (*M* = 3.42, *SD* = 1.26). Three other careers were also of interest: medical science (*M* = 3.39, *SD* = 1.20); veterinary work (*M* = 3.30, *SD* = 1.20); and medicine (*M* = 3.28, *SD* = 1.19).

Finally, data indicated congruent findings with the Friday Institute for Educational Innovation, showing that students were most favorable toward 21st century learning skills than the other three constructs measuring self-efficacy towards STEM.

Table 16

Mean Scores and Standard Deviation for Each Composite Variable Measuring Self-efficacy in STEM

Survey Variable	M	SD
Math Attitudes (n=580)	3.30	.94
Science Attitudes (n=580)	3.44	.60
Engineering & Technology Attitudes (n=580)	3.68	.70
21st Century Learning (n=576)	4.02	.60

In Table 16, students favored 21st century learning skills with a mean composite score of 4.02 compared to their attitudes toward math, science, and engineering and technology (3.30, 3.44, 3.68). Similar findings were indicated by the Friday Institute for Educational Innovation with a mean composite score of 4.00 for 21st century learning skills, and composite means of 3.6, 3.4, and 3.4 for math, science, and engineering and technology variables (Friday Institute for Educational Innovation, 2012b).

Overall, students felt confident they could do well in math and science. Students also indicated they wanted to use their creativity and innovation to create and design things people will use to improve their lives. Data also show that students respect each other's differences and work well with students of different backgrounds. These attitudes of collaboration and creativity towards STEM areas were supported in their choice of engineering as their most selected STEM career, creating, designing, and testing new products for others.

Research Question 1 Analysis

Because only 11% of the STEM workforce in the United States identifies as Black or Latino, I wanted to know if there was a correlation between students' self-efficacy in STEM and career interest in underrepresented groups (NSF, 2017). As such, my first research question was:

1. What is the relationship between students' self-efficacy in STEM and career interest in STEM fields?

A Pearson's *r* correlation was run between the four different variables and career interest to see if there was a statistically significant relationship. Table 17 presents the Pearson's *r* correlation between each variable.

Table 17

Correlation Between Four Variables of STEM Attitudes and Your Future in STEM Careers (N= 580)

	Math Attitudes (n=580)	Science Attitudes (n=580)	Engineering & Technology Attitudes (n=580)	21st Century Learning (n=576)	Your Future (n=577)
Math Attitudes	-				
Science Attitudes	.36**	-			
Engineering & Technology Attitudes	.37**	.53**	-		
21st Century Learning	.39**	.42**	.46**	-	
Your Future	.39**	.51**	.56**	.35**	-

**$p < 0.01$.

The numbers in Table 17 above indicate the relationship between the four construct variables indicating students' self-efficacy in STEM and the "Your Future" construct measuring student interest in different STEM careers. To determine strength of the correlation, Laerd Statistics' (2018) guidelines were used: small association (.1 to .3); medium association (.3 to .5); and large association (.5 to 1). There was a statistically significant moderate relationship between math attitudes and "Your Future" ($r = .39$, $p < .001$) such that an increase in math attitudes also showed an increase in the interest in a STEM career. Similarly, an interest in STEM careers has a relationship with student's attitude towards math. There was also a statistically significant large relationship between science attitudes and "Your Future" ($r = .51$, $p < .001$) such that an increase in science attitudes also showed an increase in the interest in a STEM career. There was a statistically significant large relationship between engineering and technology attitudes and "Your Future" ($r = .56$, $p < .001$) such that an increase in engineering and technology attitudes also showed an increase in the interest in a STEM career. There was a statistically significant weak relationship between 21st century learning attitudes and "Your Future" (r = .35, p < .001) such that an increase in 21st century learning attitudes also showed an increase in the interest in a STEM career.

Research question 1 conclusion. For each construct variable, math attitudes, science attitudes, engineering and technology attitudes, and attitudes toward 21st century learning, there was a statistically significant positive relationship with the "Your Future" construct measuring students' interest in STEM careers. As students' math attitudes increased, their interest in STEM careers increased as well, even though such correlations are not causal. This is also true of the other relationships between STEM careers and science attitudes, engineering and technology attitudes and attitudes towards 21st century learning.

Research Question 2 and 3 Analysis

The purpose of the first research question was to investigate the relationship between students' self-efficacy in STEM and STEM career interests in the entire study population. The purposes of the second and third research questions were to see if there were differences that existed between two student groups in the research population, those engaged with NGSS instruction and those who were not. The following research questions guided this portion of the study:

2. How does student interest in STEM careers differ between students who engage with NGSS instruction and students who engage with traditional instruction?
3. How does students' self-efficacy in STEM differ between students who engage with NGSS instruction and students who engage in traditional instruction?

Survey results. To learn if there was a difference between NGSS and non-NGSS classrooms regarding self-efficacy in STEM and interest in STEM careers, independent *t*-tests were run between the two student groups for each variable. Table 18 represents the reported data from the independent samples *t*-tests run between the two groups.

Table 18

Independent t-Test Results Comparing NGSS-Aligned and Non-NGSS-Aligned Student Groups (N= 580)

	NGSS		Non-NGSS				
	M	SD	M	SD	*t*	df	*p*
Math Attitudes	3.26	.98	3.35	.90	-1.14	578	.25
Science Attitudes	3.46	.55	3.41	.65	.80	561	.43
Engineering & Technology Attitudes	3.67	.67	3.70	.72	-.59	578	.55
21st Century Learning	4.03	.57	4.02	.62	.33	574	.74
Your Future	3.14	.78	3.14	.83	-.01	575	.99

Levene's test for equality of variance showed four out of five variables did not have significance, including math attitudes, engineering and technology attitudes, attitudes toward 21st century learning, and "Your Future" with $p > .05$, therefore equal variance could be assumed. Equal variances could not be assumed for the science attitudes variable with $p = .04$; therefore, a *t* statistic not assuming homogenity of variance was calculated.

There was no significant mean difference between NGSS and non-NGSS student groups on their attitudes towards math ($t(578) = 1.14$, $p = .25$) such that NGSS students did not have higher self-efficacy in math ($M = 3.26$, $SD = .98$) than non-NGSS students ($M = 3.35$, $SD = .90$). There was no significant mean difference between NGSS and non-NGSS student groups on their attitudes toward science ($t(560.91) = .80$, $p = .43$) such that NGSS students did not reflect higher self-efficacy in science ($M = 3.46$, $SD = .55$) than non-NGSS students ($M = 3.41$, $SD = .65$). There was no significant mean difference between NGSS and non-NGSS student groups on their attitudes toward engineering and technology ($t(578) = .59$, $p = .55$) such that NGSS students did not reflect higher self-efficacy in engineering and technology ($M = 3.67$, $SD = .67$) than non-NGSS students ($M = 3.70$, $SD = .72$). There was no significant mean difference between NGSS and non-NGSS student groups on their attitudes toward 21st century learning skills ($t(574) = 1.14$, $p = .33$) such that NGSS students did not reflect higher self-efficacy in 21st century learning skills ($M = 4.03$, $SD = .57$) than non-NGSS students ($M = 4.02$, $SD = .62$). There was no significant mean difference between NGSS and non-NGSS student groups on their interests in STEM careers ($t(575) = .01$, $p = .99$) such that NGSS students did not reflect higher interest in STEM careers ($M = 3.14$, $SD = .78$) than non-NGSS students ($M = 3.14$, $SD = .83$).

Research question 2 and 3 conclusion. Overall, there was no significant difference between the two student groups, students engaged with NGSS-aligned instruction and those in traditional classrooms. The *p* value was greater than .05, which indicated there was no significant difference between the two means.

Conclusion

There was a statistically positive relationship between self-efficacy in STEM and career interests. Students who have higher self-efficacy in STEM do have a higher interest in STEM careers, and there is also a reciprical relationship between students with higher interest in STEM careers having a higher self-efficacy in STEM. With regards to NGSS implementation, there was no statistically significant difference between the two groups of students, those who engaged with NGSS instruction in the classroom and those who did not. Reasons for this are discussed in Chapter 5.

