# SCIENCE GEORGIA STANDARDS OF EXCELLENCE IN SOUTHWEST GEORGIA: A MIXED METHOD STUDY OF SCIENCE TEACHERS' PERCEPTIONS OF SCIENCE AND ENGINEERING PRACTICES AND ADMINISTRATIVE SUPPORT

by

Shereca R. Harvey

A Dissertation
Submitted to the Faculty of
Columbus State University
in Partial Fulfillment of Requirements
for the Degree of Doctor of Education
in Curriculum and Leadership

Columbus State University
Columbus, GA

December 2017

## Dedication

To my sister-in-law, Terri D. Marcus, who encouraged me to embrace my calling to become an educator. I am grateful to have had you by my side through the doctoral process and in life. I am grateful for your friendship, love, support, and listening ear. I am still amazed that we are just two girls from Shellman, Georgia.

**Acknowledgements**

Special thanks to Dr. Pamela Lemoine, Dr. Michael Richardson, Dr. Tom Hackett and other university and school system officials for establishing the Lee County Doctoral Cohort in 2014. Thank you for providing educators in southwest Georgia access to a doctoral program that was feasible for working adults who desired face-to-face interactions with professors and peers. To my dissertation committee, thank you for pushing me to go further than I had imagined with my topic and allowing me the freedom to be explore my passion. Thank you for always believing in me.

Thank you to the school systems, middle and high school science teachers who cooperated with me during this project. To the survey respondents and focus group participants, thank you for being so willing to contribute your time to complete surveys and share your experiences. Without each of you, this study would not have been possible.

My deepest gratitude goes to my husband, Derrell, and my parents, Pinkey and Greg. Thank you for being so understanding and supportive throughout my educational journey. Your love and support made it easy for me to do what I love. Thank you for the innumerable sacrifices, the encouragement, and for making me think I could accomplish anything. To Dr. Joyce Archie, thank you for listening, giving advice, and sharing your wisdom. Last, thank you God for blessing me with talents and from whom all my blessings flow.

**Curriculum Vita**

Shereca R. Harvey

2310 Cascade Lane, Albany, GA 31707 | (229) 869-9983 | sherecahughley@yahoo.com

EDUCATION

Columbus State University, Columbus, GA
Doctorate in Education, Curriculum and Leadership 2017
Dissertation: Science teachers' perceptions of science and engineering practices and administrative support

Albany State University, Albany, GA
Specialist in Education, Educational Administration and Supervision 2012
Thesis: Truancy among students at Rural High School in Southwest Georgia

University of South Carolina, Columbia, SC
Master of Public Health, Public Health Administration 2005
Thesis: Implementation of the Body and Soul Program at Gethsemane Worship Center in Albany, Georgia

University of Georgia, Athens, GA
Bachelor of Science, Biology 2002

AWARDS

Michael D. Jarret Scholar, University of South Carolina 2004 – 2005

RELEVANT EXPERIENCE

Liaison for K-12 Partner, Calhoun County Schools and Albany State University
**University Principal Preparation Institute, Wallace Foundation** **2017**
Revises Educational Leadership Program leading to Tier II certification in partnership with state educational agencies.

**Curriculum Director, Calhoun County School System** **2017**
Provides guidance in the areas of curriculum, instruction, and assessments to three rural schools in accordance with Georgia Standards of Excellence.

**Clinical Supervisor, Western Governors University** **2016-2017** Evaluated teacher canc

RELATED EXPERIENCE

Assistant Principal, Dougherty County School System
Monroe High School 2014 – 2017

Instructional Leaders, Terrell County School System
Terrell County Middle School and Terrell County High School 2011 – 2014

Science Teacher, Terrell, Lee, and Randolph County Schools 2002 – 2011
Terrell County High School – Biology; Lee County High School – Physical Science, Environmental Science; Randolph – Clay High School – Biology, Human Anatomy and Physiology

PUBLICATIONS AND PAPERS

"Mental Health Risk Factors, Unmet Needs, and Provider Availability for Rural Children"
Paper presented at National Rural Health Conference, San Diego, CA 2005

MEMBERSHIPS

Georgia Association of Educators
Georgia Association of Curriculum and Instruction Supervisors
Georgia Association of Educational Leaders
Georgia Science Teacher Association
Georgia Chapter of the Prince Hall Order of the Eastern Star

**Abstract**

With the publication of *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (National Research Council, 2012), the dominant instructional approach for science education in the United States changed from teaching science as a process of inquiry to teaching science as a practice, using science and engineering practices. Middle and high school science teachers in the State of Georgia implemented the practices for the first time during 2017-2018 school year while teaching the new Science Georgia Standards of Excellence. Teachers who have been successful at making such instructional changes have done so with the support of their principals and when both the teacher and principal were aware of the concerns of teachers. The purpose of this mixed method study was to determine the extent to which there were differences between the perceptions middle and high school science teachers had about science and engineering practices and administrative support provided by principals during the implementation of the Science Georgia Standards of Excellence in southwest Georgia. Based on the data collected from 23 middle school and 31 high school science teachers from three school systems through web-based surveys and focus group discussions, the results indicated that there were significant differences between the two groups of science teachers in the level of concern about one of the eight practices and the level of agreement about two of six statements about administrative support provided by principals. Also, science teachers reported the quality of professional development, feedback and guidance, and students' abilities are factors contributing to their concerns about the practices. The researcher described implications for professional development and collaboration for science teachers and principals.

## Table of Contents

Table of Contents (continued)

Table of Contents (continued)

Table of Contents (continued)

Table of Contents (continued)

List of Tables

List of Figures

# CHAPTER I: INTRODUCTION

## Introduction

The publication of *Framework for K – 12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (National Research Council [NRC], 2012) (hereafter called *Framework)* marked yet another turning point for science education in the United States. Following a comprehensive review of research-based strategies that help students to learn science effectively, the authors of *Framework* (National Research Council, 2012) articulated a new vision for K-12 science education and promoted for a departure from traditional approaches to science teaching and learning (Pruitt, 2014).

Science and engineering practices, crosscutting concepts, and disciplinary core ideas (DCIs) were featured as the essential components of the new conceptual framework for science education called the three-dimensional learning model (Duncan & Cavera, 2015; NRC, 2012). SEPs required science teachers to engage students in doing science rather than only learning facts and details (Bybee, 2011). The practices described the knowledge and skills used by scientists and engineers as they investigated theories, designed and built models and systems (NRC, 2012). The crosscutting concepts were linked to science concepts included in the disciplinary core ideas to aid students in developing a comprehensible, scientific view of the world (NRC, 2012). Core ideas represented the scientific knowledge to be taught in science courses. When integrated, the practices, crosscutting concepts, and disciplinary core ideas served as a model for science educators to construct lessons to ensure that students know and understand science content and can apply the knowledge and skills to new situations (Duncan & Cavera, 2015).

**Inquiry**

Before the introduction of the three-dimensional learning model, researchers endorsed the teaching of science as a process of inquiry in the publication National Science Education Standards (1996) (National Academy of Science, 1995; National Research Council, 1996); however, after two decades, inquiry was not commonly used in science classrooms across America.

Inquiry and science achievement. Purportedly, the teaching of science as a process inquiry was not an effective method of instruction to increase student achievement in science classrooms in the United States (NRC, 2012). Among eighth graders from 39 countries, students from the United States who took the 2015 Trends in International Mathematics and Science Study (TIMSS) Science Assessment had an average score of 530 and ranked 11th; despondently, the United States lagged Singapore, Chinese Taipei, Korea, Japan, Hong Kong SAR, and Russia (Martin, Mullis, Foy, & Hooper, 2016). In 1995 and 2007, the average scores for American eighth graders were 513 and 520, respectively (Gonzales, Williams, Jocelyn, Roey, Kastberg, & Brenwald, 2008). The American College Testing 2017 report revealed that only 37% of high school graduates scored at or above the college readiness benchmark levels in science (ACT, 2017a). In Georgia, 38% of 2017 graduates who took the ACT met the college readiness benchmark for science (ACT, 2017b). On the Spring 2017 Georgia Milestones Assessment for 8th grade Physical Science, 39% of students who took the assessment scored at the proficient learner level or higher (Governor's Office of Student Achievement, 2017).

These statistics were alarming, because science was projected to be essential for many of the fastest growing careers worldwide (Change the Equation, 2015; Rothwell, 2013). Politicians, economists, and researchers warned that the United States' educational system poses a threat to the country’s competitiveness in the global market and to future economic growth (Council on Foreign Relations, Klein, Rice, & Levy, 2012; Griffiths & Cahill, 2009). In 2011, science, technology, and mathematics (STEM) comprised 20% of all U.S. jobs (Rothwell, 2013). By 2024, STEM-related careers were projected to grow by 17%, which was faster than the expected 12% overall job growth (Change the Equation, 2015). Beyond apprehensions about the future of employability, economic growth and student achievement, Americans needed skills in science to solve and understand the calamities of energy shortages, health issues, and diseases in their daily life (Kutner, Greenberg, Jin, Boyle, Hsu, & Dunleavy, 2007).