CHAPTER 5

DISCUSSION

Introduction

With only 11% of the STEM workforce composed of Black and Latino men and women, there is a strong need for change in science education to encourage more representation of these underrepresented groups (NSF, 2017). This not only is important for individual equity, but also has implications for the diversification of the workforce and society. It is important that the workforce mirrors the composition of the population, ensuring the proposed STEM solution to a problem serves the entire population. With greater diversity in the STEM fields and a wider range of individuals at the forefront of innovation, involving different perspectives will put forward more creative solutions.

Per the implementation of the Next Generation Science Standards (NGSS), the belief is that students should be learning information in class by co-constructing knowledge with their classmates, practicing the skills real scientists use in their jobs, and connecting what they learn in school to their personal lives. These standards have the potential to address known barriers for underrepresented groups. For one of the first times in science education history, diversity and equity and access were at the forefront when creating these new standards, and quickly a motto developed: "all standards, all students."

Every student, no matter what background, should be able to access the standards in an authentic way. One of the main barriers to seeking a science degree or career is a student's self-efficacy. According to Archer et al. (2014), students are curious and interested in science until age ten, and then their attitudes toward science decline until age 14. This middle school age is crucial to stopping a small leak in the STEM pipeline, especially in populations composed of students of color.

The purpose of this study was to understand the relationship between middle school students' self-efficacy in STEM and career interests, as well as compare student groups to look for differences based on engagement with NGSS in the classroom. The following research questions guided the study:

1. What is the relationship between students' self-efficacy in STEM and career interest in STEM fields?
2. How does student interest in STEM careers differ between students who engage with NGSS instruction and students who engage with traditional instruction?
3. How does students' self-efficacy in STEM differ between students who engage with NGSS instruction and students who engage with traditional instruction?

Discussion of Findings

The findings were clear that there was a relationship between students' self-efficacy in STEM and their career interests; however, there was no difference between the groups of students experiencing NGSS-aligned instruction and those experiencing traditional instruction.

Finding 1

The first finding showing the positive relationship between students' self-efficacy in STEM and their career interest in STEM coincides with recent research—if students believe they can do something, they are more likely to do it. All four variables when correlated with STEM career interests showed a moderate positive relationship, but not all variables were of equal importance. Science and engineering had a larger association with future career interests than math did. Both attitudes towards science and engineering had a correlation with future careers above .5, compared to the correlation of attitudes towards math and learning styles with career interests, which were only above .35, thus indicating a stronger relationship between science/ engineering attitudes and future careers. When analyzing career interests, there was a divide in interests between life sciences and physical science, which has been seen in prior research. Fewer people feel confidence or have a positive self-efficacy towards the physical sciences, including physics and chemistry. This is heightened for underrepresented students because stereotype threat "was associated with lower self-efficacy in chemistry and physics" (Sunny et al., 2017, p. 161).

Although math and science had varying degrees of association with future careers, students agreed that knowing math and science together would allow them to invent useful things and help others. This connection between the STEM fields is an important portion of NGSS and supports the implementation of the standards in theory, which includes the interconnected nature of science. As stated by Cunningham and Carlsen (2014), "engineering and technology provide a context in which students can test their own developing scientific knowledge and apply it to the practical problems; doing so enhances their understanding of science—and, for many, their interest in science—as they recognize the interplay among science, engineering and technology" (p. 207). This is supported by a strong correlation between engineering and technology and science attitudes.

This notion of collaboration was also reflected in the 21st century skills analysis with the highest scoring items being "students respect different opinions" and are "confident with working well with people of different backgrounds." The skills selected are essential to a STEM workforce because no matter what field, "they all have one thing in common: It's about moving forward, solving problems, learning, and pushing innovation to the next level" (Gerlach, 2012, p.

1). Working with people of various backgrounds and feeling confident to create and innovate are essential components of these STEM careers. Combining confidence with people and innovation, there is no surprise that the most selected careers of interest were medicine and engineering.

These positive attitudes towards 21st century skills and careers in engineering and medicine shape a different narrative than what was previously reported by Hughes (2001) and Archer, DeWitt, and Osbourne (2015). Their work focused on students not seeing the connection between scientific principles and what they encounter in their life. In terms of “usefulness,” as is discussed in Chapter 2, students previously stated, “I’m not very good at remembering a lot of stuff” (Archer et al., 2015, p. 215) and “I’ll understand the basic principles that doesn’t really fit anything that I will ever encounter in my entire life” (Hughes, 2001, p. 281). The data offer another perspective, showing that students can see the connection between subjects, see the value in the subject for the future, and want to help others by using engineering. Students consistently highly agreed with statements that related a subject to their life outside of school and to their future lives.

Finding 2

The second finding, that there was no difference between students in the NGSS-aligned group and the students in the non-NGSS-aligned group, spurs multiple explanations, including (a) transition time, (b) measurement error, (c) definition of variables, and (d) lesson plan alignment.

Transition time. A transition to brand new science standards, that are drastically different from their predacessor, takes time. This study occurred in year five of the transition to new standards, which is early on for a transtiion of this magnititude. Not only do teachers need to learn the new standards, they need to learn the new teaching methods and change their classroom pedagogy. Students also have to change their views on school, challenging what they have been doing in school since they entered kindergarten, applying their knowledge rather than memorizing. Bybee and Pruitt (2017) predicted that it can take anywhere from “7-10 years to change over to full implementation” (p. 304). The network still has a considerable amount of time to make progress to a full implementation, changing mindsets and pedagogical classroom techniques to match the rigor of the NGSS.

Measurement error. The Student Attitudes Towards STEM (S-STEM) survey, developed by the Friday Institute for Educational Innovation, reported that the measure was a survey about attitudes towards STEM, which taken together as a construct measured self-efficacy in STEM. It was reported to have strong reliability with Cronbach αs being above .89; however, after running statistical analyses my Cronbach αs were above .70, which were different when compared to the Friday Institute for Educational Innovation numbers. One explanation was the use of negatively worded items that were required to be reversed scored for data analysis. Students might have read the statement to be positive, thus marking an opposite response. Barnette (1997) encouraged the use of directly worded stems to increase the reliability of the measure. The math attitudes section of the survey had three negatively worded items that needed reverse scoring and had to be thrown out based on the Cronbach α, thus reducing the composite variable to five items on student’s self-efficacy in math. The science attitudes section also had a negatively worded item that decreased the Cronbach α; however, because it was only one item and the alpha was in the acceptable range, it was left in the analysis. Another explanation for different Cronbach α numbers was the variability in the surveyed population for this study, compared to the Friday Institute for Educational Innovation’s study. The Cronbach α was based on the sample who took the survey, rather than the survey itself, therefore, the numbers that were reported by both studies were not the same because different populations took the survey.

Definitions of variables. As discussed earlier, the S-STEM was a measure of attitudes towards STEM that taken together as a construct measured students' self-efficacy in STEM. Therefore, there were attitudinal questions that were used to measure a belief in self (Bandura, 1977). Within each section of the survey, there was a conflation of the definitions between attitudes and self-efficacy. Certain questions were worded in a way that would imply an attitude towards something (*Knowing science will help me earn a living*), and others were worded as a belief about oneself (*I know I can do well in science*). Other researchers have also used attitudinal items to measure self-efficacy. Fraze, Wingenbach, Rutherford, and Wolfskill (2011) used an attitudinal survey to measure self-efficacy towards agriculture. Although they stated upfront that their survey was measuring both attitudes and self-efficacy, their items were disproportionately attitudes only. Based on this, the S-STEM should be called not just a survey on attitudes towards STEM, but rather a survey on both attitudes and self-efficacy towards STEM. The analysis should also parse out attitudinal and self-efficacy questions.

Each section of the S-STEM had a mixture of self-efficacy and attitudinal questions. In the math section, four of the five included items were self-efficacy focused, such as "I am sure I could do advanced work in math." In the science section, four of the nine items were worded to measure self-efficacy, including "I am sure of myself when I do science." The engineering and technology section only had one out of nine items focused on self-efficacy. Most questions were attitudinal in nature, such as "I am interested in what makes machines work." Finally, the 21st century learning skills section of the survey contained the highest number of items measuring self-efficacy. Ten out of 11 items were worded with the stem "I am confident." This phrase implies an internal look at self, with items like “I am confident I can help my peers” and “I am confident I can make changes when things do not go as planned.” This conflation of terms should be changed or named as it implies that both attitudes and self-efficacy are the same. Although previous research does use attitudinal items to measure self-efficacy, an attitude towards a subject is differenent than ones belief in success in that subject, and therefore should be stated in the measure. There should be an attitudes section and a self-efficacy section to parse out the difference between the terms and represent the variable in a more authentic way. If all the sections of the survey are measuring a portion of STEM, then each section should contain items that sound similar. For example, if the first item in the math section is “I am good at math,” then there should be a similar question in every section following: “I am good at science” and “I am good at engineering,” which would lead to a more consistent analysis of the variable named “attitudes toward STEM.”

Lesson plan alignment. An evaluation of lesson plans was used in this study to determine the student groups to answer research questions two and three, which focused on the difference between NGSS and non-NGSS-aligned classroom experiences. This determination was done by looking at five lesson plans submitted by teachers in their typical planning format. The formats varied across teachers and schools, and although they were asked to submit lesson plans that reflected their teaching cadence, they might not have done so. Writing an NGSS-aligned lesson and implementing it with fidelity can mean two different things and might have contributed to the lack of significant difference between the two groups of students with varying degrees of implementation consistency.

Finding 3

Building off of the lack of NGSS alignment in the lesson plans and evaluating the study as a whole, I find that standards are not enough to ensure equity in science education. Old science standards, pre-NGSS, were developed under the notion that there are a set of informational constructs that students need to know across the state and were measured on a state assessment once a year. Although this is a part of the NGSS, there was a significant switch with the development of these new standards focusing on a pedagogical shift in teaching science. This needs to be acknowledged in the development of classroom lessons and implementation of those lessons with the students. The standards were developed with equity at the forefront (NGSS Lead States, 2013a), but a significant amount of work still needs to be done to change mindsets of educators as they write lesson plans with the new standards and adapt their thinking about what science looks like for their students.

Previous research supports that positive self-efficacy can lead to an increase in achievement and interest in science (Bandura et al., 2001; Fong & Krause, 2014). Although this study was not focused on achievement, it is important to focus on the root of students' self-efficacy to increase interest in science. Self-efficacy is the belief that one can "successfully execute the behavior required to produce the outcomes" (Bandura, 1977, p. 193), which is influenced by external and internal factors. Teachers can plan for some of these external factors in their classes, increasing the internal narratives that students have to increase their overall self-efficacy. For example, teachers can positively reinforce students' engagement in science and engineering practices, and they can set up their lessons to increase student dialogue and co-construction of knowledge to change their preconceptions. Finally, they can plan lessons that link to students' personal lives, utilizing students' funds of knowledge to contribute to the understanding of a scientific concept. By planning for these external factors, students can have more mastery experiences, thus changing their internal narrative contributing to a more positive self-efficacy.

Limitations

As is mentioned in previous chapters, there are seven major limitations to this study. One, this study was quasi-experimental in nature, using predetermined groups of participants. This limitation prompts future research opportunities. The second limitation, student interest in STEM is a complex variable with many different contributing factors, can be explored further in future research as well. It has implications for the current state of the science program being implemented in this network of schools. The third limitation is that teacher styles may differ in both what they submitted in their lesson plan and their actual classroom instruction. This limitation effects future studies and has implications for professional development for teachers and teacher preparation programs. The fourth limitation is measurement error through the definition of variables and reliability measures. This limitation guides a recommendation for a revision of the actual survey design. The fifth limitation is student self-reported data, which is a limitation of the research design, but it could be used in future research to combine with student achievement data that is not self-reported. The sixth limitation is my dual role as researcher and network administrator, which leads to future research in alternative networks. Lastly, self-efficacy takes time to develop and with NGSS still being in the early phases of transition, students and teachers need more time to evolve with the rigors expected in the standards.

Future Research

The findings and the limitations above give rise to many future research studies, including repeating this study redesigned as an experiment. Due to the variability in lesson plans, a fully experimental design could control for the variability in lesson plan execution. An NGSS-aligned unit would need to be designed first. Then, teachers would need to be trained on the delivery of the unit for execution purposes. Finally, the S-STEM could be given before and after the delivery of the NGSS-aligned unit to see if change existed in student's self-efficacy and attitudes toward STEM. A control group would also be established so that there could be a comparison of the group that received NGSS-aligned instruction and those who did not. The focus of this design would be to control the exposure of NGSS to the students to see if there is a difference between groups; however, this would not address the teacher's delivery differences completely.

Another study that could build off this one would also focus on study design, exploring the qualitative side of data collection, including student interviews or focus groups. Although trends can be established through the use of quantitative data, qualitative data could be used to discuss the trends and help identify reasons for the quantified trends. A few questions that I would include for this future study are the following:

1. How did you become interested in engineering and technology?
2. How do you interact with your peers during class?
3. How do you see science and engineering working together?

Although the purpose of this study was not focused on achievement, there is research that suggests that students with stronger self-efficacy also perform better on assessments (Bandura et al., 2001). A future study could see if there is a relationship between self-efficacy and achievement in science. The study could pull data on state assessments such as the California Science Test (CAST), which will be operational in 2019, TIMSS, and common assessment data from classes, which address the limitation of self-reported data from the S-STEM.

To increase generalizability beyond one network and to address the limitation of the researcher also being a network administrator in which the research was done, the study should be repeated in another network. Also, the study should be repeated in a few years, once the state has reached 7-10 years of implementation, as change at the instructional practice level takes many years (Bybee & Pruitt, 2017).

Implications

This section discusses the theoretical implications based on my proposed conceptual framework in Chapter 2, heightening the importance of constructivism on student's self-efficacy in an NGSS classroom. This section also discusses implications for practice and policy.

Theoretical Implications

In my proposed conceptual framework in Chapter 2, the foundation of an NGSS-aligned classroom was the three dimensions of NGSS, sustained through a continuum of constructivism in which students reflect on their current understanding to then socially construct knowledge with others, potentially increasing self-efficacy. This was supported through the literature from the NGSS Lead States (2013a), which documented that the three dimensions of NGSS would increase understanding of the interconnected nature of science and students would be learning through application of knowledge through real-world tasks (Quinn, 2015). The intersection of the three dimensions was the primary focus of the evaluations of lesson plans, which led to the student groups that were asked to participate in the survey. Although constructivism is emphasized in the approach to NGSS with the encouragement of the 5E lesson design, it might not be implemented in true effect in the classroom.

The importance of constructivism should be widened across instruction throughout the K-12 education system. The data support the notion that constructivism is an important part of self-efficacy in STEM with strongly agree and agree confirmations on items surrounding social construction of knowledge, specifically working with peers. In Bandura's (1977) explanation of self-efficacy, verbal persuasion and vicarious feedback are social aspects of self-efficacy. This is supported in the data with items such as "I am confident I can help my peers" and "I am confident I can encourage others to do their best," which both had high average ratings. This agreement surrounding conversations with others also aligns with research from Fosnot (1993), who discussed that knowledge is "socially and culturally mediated" (p. 69), and with Ash (2004), that collaboration progresses students' understanding of content.

Implications for Practice

Although there has been some movement in the implementation of NGSS, with three of the teachers in this study aligning with NGSS, there was still no difference between the two groups with regards to STEM attitudes and interests in STEM careers. In a change movement this large, Bybee and Pruitt (2017) predicted that it will take anywhere from 7-10 years to change over to full implementation of the new standards seen through teaching practices (p. 304). Considering it is still in the early years of implementation (year 5), I am glad to see movement on the planning side; however, the plans are not translating into the classroom. Because the standards are not just changing the amount of information taught in a classroom, but rather a way of teaching as well, the change process has to go through multiple rounds or zones of transition. Bridges and Bridges (2016) stated that in a transition "there is an ending, then a neutral zone, and only then a new beginning" (p. 110). It is hard to jump right to the new beginning without mourning the old lessons that teachers loved to teach. To move through this mourning period, teachers need time to see the difference between their old lessons and the rigors of the new standards. Further, they need support from peers who have worked with NGSS and direct feedback on their progress in the shift. As teachers learn more about the standards and pedagogy, they can then start to get to the implementation "neutral zone" and through feedback reach the "new beginning zone."