Inquiry and science teachers. A bevy of researchers documented the unsuccessful attempts to get science teachers to teach science as a process of inquiry since the post- *Sputnik* era of science education (Anderson, 2002; Barrow, 2006; Bybee, 2010; Goodlad &Klein, 1970; Hurd, 1986; Shubert, 1993; Yager, 2000). The shortcomings were well-documented in the literature (Capps & Crawford, 2013; Castle & Ferreira, 2015; Osborne, 2014). Most often reported were the misunderstandings that surrounded the meaning of inquiry and how inquiry impacted the role of the science teacher (Anderson, 2002; Barrow, 2006; Osborne, 2014; Wilcox et al., 2015). Researchers observed that when science teachers lacked a coherent understanding of how to implement changes in instructional practices, confusion, misconceptions, and concerns developed. Ultimately, the teachers resisted changing their instructional practices (Banilower, Smith, Weiss, Malzahn, Campbell, & Weis, 2013; DiBiase & McDonald, 2015; National Academies of Sciences, Engineering, and Medicine, 2015; NRC, 2012). Culpability was associated with the lack of teacher input, limited support at the school level, insufficient professional development, and a lack of coherence when implementing inquiry-based lessons (Anderson, 2002; Barrow, 2006; Goodlad & Klein, 1970; Hurd, 1986).

**Science and Engineering Practices**

When the three-dimensional learning model was developed, the primary goal of teaching science as a practice using science and engineering practices was to ensure students comprehended how the scientific community worked to build content knowledge overtime by using more than one method while thinking, acting, talking, and interacting with their peers like scientists (Duncan & Cavera, 2015). A second goal was to ensure students understood the various approaches that were used to investigate, model, and explain challenges and natural occurrences in the real world (NRC, 2012). For grades K-2, 3-5, 6-8, and 9-12, researchers proposed specific performance expectations for each of the eight practices that explicitly stated what students should be able to do by the end of each grade band in order to achieve the goals for science education in the United States (NRC, 2012).

Science and engineering practices and science teachers. In *Framework* (NRC, 2012), researchers acknowledged that many science teachers were not prepared to engage students in the style of teaching and learning demanded by the science and engineering practices. Researchers reported that science teachers had not experienced enough authentic science or engineering to sufficiently teach science as a practice using the practices (Banilower, Smith, Weiss, Malzahn, Campbell, & Weis, 2013; Cunningham & Carlsen, 2014). To add, there was little guidance for science teachers on how students should experience the practices in K-12 classrooms (Trygstad, Smith, Banilower, & Nelson, 2013). In earlier studies on science and engineering practices, middle and high school science teachers reported having concerns about incorporating the performance expectations associated with specific practices (Haag & Megowan, 2015).

Science and engineering practices and principals. Several researchers stressed the importance of principal leadership to successful educational reforms, suggesting that success was contingent upon the willingness of teachers and principals to work together to change instructional practices (Brezicha, Bergmark, & Mitra, 2015; Bridich, 2016; Fullan, 2014, 2016; Cohen & Hill, 2008; Lam, Cheng, & Choy, 2010; Leithwood & Seashore-Louis, 2012; National Association of Science, Engineering, and Mathematics [NASEM], 2015; NGSS Lead States, 2013; NRC, 2012; Robinson, Lloyd, & Rowe, 2008). Numerous researchers stated and presented empirical evidence to support the claim that principals had a significant, indirect impact on student achievement, second only to the direct impact of teachers (Day, Gu, & Sammons, 2016; Hallinger, 2005; Leithwood, Louis, Anderson, & Wahlstrom, 2004; Osborne-Lampkin, Folsom, & Herrington, 2015; Robinson, Lloyd & Rowe, 2008; Spillane & Hunt, 2010; Waters, Marzano, & McNulty, 2003).

In studies on science teachers' perceptions of science and engineering practices, science teachers reported that the lack of administrative support was a barrier to implementation (Allen & Penuel, 2015; Bridich, 2016; Cunningham & Carlsen, 2014; Daily & Robinson, 2016; Haag & Megowan, 2015; Trygstad, Smith, Banilower, & Nelson, 2013; Webster, McNeish, Scott, Maynard, & Haywood, 2012). Researchers asserted without the proper support at the building level, implementation efforts were unsuccessful (Bybee, 1995, 2010; Cohen & Hill, 2008; NRC, 2012; NASEM, 2015; Shubert, 1993; Spillane, 2004).

## Statement of the Problem

The Georgia Department of Education adopted the Science Georgia Standards of Excellence, which incorporated the three-dimensional learning model suggested by the National

Research Council (NRC) in 2012. The recommendation also required science teachers to shift from teaching science as a process of inquiry to teaching science as a practice by engaging students in specific tasks aligned to science and engineering practices. For each of the eight practices, students in grades K-2, 3-5, 6-8, and 9-12 were expected to master specific grade-level appropriate capabilities before exiting the grade band. From one grade band to the next, the complexity of the capabilities increased. Science teachers were not prepared to engage students in this style of learning and had received little guidance on how to engage students in the practices.  In many of the literature reviewed, science teachers reported the need for support from administrators to increase the likelihood of a successful shift. If middle and high school science teachers and their principals failed to work together to resolve barriers to implemenation, then it was probable that science teachers would continue to use less effective instructional practices and strategies that impeded growth in student achievement in science. For these reasons, the researcher proposed to investigate the perceptions middle and high school science teachers had about science and engineering practices and administrative support provided by principals during the implementation of the Science Georgia Standards of Excellence.

## Research Questions

The researcher addressed the following questions in the study: (1) To what extent are the perceptions middle and high school science teachers have about science and engineering practices during the implementation of Science Georgia Standards of Excellence different? (2) To what extent are the perceptions middle and high school science teachers have about administrative support provided by the principal during the implementation of the Science Georgia Standards of Excellence different?

## Conceptual Framework

The conceptual framework was grounded in teachers' concerns, science and engineering practices, and administrative support.

### Teachers' Concerns

Concerns were complex descriptions of the motivations, perceptions, attitudes, feelings, and thoughts experienced by a person in relation to a task (Hall, 1979). The concept of Concerns Theory emerged from Frances Fuller's (1969) work with student teachers. The researcher posited that teachers experienced three phases of concerns: self-concerns, task concerns, and impact concerns.

Self-concerns were indicative of the personal effects of making the change (Hall, Hord, & George, 2014). Task concerns were indicative of issues related to the job of teaching, the performance expectations associated with, and resources required to incorporate the science and engineering practices (Hall, Hord, & George, 2014). Impact concerns were suggestive of the teacher expressing issues related their ability or inability to collaborate with other science teachers to implement the science and engineering practices (Hall et al., 2014).

Building on Fuller's Concerns Theory, a team of researchers developed the Concerns-Based Adoption Model, which (CBAM) provided researchers a useful framework for measuring and diagnosing the phase of concern expressed by individuals while implementing new instructional practices within the school setting (Dailey & Robinson, 2016; Hall & Hord, 1987; Lochner, Conrad, & Graham, 2015). The researcher solely utilized the Stages of Concern dimension which described the affective domain of change associated with how people felt about doing something new and their concerns as they engaged with a new practice (Horsely & Loucks-Horsley, 1998).

At the beginning of the change process, teachers' concerns are likely to be related to self-concerns, which typically correlated to Stage 0 Awareness, Stage 1 Informational, and Stage 2 Personal. As teachers begin to use new instructional practices, they expressed task concerns about management and effectiveness, which correlated to Stage 3 Management (Hall et al, 2014). Overtime, teachers learned how to successfully execute the implementation of the new practice efficiently; as a result, self and task concerns decrease, and impact concerns – Stage 4 Consequences, Stage 5 Collaboration, and Stage 6 Refocusing – became foremost.

**Science and Engineering Practices**

Science and engineering practices comprised one dimension of the three-dimensional learning model. The practices provided science teachers a structure to engage students in performances that build scientific knowledge by thinking, acting, talking, and interacting with peers like scientists and engineers (Duncan & Cavera, 2015; NRC, 2012).

The eight practices were (1) asking questions and defining problems; (2) developing and using models; (3) planning and carrying out investigations; (4) analyzing and interpreting data; (5) using mathematics and computational thinking; (6) constructing explanations and designing solutions; (7) engaging in argument from evidence; and (8) obtaining, evaluating, and communicating information (NGSS Lead States, 2013; NRC, 2012). Included in Appendix B was the practices matrix that featured the specific performance expectations for students in grade bands K-2, 3-5, 6-8, and 9-12 (NRC, 2012).