Allowing ample time for the transition is not only for teachers and administrators but also students. This type of schooling is different from what they have previously experienced, and although the data support a more collaborative and personalized classroom, students will still need to move through the zones of transition. This prompts many guiding questions for the future:

1. If students are engaging in more NGSS-aligned classrooms through sixth, seventh, and eighth grade, will their attitudes and their self-efficacy change?
2. Will their career interests change?
3. Does more time in an aligned classroom lead to an increase in their scientific identity because they have been able to experience mastery experiences more often (Carlone & Johnson, 2007)?

Professional development for teachers and administrators is necessary to move through the zones, especially focusing on increasing the constructivist pedagogy in the classroom, increasing the frequency of the application of science to real-world problems, and making science more personalized to the students. Students said that they want to use their creativity and collaboration to build solutions to problems, so the lesson plans should reflect those types of activities. Building a more personalized curriculum (Ladson-Billings, 2016) that reflects students' lived experiences (Martin, 2016) and builds off of their funds of knowledge (Dunac & Demir, 2017) is important to focus on in the professional development for teachers and administrators.

Policy Implications

Approving the standards was a huge accomplishment and movement in the right direction; however, approving standards and implementing them are two different things. Approving them does not guarantee equity and access in schools. The first step is to ensure that all students have equal access to science courses; this an inclusive process and an expectation that all students can do science. If time in science class is linked to an increase in self-efficacy, students need to be engaged in science at a young age and continue for all of their years in school. Elementary schools struggle to make time for science, and by middle school, although students have science classes their interest and curiosity in science have declined (Archer et al., 2015). Considering time in science classes is important for STEM self-efficacy, policy makers should consider time as a factor when determining requirements for students.

The second step to implementation is making sure that teachers have the skills to plan and facilitate a three-dimensional constructivist NGSS-aligned lesson. For current teachers, this means having access to high-quality and frequent professional development. For future teachers, this means having teacher preparation programs that address student needs in every course that is required in the program. With the adoption of the new Teaching Performance Expectations (TPE) by the California Commission on Teacher Credentialing in 2016, there is movement to focus on engaging and supporting all students, which aligns to the NGSS nicely; however, it falls into the same trap of a long implementation process.

Recommendations

The limitations and findings of this study led to three major recommendations at various levels of the educational system. At the microscopic level, the first recommendation is to redesign the S-STEM, taking out the negatively worded reversed-scored items, disaggregating the self-efficacy and attitudinal items, and increasing the consistency of the items in each section of the survey. Moving up the educational system, the second recommendation is an evaluation of the science program at the district and school level. Finally, at the top of the educational system, the third recommendation is offering free statewide professional development to teachers and administrators, changing the high school science requirement to three years, and evaluating teacher preparation programs to incorporate culturally relevant pedagogy and constructivist views of education throughout the program.

District and School Level

School districts and schools should evaluate their science program by answering the following questions:

1. Does every student have access to the science content required by the state of California?
2. How are students progressing through the learning over the multiple years they are in school? What content and skills are being taught at every grade level? What level of 21st century skills and engineering are embedded in every course?
3. Do the lessons include the students' cultural backgrounds and a constructivist 5E approach to learning?
4. What supports are available to teachers, administrators, and parents to enhance their understanding of NGSS?

Every student should have access to a high-quality science education that is culturally relevant and connected to their community and encourages their application of science to the real world. The data suggest that students see the value in the interconnectedness of math and science and are interested in engineering, helping others, and medicine; therefore, an increased integration of these themes should be established in their classes. In middle schools, the data suggest an integrated science sequence that increases the connections between sciences, life science, physical science, and earth and space sciences, as well as an engineering lens in every course. For high school, the data suggest at least three years of science so that students have access to all of the standards with an engineering lens in every course as well. Administrators can support this integrated approach to their science sequence by learning about NGSS and becoming advocates for the work. Administrator teams and teachers should go together to state or local science conferences to discuss and plan integrated lessons, units, and science sequences for their school.

As student interest in STEM is a complex variable, with exterior factors like mentorships and physical lab spaces influencing the variable, one recommendation would be starting in the middle school grades students have access to mentors or STEM professionals who come to school to talk to them about STEM careers, preferably professionals who reflect the population of the schools. With regards to physical lab spaces, NGSS require a hands-on approach to learning science, and therefore, students in high school should have access to a lab space and lab equipment. The goal of NGSS, “all standards, all students,” goes beyond enrolling students in the right courses; it means giving equal access to the lab equipment that is required to meet the rigors of NGSS’ performance expectations. The NGSS require engineering in every course, and the student data suggest that students are interested in engineering solutions to the world’s problems, which cannot be done without supplies. Principals should use their Local Control and Accountability Plans (LCAPs) to budget appropriately to ensure all labs will be stocked for every student to engage in hands-on science.

State and Higher Education Level

Although the state might not want to supply lab equipment for every school, at the very least statewide science professional development should be offered by the California Department of Education free of charge. The state board has been supportive of adopting the NGSS, however; there are few state initiatives to offer professional development to teachers, administrators, and parents supporting the implementation of the standards.

Whereas the current state high school science requirement is two years of science, one life science and one physical science, it needs to change to at least three years of science to increase access to science content. With the adoption of NGSS in 2013, life science, physical science, earth and space science, and engineering and technology are now all requirements by the state. To allow equal access to science content and reach all standards for all students, three years of science is more realistic for students to develop their knowledge and application of science at a deeper level than ever before.

Finally, there needs to be an evaluation of teacher preparation programs. Given the pedagogical shifts that are expected with NGSS and the importance of culturally relevant pedagogy, it is incumbent upon teacher preparation programs to actively change their curriculum to match that which is adopted by the state. With the adoption of the new California TPE in 2016, universities are starting to work on their programs to incorporate these new expectations. The state requires universities to identify where in the program trajectory students will be introduced, given time to practice, and subsequently assessed on the TPE. This is a step in the right direction; however, adopting and implementing are on two different change timelines, which was seen with the transition to NGSS. The TPE do show promise and alignment to the NGSS with most of them focusing on engaging and supporting all students in their learning through interactive learning environments and appropriate content pedagogy (Commission on Teacher Credentialing, 2016).

Conclusion

Science education is getting an overhaul again through a standards reform focused on active science learning to create science-literate citizens who are able to interact with and impact the ever-changing world. Although scientifically literate students is one goal of science education, another is to increase interest in STEM careers, which has been proven to be associated with how students feel about STEM subject areas as well as their self-efficacy in those subjects. Research has shown that students of color have lower self-efficacy in STEM subjects and have less access to quality science courses. The standards call for “all standards, all students,” which necessitate special attention to underrepresented groups. Although this implementation is early in its transition, student data show that students are interested in the NGSS style of learning, collaborating with others, making connections between ideas, and building solutions to problems they are facing in their community. It is not about getting through the content; rather, it is about having students apply what they learn to the world. Increasing this connection to real life in the classroom not only increases equity for the individual, but also increases the diversity in perspectives needed to solve the ever-changing problems the world is facing.

If the NGSS are to offer a different impact than other science reforms, the state, school districts, and schools must stay true to this style of learning and increase the construction of knowledge with students. This is one way to reimagine a new STEM pipeline and inspire students to go beyond the classroom and see science in their community.

APPENDIX A

Sample Principal Approval Letter

[Date]

[Name and address of addressee]

Subject: Doctoral Research Study

Dear _________________________,

As principal of ___[Name of school]____, I confirm that the school site grants permission for the proposed research to be conducted once IRB approval has been obtained. The research will take place at the school site. We support __[Name of researcher]__'s proposed research plan, which includes quantitative S-STEM survey data collection from all of our 6-8th grade students and teacher lesson plan collection to identify student groups. Assurance can be given that the survey data will be kept confidential and the letters of consent will be kept confidential. I understand that all survey data will be reported in the aggregate and that the aggregated data will also be shared with the Friday Institute for Educational Innovation. I have also read and approve the survey to be administered to students, which will take approximately 30 minutes during an advisory or class period.