**Administrative Support**

Based on James House's (1981) variation of the social support workplace theory, Littrell, Billingsley, and Cross (1994) adapted House's theory to fit support behaviors exhibited by school principals. Littrell, Billingsley, and Cross (1994) proposed that administrative support for teachers included four behavioral domains:

(1) Instrumental support – principals assisted teachers with work related tasks; Principals provided instructional support when they provided the necessary resources, space, and materials to teachers. Administrators also supported teachers by ensuring there was adequate time for teaching and non-teaching duties such as collaborative planning with colleagues (Cancio, Albrecht, & Johns, 2013).

(2*)* Informational support – principals provided information teachers used to improve classroom practices. Informational support was demonstrated when principals provided or allowed teachers to attend professional development, offered practical information on effective teaching strategies, and provided suggestions to improve classroom instruction, classroom management, and work-related stressors (Cancio et al., 2013).

(3) Appraisal support – principals provided ongoing personal evaluations of teaching practices. Within the context of the study, principals demonstrated appraisal support by providing feedback to and formally and informally evaluating science teachers' instruction in ways that were aligned to the Science Georgia Standards of Excellence.

(4) Emotional support – principals demonstrated respect, trust, open communication, appreciation, and showed a genuine interest in teachers' work and recommendations. To provide emotional support within the framework of the study, principals communicated about and

encouraged the implementation of the Science Georgia Standards of Excellence, maintained open communication, and listened to science teachers' concerns (Cancio et al., 2013).

## The Practices and Supports Framework

The Practices and Supports Framework, displayed in Figure1, was a visual depiction of the research purpose and research questions. The purpose of the study was to investigate the perceptions middle and high school science teachers had about science and engineering practices and administrative support provided by principals during the implementation of the Science **Georgia Standards of Excellence.**

Ovals represented the first research question, "To what extent are the perceptions middle and high school science teachers have about science and engineering practices during the implementation of Science Georgia Standards of Excellence different?" In Figure 1, the overlapping ovals formed a Venn Diagram, which represented the similarities and differences in the level of concerns about science and engineering practices as reported by middle and high school science teachers in the study.

Rectangles characterized the second research question, "To what extent are the perceptions middle and high school science teachers have about administrative support provided by the principal during the implementation of the Science Georgia Standards of Excellence different?". The overlapping rectangular bases represented the similarities and differences in the level of agreement about administrative support provided by the principal as reported by middle and high school science teachers participating in the study.

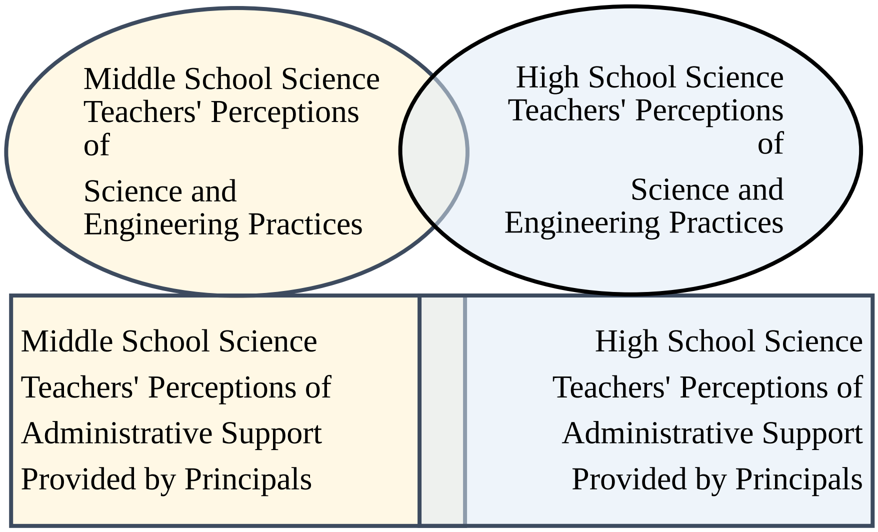


**Figure 1. Practices and Supports Framework**

## Significance of the Study

The findings from this study were noteworthy to science teachers, principals, science content coordinators, regional educational service agency representatives, colleges and university science education program leaders, and personnel with the Georgia Department of Education, especially those in southwest Georgia, who engaged in the work that led to the successful implementation of the Science Georgia Standards of Excellence. The data collection instruments, methods, results, and findings used to assess the perceptions held by middle and high school science teachers implementing Science Georgia Standards of Excellence in other settings, to inform professional development and coaching for science teachers and principals, and to generate more research on the topic. The greatest benefactors of this work were the students who were expected to know, understand, and perform the capabilities associated with science and engineering practices outlined by *Framework* (NRC, 2012). As a former science teacher, high school administrator, and current curriculum director, the researcher sought to contribute to the growing body of research on science and engineering practices and principal leadership.

## Procedures

To conduct this study, the researcher used a sequential explanatory mixed methods approach. First, the researcher identified the potential respondents using cluster sampling and total population sampling techniques. Then, the researcher obtained permission from superintendents to conduct the study with middle and high school science teachers within their school system. Next, the study plan was submitted to and approved by the Institutional Review Board at the university.  Once the survey was accessed, each respondent read the informed consent information and indicated whether or not they agreed or disagreed with the terms.

To contact respondents and participants, the researcher e-mailed the potential respondents the web-based surveys using Survey Monkey's e-mail invitation. Respondents completed a 24-item survey with perception questions about science and engineering practices, administrative support, and demographic information. Afterwards, data from the two surveys, one set from the middle school science teacher survey and another from high school science teacher survey, were combined and analyzed using Statistical Package for the Social Sciences (SPSS) software. Descriptive data (i.e. frequencies, means, standard deviations,) and inferential data from a two-sided independent *t*-test at an alpha level of .05 were performed to compare the difference in mean scores for each item.

During the survey, potential respondents could indicate a desire to participate in a focus group discussion instead of completing a survey. Using a total sampling technique to identify participants, the researchers facilitated two semi-structured, open-ended focus group discussions at a public library. A digital electronic device was used to record each of the 45- to 60-minute focus group discussions. Audio recordings were transcribed by the researcher and e-mailed to participants for member checking. Next, a spreadsheet was used to analyze qualitative data to identify themes.

## Limitations and Delimitations

Limitations were factors or influences, usually beyond the researcher's control, that affected the results of the study or how results were interpreted. Conversely, delimitations were factors or influences that affected the results of the study that were intentionally determined by the researcher.

There were assumptions that underlaid the research design. First, the researcher assumed that all participants answered questions honestly and to the best of their ability. Participation was voluntary; respondents to the survey and participants in the focus groups could withdraw at any time without penalty. The informed consent included a description of the study, its importance, and the steps to ensure that responses were kept confidential.

Second, the researcher assumed that all participants were actively employed as science teachers who used the Science Georgia Standards of Excellence, were aware of the eight science and engineering practices, and were willing to discuss the phenomena. The names, work location, and e-mail addresses for participants were provided by officials from the school system for accuracy. The e-mail invitation tool in Survey Monkey was utilized to ensure that only the intended recipients received the email and responded to the survey. The researcher assigned each participant a unique identification number; the true identity of the participants was known only by the researcher in an effort to maintain confidentiality and verify participants to the extent possible.

**Limitations**

The main limitations of the study were caused by the weaknesses associated with web-based survey data collection methods. No responses were returned from one school system included in the study, despite multiple efforts to contact school officials. Although low response rates were typical for web-based surveys, the researcher verified accurate e-mail addresses for potential participants, used the researcher's university email address for all e-mail communication, used personalized e-mail communication, followed up with science department chairs, science content coordinators, and principals that acted as champions for the research within their school system, and sent reminder e-mails days prior to the close of the survey (Edwards & Mathur, 2005). Despite these efforts, the e-mail infrastructure used by some of the school systems prevented the delivery of the emails, diverted the emails to junk and spam files, or potential respondents elected to ignore the request to participate in the study. During the data collection period, some school systems had no school due to a holiday.

Second, respondents' perceptions were collected using Likert scales, a form of attitudinal measurement (Teddlie & Tashakkori, 2009). Perceptions did not necessarily equal reality, and maintaining a level of honesty and accuracy with survey data was difficult. This limitation was partially addressed by conducting focus groups discussions with science teachers from middle schools and high schools to gain a deeper understanding of the topics of interests.

For the aforementioned reasons, caution should be exercised when interpreting the results of this study and extending the findings to larger populations.

## Delimitations

The setting for the research included schools in southwest Georgia. The decision to study the phenomena in this setting was based on both a personal research interest as well as a perceived gap in the research by the subsequent literature review. Consequently, the results and implications were only generalizable to this region. The decision to target this geographical region enabled the researcher to investigate the way specific contextual variables within these types of schools influenced the concerns science teacher had and their perceptions of administrative support provided by their principals.

The Concerns Based Adoption Model (CBAM) has been used as a theoretical framework and instrument to assess teachers' concern for many decades. The researcher determined that the use of the Stages of Concern questionnaire and CBAM yielded surface level results that identified stages of concern about the broader topic of science and engineering practices.