The school does not have an IRB committee, but would like to acknowledge that we fully support the research study as outlined in the IRB questionnaire.

Sincerely,

[Name and Signature]
____
Principal

APPENDIX B

Sample Informed Consent Form for Parents

[Date]

Loyola Marymount University

Student Attitudes Toward Science, Technology, Engineering, and Mathematics (STEM) fields.

1) I hereby authorize the invesitgator to include my child in the following research study: Self-Efficacy and STEM Career Interest in Black and Latino Middle School Students: A Study on the Next Generation Science Standards

2) My child will be asked to participate on a research project, which is designed to discover the relationships between attitudes toward STEM and interest in STEM careers by completing a survey during regular advisory time, 11:30-12:05, which could take up to 30 minutes. Advisory is intended to help students academically and social-emotionally through group discussion and individual time with the teacher.

3) I understand the reason for my child's inclusion in this project is that he/she is a middle school student.

4)I understand that if my child is a subject, he/she will complete a survey about his/her interests in STEM topics.

The investigator, will then compare the results of my child's attitudes toward STEM to their career interests. These procedures have been explained to me by the investigator.

I understand that the final results will be shared with the Friday Institute of Educational Innovation, because the Institute developed the survey.

5) I understand that the study described above may involve the following risks and/or discomforts: participants may feel nervousness because the survey may feel like a test. It will be explained to my child that this is not a test and there is no right or wrong way to answer. The choice to participate in the study will not affect your child's grade. Participants might also experience survey fatigue because it may take up to 30 minutes to complete, and all information will be kept confidential.

6) I also understand that the possible benefits of the study are being able to contribute to identifying patterns in attitudes towards STEM fields and contribute to the transition to the new science standards.

7) I understand that the investigator who can be reached at [phone number] will answer any questions I may have at any time concerning details of the procedures performed as part of this study.

8) If the study design or the use of the information is to be changed, I will be so informed and my consent reobtained.

9) I understand that I have the right to refuse to participate in, or to withdraw from this research at any time without prejudice.

10) I understand that circumstances may arise which might cause the investigator to terminate my participation before the completion of the study.

11) I understand that no information that identifies me will be released without my separate consent except as specifically required by law.

12) I understand that I have the right to refuse to answer any question that I may not wish to answer.

13) I understand that in the event of research related injury, compensation and medical treatment are not provided by Loyola Marymount University.

14) I understand that if I have any further questions, comments, or concerns about the study or the informed consent process, I may contact [insert name and phone number].

15) In signing this consent form, I acknowledge receipt of a copy of the form, and a copy of the "Subject's Bill of Rights."

Parent 's Signature ____ Date _____________

Name of Student ____ Date ____________

APPENDIX C

Student Attitudes Towards STEM Survey *(S-STEM)*

Start of Block: Block 1

Q1 You will be asked how you feel about science, technology, engineering, and math, as well as some career fields you might be interested in. You will need about 30 minutes to finish the survey on the computer, however if you need more time, it will be given to you.
RISKS: You may feel nervousness because this might feel like a test. This is not a test, and there is no right or wrong way to answer. You may also feel fatigue due to the survey length. **The choice to participate in the study will not affect your grade.**
BENEFITS: Survey results will help identify patterns in attitudes towards STEM fields and contribute to the transition to the new science standards.
PARTICIPATION: It is okay not to take the survey. It is your choice to participate and you can stop at anytime. The survey is confidential and your answers will not be connected to your name. The final report will be shared with the Friday Institute of Educational Innovation.
CONTACT: If you have questions, please raise your hand and I, Whitney McCormick, or Sheena Velasquez will answer your question as you complete the survey.
Consent to Participate: "I understand what the survey is for and that I do not have to participate. I choose to....

○ Yes, I agree to take the survey (1)

○ No, I do not want to participate (2)

Skip To: End of Survey If You will be asked how you feel about science, technology, engineering, and math, as well as some... = No, I do not want to participate

End of Block: Block 1

Start of Block: Default Question Block

Q2 Teacher

- [Teacher names will be filled in when determined] (1)
- Click to write Choice 2 (2)
- Click to write Choice 3 (3)
- Click to write Choice 4 (4)
- Click to write Choice 5 (5)
- Click to write Choice 6 (6)
- Click to write Choice 7 (7)
- Click to write Choice 8 (8)

Q3 Your Grade:

- 6th Grade (1)
- 7th Grade (2)
- 8th Grade (3)

Q4 Gender:

- Male (1)
- Female (2)
- Prefer not to say (3)

Q5 I identify as:

- ○ American Indian/Alaska Native (1)
- ○ Asian (2)
- ○ Black/African American (3)
- ○ White/Caucasian (4)
- ○ Hispanic/Latino (5)
- ○ Multiracial (6)
- ○ Other (7)

Q6 There are lists of statements on the following pages. Please mark how you feel about each statement.

As you read the sentence, you will know whether you agree or disagree. Fill in the circle that describes how much you agree or disagree.

Even though some statements are very similar, please answer each statement. This is not timed; work fast, but carefully.

There are no "right" or "wrong" answers! The only correct responses are those that are true to you. Whenever possible, let your personal experiences help you make a choice.

PLEASE FILL IN ONLY ONE ANSWER PER QUESTION.

Q7 Math

	Strongly Disagree (1)	Disagree (2)	Neither Agree nor Disagree (3)	Agree (4)	Strongly Agree (5)
Math has been my worst subject (1)	o	o	o	o	o
I would consider choosing a career that uses math (2)	o	o	o	o	o
Math is hard for me (3)	o	o	o	o	o
I am the type of student to do well in math (4)	o	o	o	o	o
I can handle most subjects well, but I cannot do a good job with math (5)	o	o	o	o	o
I am sure I could do advanced work in math (6)	o	o	o	o	o
I can get good grades in math (7)	o	o	o	o	o
I am good at math (8)	o	o	o	o	o

Q8 Science

	Strongly Disagree (1)	Disagree (2)	Neither Agree nor Disagree (3)	Agree (4)	Strongly Agree (5)
I am sure of myself when I do science (1)	○	○	○	○	○
I would consider a career in science (2)	○	○	○	○	○
I expect to use science when I get out of school (3)	○	○	○	○	○
Knowing science will help me earn a living (4)	○	○	○	○	○
I will need science for my future work (5)	○	○	○	○	○
I know I can do well in science (6)	○	○	○	○	○
Science will be important to me in my life's work (7)	○	○	○	○	○
I can handle most subjects well, but I cannot do a good job with science (8)	○	○	○	○	○
I am sure I could do advanced work in science (9)	○	○	○	○	○

Q9 Engineering and Technology
Please read this paragraph before you answer the questions.

Engineers use math, science, and creativity to research and solve problems that improve everyone's life and to invent new products. There are many different types of engineering, such as chemical, electrical, computer, mechanical, civil, environmental, and biomedical. Engineers design and improve things like bridges, cars, fabrics, foods, and virtual reality amusement parks. Technologists implement the designs that engineers develop; they build, test, and maintain products and processes.

	Strongly Disagree (1)	Disagree (2)	Neither Agree nor disagree (3)	Agree (4)	Strongly Agree (5)
I like to imagine creating new products (1)	○	○	○	○	○
If I learn engineering, then I can improve things that people use every day (2)	○	○	○	○	○
I am good at building and fixing things (3)	○	○	○	○	○
I am interested in what makes machines work (4)	○	○	○	○	○
Designing products or structures will be important for my future work (5)	○	○	○	○	○
I am curious about how electronics work (6)	○	○	○	○	○
I would like to use creativity and innovation in my future work (7)	○	○	○	○	○
Knowing how to use math and science together will allow me to invent useful things (8)	○	○	○	○	○
I believe I can be successful in a career in engineering (9)	○	○	○	○	○

Q10 21st Century Learning

	Strongly Disagree (1)	Disagree (2)	Neither Agree nor Disagree (3)	Agree (4)	Strongly Agree (5)
I am confident I can lead others to accomplish a goal (1)	○	○	○	○	○
I am confident I can encourage others to do their best (2)	○	○	○	○	○
I am confident I can produce high quality work (3)	○	○	○	○	○
I am confident I can respect the difference of my peers (4)	○	○	○	○	○
I am confident I can help my peers (5)	○	○	○	○	○
I am confident I can include others' perspectives when making decisions (6)	○	○	○	○	○
I am confident I can make changes when things do not go as planned (7)	○	○	○	○	○
I am confident I can set my own learning goals (8)	○	○	○	○	○
I am confident I can manage my time wisely when working on my own (9)	○	○	○	○	○

When I have many assignments, I can choose which ones need to be done first (10)	○	○	○	○	○
I am confident I can work well with students from different backgrounds (11)	○	○	○	○	○

Q11 Your Future

Here are descriptions of subject areas that involves math, science, engineering and/or technology, and lists of jobs connected to each subject area. As you read the list below, you will know how interested you are in the subject and the jobs. Fill in the circle that relates to how interested you are.

There are no "right" or "wrong" answers. The only correct responses are those that are true for you.

	Not at all Interested (1)	Not so Interested (2)	Somewhat Interested (3)	Very Interested (4)	Extremely Interested (5)
Physics: is the study of basic laws governing the motion, energy, structure, and interactions of matter. This can include studying the nature of the universe. (1)	○	○	○	○	○
Environmental Work: involves learning about physical and biological processes that govern nature and working to improve the environment. This includes finding and designing solutions to problems like pollution, reusing waste and recycling. (2)	○	○	○	○	○
Biology and Zoology: involve the study of living organisms and the processes of life. This includes working with farm animals and in areas like nutrition and breeding. (3)	○	○	○	○	○
Veterinary Work: involves the science of preventing or treating disease in animals. (4)	○	○	○	○	○

Mathematics: is the science of numbers and their operations. It involves computation, algorithms and theory used to solve problems and summarize data. (5)	○	○	○	○	○
Medicine: involves maintaining health and preventing and treating disease. (6)	○	○	○	○	○
Earth Science: is the study of earth, including the air, land, and ocean. (7)	○	○	○	○	○
Computer Science: consists of the development and testing of computer systems, designing new programs and helping others to use computers. (8)	○	○	○	○	○
Medical Science: involves researching human disease and working to find solutions to human health problems. (9)	○	○	○	○	○

Chemistry: uses math and experiments to search for new chemicals, and to study the structure of matter and how it behaves. (10)	○	○	○	○	○
Energy: involves the study and generation of power, such as heat or electricity. (11)	○	○	○	○	○
Engineering: involving designing, testing, and manufacturing new products (like machines, bridges, buildings, and electronics) through use of math, science, and computers. (12)	○	○	○	○	○

REFERENCES

Achieve. (2016). EQuIP rubric for lessons & units: Science, version 3.0. Retrieved: https://www.nextgenscience.org/sites/default/files/EQuIP%20Rubric%20for%20Science%20v3.pdf

Achieve. (2017). EQuIP rubric. Retrieved: https://www.achieve.org/EQuIP

Aikenhead, G.S. (2006). *Science education for everyday life: Evidence-based practice.* New York, NY: Teachers College Press.

American Association for the Advancement of Science. AAAS - Project 2061 - Project 2061 — Having an impact. (2013). Retrieved July 27, 2016, from http://www.project2061.org/publications/articles/SRI/default.htm

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2010). "Doing' science versus 'being' a scientist: Examining 10/11-year-old schoolchildren's constructions of science through the lens of identity." *Science Education, 94*(4), 617–639.

Archer, L., DeWitt, J., & Willis, B. (2014), Adolescent boys' science aspirations: Masculinity, capital, and power. *Science Teacher, 51*, 1–30. doi:10.1002/tea.21122

Archer, L., Dewitt, J., & Osborne, J. (2015). Is science for us? Black students' and parents' views of science and science careers. *Science Education, 99*(2), 199-237.

Ash, D. (2004). Reflective scientific sense-making dialogue in two languages: The science in the dialogue and the dialogue in the science. *Science Education, 88*(6), 855-884.

Atkins, J., & Karplus, R. (1962). Discovery of invention? *The Science Teacher 29*(5), 45-51.

Atwater, M. M. (2000). Females in science education: White is the norm and class, language, lifestyle, and religion are nonissues. *Journal of Research in Science Teaching 37*(4), 386-387.

Ball, C., Huang, K.T., Cotten, S. R. & Rikard, R. V. (2017). Pressurizing the STEM pipeline: An expectancy-value theory analysis of youths' STEM attitudes. *Journal of Science Education and Technology, 26*(4), 372-282. doi: 10.1007/s10956-017-9685-1

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84*(2), 191-215.

Bandura, A., Barbaranelli, C., Caprara, G. V., & Pastorelli, C. (2001). Self-Efficacy beliefs as shapers of children's aspirations and career trajectories. *Child Development, 72*(1), 187-206.

Banks, J. A., Au, K. H., Ball, A. F., Bell, P., Gordon, E. W., Gutierrez, K., Heath, S. B., Lee, C. D., Lee, Y., Mahiri, J., Nasir, N. S., Valdes, G., & Zhour, M. (2007). *Learning in and out of school in diverse environments: Lifelong, life-wide, life deep.* Seattle, WA: Center for Multicultural Education, University of Washington.

Barman, C. R. (1997) Students' views of scientists and science: Results from a national study. *Science and Children 35*(1), 18-24.

Barnette, J. J. (1997, March). *Effects of item and response set reversals on survey statistics.* Paper presented at the meeting of American Educational Research Association, Chicago, IL.

Bayri, N., Koksal, M. S., & Ertekin, P. (2016). Investigating gifted middle school students' images about scientists: A cultural similarity perspective. *Science Education International, 27(*1), 136-150.

Beasley, M. A., & Fischer, M. J. (2012). Why they leave: The impact of stereotype threat on the attrition of women and minorities from Science, Math and Engineering majors. *Social Psychology of Education: An International Journal, 15*(4), 427-448.

Birman, B. (2013, October 30). Three decades of education reform: Are we still “A Nation at Risk?” Retrieved July 27, 2016, from http://www.air.org/resource/three-decades-education-reform-are-we-still-nation-risk

Boyd, B., & Gregson, S. (2017, April). Update on the *California Science Curriculum Framework.* Poster session presented at the meeting of National Science Teachers Association, Los Angeles.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). *How people learn.* Washington, DC: National Academy of Sciences.

Brickhouse, N. W., Lowery, P., & Schultz, K. (2000). What kind of a girl does science? The construction of school science identities. *Research In Science Teaching, 37*(5), 441-58.

Brickhouse, N., & Potter, J. (2001). Young women’s scientific identity formation in urban context. *Journal of Research in Science Teaching 38*(8), 965-980.

Bridges, W., & Bridges, S. (2016). *Managing transitions: Making the most of change.* Philadelphia, PA: Da Capo Press.

Business-Higher Education Forum. (2005). *A commitment to America’s future: Responding to the crisis in mathematics & science*. Washington, DC: Author.

Bybee, R. W., Taylor, J. A., Gardner, A., Van Scotter, P., Powell, J. C., Westbrook, A., & Landes, N. (2006). The BSCS 5E instructional model: Origins and effectiveness. A report prepared for the office of science education National Institutes of Health. Colorado Springs, CO: BSCS.

Bybee, R. W. (2009). The BSCS 5E instructional model and 21st century skills. Commissioned paper prepared for a workshop on exploring the intersection of science education and the development of 21st century skills. January 2009.

Bybee, R. W. (2014). NGSS and the Next Generation of Science Teachers. *Journal of Science Teacher Education*, *25*(2), 211–221.

Bybee, R. W., & Pruitt, S. L. (2017). *Perspectives on science education.* Arlington, VA: National Science Teachers Association.

Calabrese Barton, A., Tan, E., & Rivet, A. (2008). Creating hybrid spaces for engaging school science among urban middle school girls. *American Educational Research Journal 45*(1), 68-103. doi: 10.3102/0002831207308641

Calabrese Barton, A., & Tan., E. (2010). We be burnin: Agency, identity and learning in a green energy program. *Journal of Learning Science 19*(2), 187-229.