The researcher utilized a mixed methods approach to complement the limitations of survey and focus group data collections methods. To answer the key research questions, data collection methods for neither quantitative nor qualitative research designs yielded data that were as comprehensive as using the two methods.

## Definition of Terms

The following definitions were provided to ensure a common understanding throughout the study. The researcher developed all definitions not accompanied by a citation.

Administrative Support: referred to the four specific behavioral areas of support for teachers – emotional, instrumental, informational, and appraisal (Littrell, Billingsley, & Cross, 1994)

Appraisal Support: Principals were charged with providing ongoing personnel appraisal, including frequent and constructive feedback about work, information regarding effective teaching, and clear guidelines regarding job responsibilities (Littrell et al., 1994)

Concerns: complex descriptions of the motivations, perceptions, attitudes, feelings, and thoughts experienced by a person in relation to a task (Hall, 1979)

Emotional Support: Principals showed teachers that they were esteemed and trusted professionals who were worthy of concern by considering teachers' suggestions and ideas, maintaining open communication, showing appreciation, and taking an interest in teacher's work and ideas (Littrell et al., 1994).

*Framework*: The shortened title for the book *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012), which provided the empirical basis for the three-dimensional learning model

High School Science Teacher: a teacher of record who provided instruction to students using the approved Science Georgia Standards of Excellence for Biology, Physical Science, Chemistry, Environmental Science, or Physics during the 2017-2018 school year in Georgia

Informational Support: Principals provided teachers with useful information to improve practices. For example, principals provided informational support by authorizing teachers' attendance at in-service workshops, and providing suggestions to improve instruction and classroom management (Littrell et al., 1994).

Instrumental Support: Principals directly helped teachers with work-related tasks, such as providing necessary resources, materials, space, helping with managerial concerns and ensuring adequate time for teaching and non-teaching duties (Littrell et al., 1994).

Middle School Science Teacher: a teacher of record who provided instruction to students using the approved Science Georgia Standards of Excellence for 6th grade Earth Science, 7th grade Life Science, or 8th grade Physical Science during the 2017-2018 school year in Georgia.

Science and Engineering Practices: one dimension of the three-dimensional learning model; "… behaviors that scientists engage in as they investigate and build models and theories about the natural world and the key set of engineering practices that engineers use as they design and build models and systems." (NRC, 2012, p.30); the eight practices were (1) asking questions and defining problems; (2) developing and using models; (3) planning and carrying out investigations; (4) analyzing and interpreting data; (5) using mathematics and computational thinking; (6) constructing explanations and designing solutions; (7) engaging in argument from evidence; and (8) obtaining, evaluating, and communicating information (NGSS Lead States, 2013; NRC, 2012).

Three-dimensional learning model: A framework that was comprised of science and engineering practice, crosscutting concepts, and disciplinary core ideas.

## Summary

The dominant instructional approach for science education in the United States changed from inquiry to the three-dimensional learning model following the publication of *Framework* in 2012, because for several years, student achievement data indicated students in the United States were performing poorly in the area science and ill equipped for jobs in the fastest growing sectors like STEM. In accordance with the shift, science and engineering practices were to be incorporated in the science classrooms.

In earlier studies conducted in other states, science teachers reported the need for administrative support during the implementation. Based on findings from studies conducted during previous educational reform, researchers asserted that in order for such educational reforms to be successful, teachers and principals must work together to ensure that the necessary changes are made and sustained.

Science teachers in Georgia began implementing the new practices embedded in the Science Georgia Standards of Excellence during the 2017- 2018 school year. The researcher used a sequential explanatory mixed method approach to investigate the perceptions middle and high school science teachers had about science and engineering practices and administrative support provided by principals during the implementation of the Science Georgia Standards of Excellence. The research questions were answered using data collected from web-based surveys and focus group discussions.

# CHAPTER II: REVIEW OF LITERATURE

The educational literature and research on the topics of science and engineering practices, administrative support, and teacher concerns were reviewed in chapter two. The chapter was divided into four major sections: Historical Perspective of Science Instructional Methods, The Practices, Leading and Support Change, and the Theoretical Framework.

## Historical Perspective of Science Instructional Methods

With every decade since World War II, there had been significant national pressure to improve science teaching in the United States (Rudolph, 2014). Nationwide improvement efforts in science education originated in the 1950s and 1960s, following the *Sputnik.* In the early to mid-1990s, the dominant method of instruction, inquiry, was revamped. Following the release of the three-dimensional learning model, the dominant method of instruction in science classroom changed again to teaching science as a practice. This change marked a major departure from the dominant paradigm of teaching science as a process of inquiry in the United States.

### Teaching Science as a Process

Rote memorization and scientific method. In the mid- to late- 19$^{th}$ century, scientists utilized rote memorization and direct contact with natural phenomena as the dominant instructional approaches to increase intellectual rigor for hand-picked students who attended elite high schools, colleges, and universities famous for preparing students for science related careers (DeBoer, 2014). For all other students, the basic curriculum consisted of reading, writing, and arithmetic, rather than science. In 1894, the National Education Association (NEA) appointed educational scholars to three committees to create curriculum policy in the United States (NEA, 1894; Pinar, Reynolds, Slattery, & Taubman, 2008). The committees established that science instruction would be limited to the context of citizenship, health, and practical uses in everyday life (NEA, 1984; Spring, 1970). Teachers taught facts and principles related to scientific concepts, conducted specific laboratory experiments, and at the elementary level, instructed students with the use of simple observations in nature (NEA, 1894).

During World War II, scientific and technological advances, such as nuclear power, televisions, jet airplanes, antibiotics, and automation, created a demand for skilled citizens to develop and to maintain needed technologies (Conner & Bohan, 2013; Hurd, 1986). Therefore, the dominant form of science instruction changed from teaching scientific facts for improving the everyday lives of students and adults, as suggested by the Committee of Ten, to teaching science to ensure the success of scientific and technological enterprises developed during the war (Rudolph & Meshoulam, 2014).

During the waning years of the Progressive Era, members of society and politicians began to question the schooling students received, since most students lacked fundamental skills and knowledge (Kessinger, 2011; Schubert, 1993). Overtime, the Essentialism Movement, also called *Back-to-Basics*, was birthed. The goals of the movement demanded that teachers teach students the factual knowledge of core subjects to combat low academic standards and assess their acquisition of knowledge using tests (Kessinger, 2011; Schubert, 1993). The ongoing debate between those who supported the Progressive Era education reforms and those that supported the *Back to Basics* Movement was settled after Russia launched the *Sputnik* into orbit during the Cold War in 1957.

Inquiry-based instruction. In 1910, John Dewey, a former science teacher and philosopher, argued that there was too much emphasis on teaching scientific facts and not enough emphasis on scientific thinking (Barrow, 2006; Dewey, 1910; Rudolph, 2014). He recommended that students actively address real world problems that were of interest to them as they applied the scientific method and used their personal knowledge of science to observe natural phenomena. (Barrow, 2006; Tschaepe, 2012). He recognized the need for students to make mistakes during learning, to develop explanations, and think as scientists (Tschaepe, 2012). Although Dewey communicated clearly how science should be taught, he failed to construct a compelling argument about why this approach to the scientific method could be better. (Barrow, 2006; NRC, 1996, 2000). Dewey's description formed the basis for the inquiry-based learning as a teaching strategy in science classrooms.

*Inquiry-based instruction post-Sputnik.* During the 1960s, science education reform was dominated by the desire of the American public and government to regain its competitive edge. Following the launching of the *Sputnik*, unprecedented changes in policies and approaches ensued. For the first time, the federal government allocated funds for science education (Hurd, 1986; Kessinger, 2011). Under the National Defense Education Act of 1958, the federal government justified its involvement in education by giving the rationale that improving science education was a matter of national security (Kessinger, 2011). Secondly, research scientists, not teachers, were recruited to develop "teacher proof" (Yager, 2000, p. 51) curricula that consisted of "ready-made packages with specified instructions for conveyance to students" (Shubert, 1993, p. 100) using an "inquiry format" (Barrow, 2006, p. 266).

Teachers were encouraged to use laboratory investigations; students were expected to read books and write reports about research, discuss problems and data, interpret data, and reach conclusions, as scientists did (Anderson, 2002; Barrow, 2006; Hurd, 1986). While the instructional focus for curriculum materials was to teach science as inquiry in the manner used by scientists, teachers used direct instruction, as outlined in textbook lesson plans (Yager, 2000).

From the perspectives of science teachers, this approach to curriculum reform was not welcomed (Bybee, 2010). They had little to no input in the development of the curricula (Yager, 2000). There was resistance to the change, because the content and pedagogy needed to teach science as a process of inquiry were difficult, teachers lacked support within their local systems, and the implementation was impacted by political forces outside of the school. According to Bybee (2010), professional development was offered for teachers; however, the professional development was infrequent and excluded non-teaching personnel that could help support teachers during the implementation. Some researchers suggested that the science reforms efforts did not fail, rather they were neither understood nor implemented (Bybee, 1995; Shubert, 1993).

During this period of educational reform, the goal for inquiry was rarely realized (Shubert, 1993). In *Behind the Classroom Door*, Goodlad and Klein (1970) reported that traditional teaching practices were still dominate, and little evidence of the reformed practices were seen in science classrooms. The unsuccessful implementation at this attempt at inquiry was attributed to the lack of interest among science teachers, the exclusion of research on how students learned science, the absence of national leadership to merge the scientific and educational realms, and the missing system to manage problems with the implementation at the school level (Hurd, 1986).

*Inquiry-based instruction in the 1990s and 2000s.* Contrary to the 1960s, the science education reform of the 1990s was for the explicit purpose of cultivating scientifically literate citizens for the 21$^{st}$ century. Consequently, scientific literacy for everyday choices became the inspiration for two major documents, *Science for All Americans* (AAAS, 1990) and *Benchmarks* *for Science Literacy* (AAAS, 1993), which were used by school districts to develop science curricula. The National Research Council (NRC) (1996, 2000) strengthened its stance on the use of inquiry as a method of instruction in K-12 science classrooms with the publication of the *National Science Education Standards* (NRC, 1996) and *Inquiry and the National Science Education Standards* (NRC, 2000). Researchers expected that inquiry would result in a richer understanding, a set of cognitive abilities for students, and more effective teaching strategies (NRC, 2000). In the early 2000s, due to extensive professional development, science teachers expanded and improved their use of inquiry processes. Although the reforms resulted in a greater emphasis on the use of hands-on activities and investigations as teaching strategies for science concepts, inquiry was not implemented as widely as expected (NRC, 2012).

Rationale for the change. The justification for the change from teaching science as a process of inquiry to teaching science as a set of practices was multifaceted (NRC, 2012; Osborne, 2014; Wilcox, Kruse, & Clough, 2015). According to the NRC (1996), inquiry was defined as "the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world" (p. 23). Instead of seeking to create new knowledge and apply principles of inquiry to solve problems, students engaged in learning facts and following instructions to complete laboratory experiments and hands-on activities that had pre-determined outcomes (Osborne, 2014). To the contrary, the shift to science and engineering practices made explicit what students should experience, learn, and enhanced the professional language for coherence among science teachers (Osborne, 2014).

Secondly, many teachers were not certain when they were or were not engaging students in inquiry-based instructional activities (Capps & Crawford, 2013). In a study to examine teachers' perceptions about inquiry practices in their classrooms, Capps and Crawford (2013) analyzed lesson descriptions, observations, videotape recordings, administered questionnaires, and conducted interviews. Only six of 26 teachers were correctly documenting inquiry in their instruction based on lesson descriptions; when asked to give examples of inquiry, six of the eight interviewed described non-examples. What was more alarming was captured in this statement from the researchers: “It was particularly troubling that many of teachers in this study believed they were teaching science as inquiry even when they were not.” (Capp & Crawford, 2013, p. 522).

Teachers held partial understandings of the process for teaching science through inquiry (Wilcox, Kruse, & Clough, 2015). In *Teaching Science Through Inquiry* (2015), Wilcox, and colleagues clarified common inquiry myths that may prevent science teachers from fully engaging in teaching using science and engineering practices. According the trio, teachers were criticized for the following: not scaffolding lessons to provide sufficient guidance; not mentally engaging students during hands-on learning; their inability to create a learning environment that was conducive to extensive interactions among students; wasting time using directive instruction that did not promote a greater understanding of content; and not including all students in inquiry learning activities (Wilcox et al., 2015).

Last, teachers and those who supported their work lacked a common understanding of inquiry and what it entailed (Capp & Crawford, 2013; Osborne, 2014). There was no common professional language to define, discuss, and communicate the activities of inquiry which led to confusion, misconceptions, and concerns (NRC, 2012; Osborne, 2014; Wilcox et al., 2015).

In review, teaching science as a process evolved overtime to include various instructional strategies; however, none were as dominant and inconsistently implemented as inquiry-based instruction. The process of changing from the science instructional methods of the early 1900s, which included rote memorization, basic laboratory experiments, and the teaching of factors, to teaching science as a process of inquiry were largely unsuccessful in the 1950s, 1990s, and 2000s. Culpability had been associated with the lack of teacher input, limited support at the school level, insufficient professional development, and a lack of coherence when implementing inquiry-based lessons.

**Teaching Science as a Practice**

In 2007, The Carnegie Corporation of New York convened a committee to assess the current state of math and science education and the capacity of schools in the United States (Griffiths & Cahill, 2009). The Commission recommended a unified agenda for school system reform aligned to concurrent education initiatives and the rigorous transformation of math and science learning, citing, "…math and science learning will rise only if schools and instruction change profoundly, but also that schools were much more likely to improve if they tap the motivating power of science and math learning" (Griffiths & Cahill, 2009, p. 4).

In response to the recommendation from the Carnegie Foundation of New York, the National Research Council (NRC) led the charge to establish a new national vision for science education. The first publication, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (*Framework*) (NRC, 2012), provided a comprehensive, research-based foundation for the revision of science standards by drawing on current research about the way students learned science effectively. The committee of 18 experts identified the ideas and practices that all students in grades K-12 needed to know and experience before graduating high school. They also developed a new instructional model, the three-dimensional learning model, which consisted of disciplinary core ideas, eight science and engineering practices, and seven crosscutting concepts (NRC, 2012). The committee strongly emphasized that no one dimension sufficiently characterized what it meant to know science; teaching any one or two dimensions alone failed to meet the goals of the *Framework* (Duncan & Cavera, 2015; NASEM, 2015; NRC, 2012).

Guided by the *Framework* (NRC, 2012), a second organization, Achieve, led the collaborative work of stakeholders from science education, higher education, industry, and state education departments from 26 states to develop the authentic science education standards, which added more depth to the disciplinary core ideas (NGSS Lead States, 2013). The team committed to assist with the science reform by synthesizing the *Next Generation Science Standards* (NGSS). In the end, the NRC endorsed the newly developed and approved NGSS, because the standards were consistent with the content and structure of the *Framework*. As part of the development process, the standards underwent numerous reviews from stakeholders including two public drafts, allowing all who had a stake in science education an opportunity to inform the development of the standards, unlike earlier science education reform efforts in the in 1950s and 1960s. This process resulted in a set of high quality, college- and career-ready K–12 *Next Generation Science Standards* ready for state adoption (NGSS Lead States, 2013).

Science and engineering practices. Science and engineering practices described the knowledge and skills used by scientists and engineers as they investigated theories, designed and built models and systems (NRC, 2012).  The concept of teaching science as a set of practices emerged from the work of scientific philosophers, historians, psychologists and sociologists (NRC, 2012). Thomas Kuhn, a trained physicist and scientific philosopher, illustrated a postmodern view of how scientists engage with each other in communities of practice in his publication *The Structure of Science Revolutions* (Kuhn, 1962, 1970; Sanbonmatsu &

Sanbonmatsu, 2017). According to Kuhn, scientists engaged in specific, agreed upon practices and held a set of values and normative criteria that guided their work (Jacobs, 2006; Osborne, 2014). “They have studied the same specialist literature, drawing similar conclusions from it, and have learnt a common language “(Jacobs, 2006, p. 164). Kuhn credited his concept of scientific communities to the work of Ludwick Fleck (Jacobs, 2006).

After the 1970s, Paul Feyerabend criticized Kuhn’s explanation of scientific communities on the basis of his belief that Kuhn’s approach was elitist, narrow-minded, and that citizens and their interests need to influence the focus of research (Jacobs, 2006). However, the body of empirical research that supported Kuhn’s assertion continued to illuminate how science was done (NRC, 2012; Osborne, 2014). Considering science as a set of practices, Latour (1999) and Longino (2002) revealed that developing theories, testing and reasoning were parts of a larger group of activities that included systems of participants and institutions (NRC, 2012; Osborne, 2014). According to Bazerman (1988), those who engaged in communities of scientific practice had specialized ways to talk and write. They also created models, used mechanical and mathematical models, computer-based simulations, made predictive inferences, constructed instrumentation, and developed representations of phenomena in ways that promoted the advancement of science (Latour & Woolgar, 1986; Lehrer & Schauble, 2006; Nercessian, 2008; NRC, 2012; Osborne, 2014).