California Department of Education. (2018). Access and equity. In C. Cuccia, L. Grant, B. Boyd, and K. Allen (Eds.), *2016 Science framework for California public schools: Kindergarten through grade twelve* (pp. 1365-1431). Sacramento, CA: California Department of Education.

Carlone, H. B. (2004). The cultural production of science in reform-based physics: Girls' access, participation, and resistance. *Journal of Research in Science Teaching, 41*(4), 392-414.

Carlone, H. B., & Johnson, A. (2007). Understanding the science experience of women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching, 44*(8), 1187-1218.

Carlone, H. B., Haun-Frank, J., & Webb, A., (2011). Assessing equity beyond knowledge-and skills-based outcomes: A comparative ethnography of two fourth-grade reform-based science classrooms. *Journal of Research in Science Teaching, 48*, 459-485.

Chambers, D. (1983). Stereotypic images of the scientists: The Draw-a-Scientist test. *Science Education, 67*(2), 255-265.

Christensen, R., Knezek, G., & Tyler-Wood, T. (2015). Alignment of hands-on STEM engagement activities with positive STEM dispositions in secondary school students. *Journal of Science Education and Technology*, *24*(6), 898–909. doi: 10.1007/s10956-015-9572-6

Commission on Teacher Credentialing. (2016). *California teaching performance expectations.* Retrieved from https://www.ctc.ca.gov/docs/default-source/educator-prep/standards/adopted-tpes-2016.pdf

Corcoran, T., Mosher, F. A., Rogat, A.(2009). *Learning progressions in science: An evidence-based approach to reform*. (CPRE Research Report # RR-63).

Crowther, D. (2017). Context makes science more accessible. *NSTA Reports, 29*(4), 14-15.

Cunningham, C. M., & Carlsen, W. S. (2014). Teaching engineering practices. *Journal of Science Teacher Education, 25*(2), 197–210.

Darling-Hammond, L. (2004). The color line in American education: Race, resources, and student achievement. *Du Bois Review 1*(2), 213-46. doi:10.1017/S1742058X0404202X

Dewey, J. (1916). Democracy and education: An introduction to the philosophy of education. New York: Macmillan.

Donovan, S., & Bransford, D. (2005). *How students learn: Science in the classroom.* Report prepared for National Research Council, Washington, DC.

Dunac, P. S., & Demir, K. (2017). Negotiating white science in a racially and ethnically diverse United States. *Educational Review, 69*(1), 25–50.

Duran, L. B., & Duran, E. (2004). The 5E instructional model: A learning cycle approach for inquiry-based science teaching. *Science Education Review, 3*(2), 49-58.

Educate America Act of 1994, P. L. 103-227, 20 U.S.C. §5812 (1994).

Elementary and Secondary Education Act of 1965, P. L. 89-10, 20 U.S.C. §1001 (1965).

Every Student Succeeds Act of 2015, P. L. 114-95, 20 U.S.C. § 4201 (2015).

Farland-Smith, D. (2012). Development and field test of the modified draw-a-scientist test and the draw-a-scientist rubric. *School Science and Mathematics, 112*(2), 109-116.

Fayer, S., Lacey, A., & Watson, A. (2017, January). STEM occupation: Past, present, and future. Report prepared for U.S. Bureau of Labor Statistics, Washington, DC.

Finson, K. D. (2002). Drawing a scientist: What we do and do not know after fifty years of drawings. *School Science and Mathematics, 102*(7), 335-45.

Finson, K. D., Pedersen, J., & Thomas, J. (2006). Comparing science teaching styles to students' perceptions of scientists. *School Science and Mathematics, 106*(1), 8-15.

Friday Institute for Educational Innovation (2012a). *Student attitudes toward STEM survey: Development and psychometric properties,* Raleigh, NC: Author.

Friday Institute for Educational Innovation (2012b). *Student attitudes toward STEM survey: Middle and high school students,* Raleigh, NC: Author.

Friday Institute for Educational Innovation (2012c). *Student attitudes toward STEM survey: Tips for using your data,* Raleigh, NC: Author.

Fong, C. J., & Krause, J. M. (2014). Lost confidence and potential: A mixed methods study of underachieving college students' sources of self-efficacy. *Social Psychology Education 17*, 249-268. doi: 10.1007/s11218-013-9239-1

Fosnot, C. T. (1993). Learning to teach, teaching to learn: The center for constructivist teaching-teacher preparation project. *Teaching Education, 5*(2), 69-78.

Fraze, L. B., Wingenbach, G., Rutherford, T., & Wolfskill, L. A. (2011). Effects of a recruitment workshop on selected urban high school students' self-efficacy and attitudes toward agriculture as a subject, college major, and career. *Journal of Agricultural Education, 52*(4), 123–135.

Gerlach, J. (2012). *STEM: Defying a simple definition.* Report prepared for National Science Teachers Association, Arlington, Virginia.

Gorard, S., & See, B. H. (2009). The impact of socioeconomic status on participation and attainment in science. *Studies in Science Education 45*(1), 93-129.

Guzey, S. S., Harwell, M., & Moore, T. (2014). Development of an instrument to assess attitudes toward science, technology, engineering, and mathematics (STEM). *School Science and Mathematics, 114*(6), 271-279.

Haag, S., & Megowan, C. (2015). Next generation science standards: A national mixed-methods study on teacher readiness. *School Science and Mathematics, 115*(8), 416-426.

Haste, H. (2004). Science in my future: A study of values and beliefs in relation to science and technology amongst 11-21 year olds. London: Nestle Social Research Programme.

Home School Legal Defense Association (2002). The history of goals 2000. Retrieved July 27, 2016, from http://hslda.org/docs/nche/000010/200209010.asp

Hughes, G. (2001). Exploring the availability of student scientist identities within curriculum discourse: An anti-essentialist approach to gender-inclusive science. *Gender and Education, 13*(3), 275-90.

Jackson, J., & Rich, A. (2014). Methods & strategies: Sculpt-a-scientist. *Science and Children, 52*(1), 75-79.

Januszyk, R., Miller, E.C., & Lee, O. (2016). Addressing student diversity and equity. *Science Teacher, 83*(4), 47-50.

Jenkins, E. W., & Nelson, N. W. (2005). Important but not for me: Students' attitudes towards secondary school science in England. *Research in Science and Technological Education*, *23*(1), 41–57. doi: 10.1080/02635140500068435

Jolly, J. L. (2009). The national defense education act: Current STEM initiative, and the gifted. *Gifted Child Today*, *32*(2), 50–53.

Jones, M. G., Howe, A., & Rue, M. J. (2000). Gender differences in students' experiences, interests, and attitudes toward science and scientists. *Science Education 84*, 180-192.

Judson, E. (2012). When science counts as much as reading and mathematics: An examination of differing state accountability policies. *Education Policy Analysis Archives, 20*(26). doi: 10.14507/epaa.v20n26.2012

Juvova, A., Chudy, S., Neumeister, P., Plischke, J., & Kvintova, J. (2015). Reflection of constructivist theories in current educational practice. *Universal Educational Research*, *3*(5), 345-349.

Konicek-Moran, R., & Keeley, P. (2015). *Teaching for conceptual understanding in science*. Arlington, Virginia: National Science Teachers Association.

Kroll, L. R. (2004). Constructing constructivism: How student-teachers construct ideas of development, knowledge, learning, and teaching. *Teachers and Teaching: Theory and Practice, 10*(2), 199-221.

Ladson-Billings, G. (1995). But that's just good teaching! The case for culturally relevant pedagogy. *Theory into Practice*, *34*(3), 159–65.

Ladson-Billings, G. (2016). And then is this thing called the curriculum: Organization, imagination and mind. *Educational Researcher, 45*(2), 100-104. doi: 10.3102/0013189X16639042

Laerd Statistics (2018). Pearson product-moment correlation. Retrieved from: https://statistics.laerd.com/statistical-guides/pearson-correlation-coefficient-statistical-guide.php

Landivar, L. C. (2013). *Disparities in STEM employment by sex, race, and hispanic origin.* (Report no. ACS-24). Report prepared for United States Census Bureau, Washington, DC.

Lawson, A., Abraham, M., & Renner, J. (1989). *A theory of instruction: Using the learning cycle to teach science concepts and thinking skills*. Manhattan, KS: National Association for Research in Science Teaching.