To add, a group of philosophers (Giere, Bickle, & Maudlin, 2006) and a team of psychologists (Klahr & Dunbar, 1988) independently sought to develop a model of scientific activity to understand how scientists established credibility for claims they advanced (Osborne, 2014). Klahr and Dunbar (1988) analyzed psychological studies of practices and concluded that the practices of science involved three processes: hypothesizing, experimentations, and evidence evaluation. From a philosophical perspective, Giere et al. (2006) provided a similar model by suggesting that there were three phases of inquiry as a structure for scientific reasoning. Osborne (2014) combined the two models to create a model of scientific activity that involved investigating (e.g. observing, experimenting, measuring, testing, collecting data, test solutions), evaluating (e.g. arguing, critiquing), and developing explanations and solutions (e.g. creative thinking, reasoning, calculating, planning, formulating hypotheses, propose solutions). Osborne's (2014) model incorporated the eight science and engineering practices included in the three-dimensional learning model.

*Science and engineering practices in Georgia.* At the onset, educational leaders in the State of Georgia committed to the work as one of the 26 lead states (NGSS Lead States, 2013); however, it was later determined that a local process for the reformation of science education would be best to meet the unique needs of industry in the state after the standards were created (Evans, 2015). Hence, the Next Generation Science Standards (NGSS) were not adopted in Georgia.

Instead, Georgia stakeholders revised their previous set of performance standards, the Georgia Performance Standards. After multiple opportunities for feedback from internal and external stakeholders, the Science Georgia Standards of Excellence were adopted by the State Board of Education in March 2016 (Evans, 2015; Peacock, 2016). The Science Georgia Standards of Excellence were designed to provide deep knowledge and skills for all students to reach proficiency in science. Likewise, teachers were expected to teach the Science Georgia Standards of Excellence by integrating the three-dimensional learning model, incorporating content related to specific learning progressions, and connecting the standards to Science, Technology, Engineering, and Mathematics (STEM) and literacy (Evans, 2015).

In April 2016, the Georgia Department of Education's Science Ambassador Program was enacted to support the implementation and professional development needs associated with the new approach to instruction (Peacock, 2016). According to an official with the Georgia Science Teacher Association (GSTA), science teachers, science curriculum specialists, RESA science specialists, science academic coaches and instructors, and other science educators who supported professional development for their local school districts were permitted to participate in trainings to augment their leadership capacity (Peacock, 2016).

Guidance for principals was communicated in a one-page document that explained what the standards were, how their adoption changed science education, and offered suggestions to principals about how to support the implementation. This document was adapted from the *NGSS: An Overview for Principals* document (NRC, 2015). In August 2016, the Deputy Superintendent of Curriculum and Instruction at the Georgia Department of Education e-mailed superintendents, curriculum directors, and Regional Education Service Agencies (RESA) directors the follow message:

> The State Board of Education adopted the Science Georgia Standards of Excellence (GSE) on March 31, 2016. The Science GSE will be implemented beginning in school year 2017-2018. In an effort to support the role that district-level and school administrators will have in guiding the implementation of the Science GSE, a five-webinar series will be provided to share information about the new standards, describe the expected changes in instructional practices, and explain how support will be made available. (C. M. Dooley, personal communication, August 5, 2016)

The webinar titles to be viewed were "Highlights of Changes and Professional Learning Plan", "Understanding Instruction Under the New Science GSE", Making Thinking Visible, A Way to Assess Science Learning", "Addressing Differentiation in The Science Classroom", and "Universal Design for Learning Supporting Science Instruction". The webinars were scheduled on dates ranging from August 18, 2016 through January 18, 2017. In May 2017, the Georgia

Department of Education hosted one-day sessions for principals to review the new process and receive documents to aid in monitoring the implementation and providing feedback.

In summary, the waves of national pressure to implement inquiry-based instruction were largely unsuccessful from the 1950s through the 2000s. Teachers expressed displeasure with the lack of input, insufficient time to implement programs and strategies, the quality of professional learning, unclear expectations, and the lack of support from administrators. By and large, several challenges that prevented the widespread implementation of inquiry-based instruction were addressed in hopes of a successful change in teacher practices. For this shift, the following were different from past science reform efforts: researchers incorporated evidence-based strategies about how students learn science best to develop the new model; teachers and other stakeholders had multiple opportunities to give input during the developmental stages; teachers and those who support their work were invited to participate in professional development prior to the implementation; and a common language and clear definition of the practices were communicated in print material, webinars, and professional development sessions.

## The Practices

According to the National Research Council (2012), the science and engineering practices described the "behaviors that scientists engage in as they investigate and build models and theories about the natural world and the key set of engineering practices that engineers use as they design and build models and systems." (NRC, 2012, p.30) The eight practices were (1) asking questions (for science) and defining problems (for engineering), (2) developing and using models, (3) planning and carrying out investigations, (4) analyzing and interpreting data, (5) using mathematics and computational thinking, (6) constructing explanations (for science) and designing solutions (for engineering), (7) engaging in argument from evidence, and (8) obtaining, evaluating, and communicating information (NRC, 2012). This section of the literature review included short descriptions of each practice and information about the practices matrix.

### Eight Science and Engineering Practices

Researchers with the National Research Council (NRC, 2012, 2015) acknowledged there was limited guidance for science teachers on how students were expected to experience the science and engineering practices in K – 12 classrooms (Trygstad, Banilower, & Pasley, 2016). Due to the scarcity of literature and empirical studies on the practices in the context of the three-dimensional learning model and its impact on the roles of science teachers, the information on some practices in this section were limited to the descriptions included in *Framework* (NRC, 2012).

Asking questions and defining problems. A student once stated, "The problem with science is that it gives answers to questions you never asked." (Osborne, 2014, p. 184). The performance expectations aligned to asking questions dictated that students ask and refine questions, which could be empirically tested, that led to descriptions and explanations of how the natural and designed worlds work (NRC, 2012). Researchers emphasized the value of students' question about learning (Osborne, 2014). Schmidt (1993) reported that questions, when raised by students, activated their prior knowledge, focused their learning, and aided them in elaborating on their learning. By engaging in the act of posing questions, students were better able to identify the main ideas and check for understanding (Rosenshine, Meister, & Chapman, 1996; Osborne, 2014).

The performance expectations aligned to defining problems were created based on the practices consistent with the work of engineers, in theory (Cunningham & Carlsen, 2014; NRC, 2012). Students were expected to use questioning strategies to clarify problems, determine criteria for successful solutions, and identify constraints to solve problems about the designed world (Bybee, 2011; NRC, 2012).

Developing and using models. The performance expectations aligned to developing and using models were derived from the practices of both scientists and engineers (Bybee, 2011; Osborne, 2014; NRC, 2012). Examples of models included diagrams, physical replicas, mathematical representations, analogies, and computer simulations. Students were expected to use and construct models for representing ideas and constructing explanations (Osborne, 2014; NRC, 2012). Typically, students developed and used models to help them represent things that were too small or too large (Gilbert, Boutler, & Elmer, 2000; Harrison & Treagust, 2002; Osborne, 2014). Osborne (2014) stated that it was important that students understand the goal of science not to create a representation or picture that was an accurate depiction of the natural and design worlds, but students were to engage in the practice to enhance their knowledge of science and their role in contributing to its advancement (Osborne, 2014).

Planning and carrying out investigations. The performance expectations aligned to the practice of planning and carrying out investigations were developed based on the following premises: investigations occur in the field or laboratory; the work can be performed collaboratively or individually; and investigations were systematic with data, variables, and parameters clearly defined (NRC, 2012). Students who engaged in these practices developed a functional understanding of the nature of science; however, according to Watson, Swain, and McRobbie (2004), students rarely engaged in such practices in science classrooms (OECD, 2016). With regards to engineering investigations, students were expected to identify the effectiveness, efficiency, and durability of designs under different conditions (NRC, 2012).

Analyzing and interpreting data. The performance expectations aligned to the practice of analyzing and interpreting data were linked to the execution of several other practices (Osborne, 2014). Students were expected to analyze and to test data gathered from investigations to derive meaning. They were to observe patterns and trends by using a range of tools, from tabulation to statistical analyses, using modern technology (NRC, 2012).

Using mathematics and computational thinking. Like the practice of analyzing and interpreting data, the practice of using mathematics and computational thinking was to be integrated with other practices seamlessly. The performance expectations of this practice required students to construct simulations, solve equations, apply quantitative relationship between variables to predict the behavior of systems and test the validity of such predictions (NRC, 2012). Osborne (2014) stated, “For too many teachers of science, however, mathematics was not something that was central and core to the practice of science.” (p. 187).

Constructing explanations and designing solutions. The performance expectations aligned to constructing explanations and designing solutions were intended to engage students in constructing theories and proposing solutions to problems that can be tested using criteria (NRC, 2012). Like developing and using models, the recommended tasks associated with constructing explanations and designing solutions required cognitive engagement, reflection, and self-correction by students (Osborne, 2014).

Engaging in argument from evidence. There was a growing body of empirical research on the benefits of students engaging in argumentation (Erduran, Ozdem, & Park, 2015; Osborne, 2014; NRC, 2015). The performance expectation aligned to engaging in argument from evidence required students to individually or collectively reach agreements about explanations and design solutions. Additionally, students were expected to use evidence from claims and argumentation to listen to, compare, and evaluate competing ideas and methods based on their merits when conducting investigations, testing solutions, resolving questions, and creating models (NRC, 2012).

Obtaining, evaluating, and communicating information. The performance expectations for obtaining, evaluating, and communicating information were formulated under the basis that students needed to be able to read, interpret, write scientific and technical text, communicate clearly and persuasively, and evaluate the merit and validity of claims, methods, and designs (NRC, 2012). Tenopir and King (as cited in Osborne, 2014, p.188) found that more than 50% of the time, scientists and engineers engaged in reading and writing.

**Practices Matrix**

Each set of practices were designed to align student performances in science classrooms to the work performed by scientist and engineers in the field (NRC, 2012). The specific tasks associated with the science and engineering practices were performance expectations, which had been described for students by grade bands, K-2, 3-5, 6-8, and 9-12 (NRC, 2012). Students were expected to engage in specific tasks aligned to each of the eight practices throughout their K-12 education; however, as grade bands increased, the complexity and sophistication of the performance expectations increased, also (NRC, 2012). The “Practices Matrix” was a term used to describe the chart of all performance expectations by practice and grade band. The purpose of the practice matrix was to enable readers to better understand the performance expectations (NRC, 2012). For this study, the investigation into the perceptions middle school science teachers and high school science teachers had about the science and engineering practices were based on the performance expectations for students listed in the 6-8 and 9-12 grade bands of the practice matrix, respectively. See Appendix B for the "Practices Matrix" document.

Science Teachers' Concerns about the Science and Engineering Practices

When changing instructional practices, some teachers incorporated new practices into their teaching style with ease and enthusiasm; in contrast, others never attempted the practice, modified its implementation, or after a few failed attempts, found it difficult and returned to traditional teaching practices (Lam, Cheng, & Choy, 2010). Educational change required the developmental growth of the feelings and skills of an individual who experienced the process of change (Loucks & Pratt, 1979). The National Research Council (NRC) (2012) emphasized that the implementation of science and engineering practices required significant changes in teachers' knowledge, skills, and feelings (Fullan, 2016). This section of the literature review featured themes from the literature on science teachers' concerns about the science and engineering practices were feelings of preparedness, knowledge and skills, support and guidance, and pedagogical beliefs.

**Science Teachers' Concerns**

The term *concerns* was defined as the complex descriptions of the feelings, perceptions, attitudes, motivations, and thoughts experienced by a person in relation to a task (Hall, 1979). According to the Concerns Theory, at the beginning of the change process, teachers' concerns were focused on their feelings about how the instructional change impacted them personally, also termed self-concerns. As teachers began to use new instructional practices, they expressed task concerns, which were described as the feelings, thoughts, attitudes, and perceptions of their performance, their management of time and resources, and their effectiveness. Overtime, as teachers became skilled in managing the new practice, teacher became more concerned about the impact the new practice had on students and their colleagues (Fuller, 1969; Hall, 1979; Hall, Hord, & George, 2014).

Concerns-based adoption model. The Concerns-Based Adoption Model provided researchers a useful framework for supporting and facilitating individuals in implementing new instructional practices within the school setting (Dailey & Robinson, 2016; Hall & Hord, 1987; Lochner, Conrad, & Graham, 2015). It allowed researchers to evaluate the evolution of teachers' concerns and behaviors throughout the change process using three diagnostic dimensions – (1) Stages of Concern, (2) Levels of Use, and (3) Innovation Configuration (Hall & Hord, 1987). However, for the current study, the researcher only utilized the Stages of Concern dimension, which described the affective domain of change associated with how people feel about doing something new and their concerns as they engage with a new practice (Horsely & Loucks-Horsley, 1998).

The Stages of Concern comprised three phases and seven stages teachers could experience when they are implementing an innovation. From Stage 0 to Stage 6, the stages were as follows:

**Self-Concerns**

(0) Awareness – Teachers had little concern or no involvement with the practice or change.

(1) Informational – Teachers had a general interest in the practice and would like to know more about it.

(2) Personal – Teachers wanted to learn about the personal ramifications of the practice. They questioned how the practice affected them.

**Task Concerns**

(3) Management – Teachers learned the processes and tasks associated with the practice by focusing on information and resources.

**Impact Concerns**

(4) Consequence – Teachers focused on the impact the practice had on students.

(5) Collaboration – Teachers worked with other teachers in implementing the practices.

(6) Refocusing – Teachers considered the benefits of implementing the practices and thought of additional alternatives that would make the practice more impactful.

*Relevant studies about science teachers' concerns.* For several decades, researchers applied the Concerns-Based Adoption Model (CBAM) to describe, measure, and explain the concerns of teachers as they adopted new practices. In recent years, CBAM studies contributed to the body of research on teacher concerns associated with the use of technology (Gabby, Avargil, Hercovitz, & Dori, 2017; Hall, Chamblee, & Slough, 2013; Lochner, Conrad, & Graham, 2015). Only a few studies provided empirical evidence to support the nature of science teachers' concerns in the context of implementing new innovations or practices (Daily & Robinson, 2016; Milner, Sondergeld, Demir, Johnson, and Czernicki, 2012).

Milner and colleagues (2012) reported that elementary science teachers responsible for implementing a new program experienced specific self- and task-related concerns. The teachers expressed their concerns about their needs for time for training and implementation, support from administrators to implement the program, and the limited availability of materials and resources.

Daily and Robinson (2016) conducted a mixed methods study to assess the concerns among elementary science teachers who participated in an extensive, sustained two-year professional development program to aid in the implementation of new practices. According to results from the *Stages of Concerns Questionnaire*, elementary science teachers exhibited self- and task-related concerns. During interviews, science teachers reported such concerns as limited content and pedagogical knowledge, resources, support from administrators, and time to teach (Daily & Robinson, 2016). Dailey and Robinson (2016) concluded that although concerns could not be eliminated, with extensive support from administrators, science teachers lessened their focus on self and eventually focused more on the impact of their practices on students.

**Feelings of Preparedness**

Since the publication of *Framework* (NRC, 2012), researchers conducted studies on science teachers' concerns about science and engineering practices (Haag & Megowan, 2015; Nollmeyer & Bangert, 2015). Using a mixed method design, Haag and Megowan (2015) surveyed middle and high school science teachers from across the United States to examine their perceptions of readiness and motivation to adopt the three-dimensional learning model. The researchers also sought to determine characteristics of teachers who felt well prepared, as well as examined the perceived barriers to implementation. High school science teachers reported a higher degree of motivation to use science and engineering practices, felt more prepared to implement the practices, and enacted modeling instruction at higher rates than middle school teachers. Their increased motivation was credited to science teachers in grades 9-12 attending more days of training in modeling than science teachers of seventh and eighth graders (Haag & Megowan, 2015).

Nollmeyer and Bangert (2015) reported solid readiness to teach science and engineering practices from 167 elementary teachers from Montana, Wyoming, Utah, and Idaho. Using the electronic, online version of the *Framework for Science Education: Survey of Teacher Readiness and Understanding* instrument, elementary teachers rated themselves on a scale from one to six based on their level of understanding the new framework, ranging from no understanding to advanced understanding, and on their level of readiness to implement the ideas of the framework, ranging from no readiness to advanced readiness. Although data from teachers yielded similar descriptive statistical results that indicated solid understanding and solid readiness, the results revealed a "substantial difference" (p. 11) between the teachers' understanding of the framework and their levels of readiness to use it due to the differences in the grouping of particular ideas (Nollmeyer & Bangert, 2015).

## Knowledge and Skills

For the first time, an emphasis was placed on coupling engineering and science practices as a method of instruction (Pruitt, 2014; National Research Council, 2012). According to the National Research Council (National Research Council, 2012), engineering was both a process for solving problems and a body of knowledge that represented how one designed and created man-made products. Although the two fields of study were distinctly different in scope and goals, they shared practices in reaching their goals (Bybee, 2011; Whitworth & Wheeler, 2017). For instance, both scientists and engineers conducted studies to better understand problems, used models to understand complex systems, argued with evidence to support hypotheses or design plans, conducted investigations, interpreted and analyzed data, used math to evaluate data, and communicated results and outcomes to others (Crismond, 2013; Whitworth & Wheeler, 2017).