Lee, O., Deaktor, R., Enders, C., & Lambert, J. (2008). Impact of a multiyear professional development intervention on science achievement of culturally and linguistically diverse elementary students. *Research In Science Teaching, 45*(6), 726-747.

Lee, O., Miller, E. C., & Januszyk, R. (2014). Next generation science standards: All standards, all students. *Journal of Science Teacher Education, 25*(2), 223–233.

Lemke, J. L. (2001). Articulating communities: Sociocultural perspectives on science education. *Journal of Research in Science Teaching, 38*(3), 296–316. doi: 10.1002/1098-2736(200103)38:3

Licona, M. M. (2013). Mexican and Mexican-American children's funds of knowledge as interventions into deficit thinking: Opportunities for praxis in science education. *Cultural Studies of Science Education, 8*(4), 859-872.

Lisciandro, J. G., Jones, A., & Geerlings, P. (2018). Enabling learners starts with knowing them: Student attitudes, aspiration and anxiety towards science and maths learning in an Australian pre-university enabling program. *Australian Journal of Adult Learning, 58*(1), 13–40.

Malcom, S. M., Van Horne, V. V., Gaddy, C. D., & George, Y. S. (1998). *Losing ground: Science and engineering graduate education of black and hispanic americans*. Report prepared for American Association for the Advancement of Science, Washington, DC.

Martin, D. C. (2016). It's not my party: A critical analysis of women and minority opposition towards STEM. *Critical Questions in Education, 7*(2), 96-115.

McCarthy, N. (2017). *The countries with the most STEM graduates*. Retrieved from https://www.statista.com/chart/7913/the-countries-with-the-most-stem-graduates/

Mead, M., & Metraux, R. (1957). Image of the scientist among high school students. *Science, 126,* 384-390.

Miller, E., & Januszyk, R. (2014). Guest editorial: The “NGSS” case studies: All standards, all students. *Science and Children, 51*(5), 10–13.

Miller, P. H., Slawinski Blessing, J., & Schwartz, S. (2006). Gender differences in high-school students' views about science. *International Journal of Science Education, 28*(4), 363-381.

Morgan, P.L., Farkas, G., Hillemeier, M.M., & Maczuga, S. (2016). Science achievement gaps begin very early, persist, and are largely explained by modifiable factors. Educational Researcher, *45*(1), 18-35. doi: 10.3102/0013189X16633182

National Defense Education Act of 1958, P. L. 85-864, 20 U.S.C. §301 (1958).

National Research Council. (2007). *Taking science to school: Learning and teaching science in grades K-8*. Washington, DC: The National Academies Press. doi: 10.17226/11625

National Research Council. (2012). *A framework for K-12 science education: Practices, Crosscutting Concepts and Core Ideas.* Committee on a conceptual framework for a new K-12 science education standards. Board on science education, division of behavioral and social sciences and education. Washington, DC: The National Academies Press.

National Science Foundation (2012). *S&E Indicators: Industry, technology and the global marketplace.* Retrieved from http://www.nsf.gov/statistics/seind12/c6.htm#s3

National Science Foundation, National Center for Science and Engineering Statistics. (2017). *Women, minorities, and persons with disabilities in science and engineering: 2017.* Special Report NSF 17-310. Arlington, VA.

NGSS Lead States. (2013a). *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press.

NGSS Lead States. (2013b). *The need for standards.* Retrieved from https://www.nextgenscience.org/need-standards#9.%20Adult%20literacy

No Child Left Behind Act of 2001, P. L. 107-110, 20 U.S.C. § 1426 (2002).

Pantic, Z. (2007). STEM sell. *New England Journal of Higher Education*, *22*(1), 25–26.

Petrinkjak, L., & Shapiro, D. (Eds.). (2017). Scientist stereotypes eroding among students [Summer Issue]. *NSTA Reports 29*(1), 6-7.

Plucker, J. A. (1996). Secondary science and mathematics teachers and gender equity: Attitudes and attempted interventions. *Journal of Research In Science Teaching, 33*(7), 737-51.

Pruitt, S. L. (2014). The next generation science standards: The features and challenges. *Journal of Science Teacher Education*, *25*(2), 145–156.

Pruitt, S. L. (2015). Next Generation Science Standards: Giving every student a choice. In O. Lee, E. Miller, & R. Januszyk (Eds.), *NGSS for all students* (pp. 1-6). Arlington, VA: National Science Teachers Association.

Qualtrics (Version 0618) [Computer software]. Provo, UT: http://qualtrics.com

Quinn, H. (2015). Science and engineering practices for equity: creating opportunities for diverse students to learn science and develop foundational capacities. In O. Lee, E. Miller, & R. Januszyk (Eds.), *NGSS for all students* (pp. 7-19). Arlington, VA: National Science Teachers Association.

Rascoe, B., & Atwater, M. M. (2005). Black males' self-perception of academic ability and gfted potential in advanced science classes. *Journal of Research in Science Teaching 47*(8), 888-911. doi: 10.1002/tea.20077

Renner, J. W., Abraham, M. R., & Birnie, H. H. (1988). The necessity of each phase of the learning cycle in teaching high school physics. *Journal of Research in Science Teaching 25*(1), 39-58.

Riechard, D. E. (1994). National science-education standards: Around the reform bush...again? *Clearing House, 67*(3), 135–36.

Rodriguez, A. J. (2015). What about a dimension of engagement, equity and diversity practices? A critique of the next generation science standards. *Journal of Research in Science Teaching, 52*(7), 1031-1051.

Sanders, M. (2009). STEM, STEM Education, STEMmania. *The Technology Teacher, December,* 20-26.

Sanders, P., & Sanders, L. (2006). Understanding academic confidence. *Psychology Teaching Review, 12*(1), 29-42.

Scantlebury, K., Baker, D. (2007). Gender issues in science education research: Remembering where the difference lies. In S. Abell & N. Lederman (Eds.), *Handbook of research on science education* 257-286, Mahwah, NJ: Lawrence Erlbaum.

Secretary of State California General Election. (2016). *Official voter information guide.* Retrieved from http://voterguide.sos.ca.gov/en/propositions/#mainCont

Spiegel, J. (2017, June). *Phenomenon*. Symposium conducted at the meeting of Los Angeles County Office of Education NGSS rollout #4, Norwalk, CA.

Sunny, C. E., Taasoobshirazi, G., Clark, L., & Marchand, G. (2017). Stereotype threat and gender differences in chemistry. *Instructional Science: An International Journal of the Learning Sciences, 45*(2), 157–175. doi: 10.1007/s11251-016-9395-8

Teo, T. W. (2014). Hidden currents in the STEM pipeline: Insights from the dyschronous life episodes of a minority female STEM teacher. *Theory Into Practice, 53*(1), 48-54.

Trends in International Mathematics and Science Study (TIMSS) - TIMSS 2011 Results. (n.d.). Retrieved July 27, 2016, from https://nces.ed.gov/timss/results11.asp

U.S. Department of Education (2015). *Every student succeeds act.* Retrieved from: https://www.ed.gov/essa?src=rn

Vygotsky, L. S. (1978) *Mind in society: The development of higher psychological processes.* Cambridge, MA: Harvard University Press.

Wenglinsky, H. (2002). The link between teacher classroom practices and student academic performance. *Education Policy Analysis Archive*s 10(12), 1068-2341.

Which is best: Teacher-centered or student-centered education? (2016). Retrieved from Concordia University website: https://education.cu-portland.edu/blog/classroom-resources/which-is-best-teacher-centered-or-student-centered-education/

Wong, B. (2015), Careers “from” but not “in” science: Why are aspirations to be a scientist challenging for minority ethnic students? *Science Teacher, 52*: 979–1002. doi:10.1002/tea.21231

Wright, S., & Grenier, M. (2009). Examining effective teaching via a social constructivist pedagogy "Case Study." *Education*, *130*(2), 255-264.

Zimmerman, B. (1995). Self-efficacy and educational development. In A. Bandura (Ed.), *Self-efficacy in changing societies*. (pp. 202-228). Cambridge, United Kingdom: Cambridge University Press.