Although critics agreed that the inclusion of engineering practices into K-12 classrooms was beneficial for raising the visibility of engineering, they argued that practices associated with engineering within the three-dimensional learning model were not clearly articulated and were incompletely modeled for students (Cunningham & Carlsen, 2014). They expressed that the science and engineering practices represented a “piecemeal approach” to teaching engineering practices (Cunningham & Carlsen, 2014, p. 197). The National Research Council’s (2012) stance was:

> Any education that focuses predominantly on the detailed products of scientific labor—the facts of science—without developing an understanding of how those facts were established or that ignores the many important applications of science in the world misrepresents science and marginalizes the importance of engineering. (pp. 42–43)

Traditionally, science teachers had little preparation to teach science in the context of engineering (Banilower, Smith, Weiss, Malzahn, Campbell, & Weis, 2013; NRC, 2012). Only 10 percent of science teachers who did not teach physics reported that they had taken an engineering course, while only 28 percent of physic teachers reported that they had taken at least one engineering course. Consequently, teaching engineering has been considered a challenge for teachers at all levels (Banilower et al., 2013; Cunningham & Carlsen, 2014). In the same study, only 7 percent of high school science teachers reported feeling very well prepared to teach engineering (Banilower et al., 2013).

Similar results were reported by Trygstan, Smith, Banilower, and Nelson (2013) for elementary school teachers. Trygstan and colleagues analyzed data from the 2012 National Survey of Science and Mathematics Education to investigate elementary teachers’ preparedness to implement the three-dimensional learning model. Science teachers in grades 3-5 perceived themselves as less than fairly prepared (22%) at higher rates that K-2 science teachers (14%).

Fewer than five percent of elementary science teachers reported that they had completed coursework in engineering, Consistent with this data, less than 10% of teachers felt they were very well prepared or fairly prepared to teach engineering practices in K – 2 (9%) and 3 – 5 (9%) (Trygstan et al., 2013).

Before the *Framework* (NRC, 2012) was published, the integration of engineering standards into K-12 science classrooms was limited. According to Carr, Bennett, and Strobel (2012), engineering skills and knowledge were embedded in the science, technology, or vocational standards in 41 states. With regards to integrating engineering skills and knowledge into science standards specifically, 12 states met the criteria. In most instances, the integration was limited in scope and failed to address all aspects of engineering. In Georgia, engineering standards were integrated in vocational standards only (Carr et al., 2012).

To ascertain chemistry teachers' ability to incorporate engineering practices in science classrooms, researchers asked teachers to create lessons (Baesdorfer & Staude, 2016). Prior to the professional learning sessions, only one of the 24 teachers accurately described how to incorporate the engineering practices into lessons. After the professional learning sessions, only four of 19 lesson plans accurately incorporated engineering practices.

**Support and Guidance**

Science teachers were provided limited guidance on what the science and engineering practices looked like when enacted (Parsley, Trystad, & Banilower, 2016). Parsley and colleagues (2016) reviewed published literature that claimed to assist teachers with understanding, incorporating and adapting instruction to include science and engineering practices into classroom instruction. In total, 76 empirical and practitioner articles and conference papers were identified; however, only 47 studies, articles, and paper provided relevant information that was not too general (Parsley et al., 2016). In conclusion, researchers reported that published literature had offered little assistance to teachers about ways to make the science and engineering practices accessible to all students (Parsley et al., 2016).

### Pedagogical Beliefs

Researchers identified several potential barriers to the successful implementation of science and engineering practices. Science teachers reported that they held pedagogical beliefs that were not aligned to research on how students learned science best (Trygstan et al., 2013). Boesdorfer and Straude (2016) studied the views of 24 high school chemistry teachers before and after a professional development program centered on engineering practices. To assess how the teachers viewed engineering, the researcher administered the survey before and after participants attended the professional development sessions. Researchers reported that the high school chemistry teachers mostly had positive, accurate beliefs about engineering but had naïve thoughts about the concepts of engineering. The chemistry teachers reported that they believed engineers and scientists were very similar, which they were not (Boesdorfer & Staude, 2016). Post-survey results were not statistically different.

In summary, science teachers’ concerns about science and engineering practices documented in the literature were inadequate training, a lack of resources, limited instructional time, and inadequate teacher preparation (Haag & Megowan, 2015; Nollmeyer & Bangert, 2015; Trygstan, Smith, Banilower, & Nelson, 2013). Boesdorfer and Staude (2016) noted that changing the preconceptions held by teachers was difficult and required intensive and sustained professional development. Cunningham and Carlsen (2014) suggested the necessity for teachers to participate in professional development that allowed them to engage in the practices that modeled pedagogies that support the practices, that gave them experiences as learners and teachers, and aided in the development of teachers' understandings of the fundamentals of engineering and the interconnections between engineering and science. The researchers also urged that the professional learning be designed in ways that allowed teachers to understand science and engineering as a social practice, which echoed the earlier observations of Thomas Kuhn (Cunningham & Carlsen, 2014).

## Leading and Supporting Change

School leadership drove change (Bryk, Bender-Sebring, Allensworth, Lupescu, & Easton, 2010). According to Fullan (2016) change efforts were unsuccessful when the next level of leadership above the unit of focus was weak. Several researchers proposed that educational change with the agreement and support of principals and teachers had a greater chance of succeeding (Cohen & Hill, 2008; Fullan, 2014; Fullan, 2016; Hall & Hord, 1987; Leithwood & Seashore-Louis, 2012; Robinson, Lloyd, & Rowe, 2008). In a broader sense, principals had a significant, indirect impact on student learning, second only to that of teachers (Day, Gu, & Sammons, 2016; Hallinger, 2005; Leithwood, Louis, Anderson, & Wahlstrom, 2004; Robinson, Lloyd & Rowe, 2008; Spillane & Hunt, 2010).

Guidance for principals about the change was communicated in a one-page document that explained what the standards were, how their adoption changed science education, and offered suggestions for how principals needed to support the implementation (NRC, 2015). In Georgia, principals received training via webinars and one face-to-face training. Titles were "Highlights of Changes and Professional Learning Plan", "Understanding Instruction Under the New Science

GSE", Making Thinking Visible, A Way to Assess Science Learning", "Addressing Differentiation in The Science Classroom", and "Universal Design for Learning Supporting Science Instruction". The webinars were scheduled on dates ranging from August 18, 2016 through January 18, 2017.

Relevant literature and research on the topic of administrative support were included in the literature review for "Supporting Change".

**Administrative Support**

In *Change in Schools: Facilitating the Process* (Hall & Hord, 1987), researchers emphasized the assumption that for change to be successful, the perceptions of the teacher had to be understood by themselves and the change facilitator, in this case, the principal. By understanding teacher concerns, the principal could be more certain that the planned actions to support change were relevant to the perceived needs of teachers (Hall & Hord, 1987).

Littrell, Billingsley, and Cross (1994) adapted James House's (1981) variation of the social support theory and proposed that administrative support for teachers included four behavioral domains:  instrumental support, informational support, emotional support, and appraisal support. Cancio, Alberecht, and Johns (2013) investigated how administrative support behaviors impacted teacher decisions. The researchers concluded that specific administrative behaviors can influenced the decisions made by teachers (Cancio et al., 2013).

Instrumental support. Instrumental support behaviors exhibited by principals included providing necessary resources, space, and materials to teachers. Additionally, principals supported teachers by ensuring there was adequate time for teaching and non-teaching duties such as collaborative planning (Cancio, Albrecht, & Johns, 2013; Littrell et a., 1994).

Instrumental support characteristics listed on guidance provided to principals on how to support the implementation included the selection of aligned instructional materials and methods to assess the quality of materials. Principals were encouraged to revisit their vision for science education through the lens of the new standards.

Informational support. Information support provide by principals consisted of principals sharing information with teachers on ways to improve classroom practices. Informational support was also demonstrated when principals provided or allowed teachers to attend professional development, offered practical information on effective teaching strategies, and provided suggestions to improve classroom instruction, classroom management, and work-related stressors (Cancio et al., 2013). As lead learners, principals were to lead teachers in a process of learning and development to improve their teaching (Robinson, Lloyd, & Rowe, 2008). Brezicha and colleagues (2015) recommended that principals provide differentiated support to teachers during the implementation of reform initiatives to facilitate teacher voice and participation in the process. Guidance from the National Research Council (2015) also urged principals to become knowledgeable about the standards and practices to the point where they could identify practices in action and provide feedback (NRC, 2015).

Emotional support. When emotionally supportive, principals demonstrated respect, trust, open communication, appreciation, and showed a genuine interest in teachers' work and recommendations. Effective leaders supported the change process by shaping and sustaining an environment that promoted positive relationships among adults by facilitating collegiality and growth through collaboration (Brezichia et al., 2015). Using a sample from the School and Staffing Survey, a researcher studied how affective relationships shaped principal and teacher attitudes. Price (2011) reported that a teacher's relationship with the principals strongly and directly affected the teachers' attitudes.

Appraisal support. Principals supported teachers by providing ongoing personal evaluations of teaching practices and feedback to teachers on their instruction formally and informally. Within the context of the study, evaluations of science teachers by principals was not investigated.

Ultimately, the success of educational reforms was dependent upon the principal's capacity to implement policies and influence change (Byrk et al., 2010; Leithwood et al., 2012). Principal impacted the change process positively when they participate in the process of learning with teachers, differentiated supports based on teachers' needs, established a positive relationship and a positive school climate. Hence, it was essential for science teachers to receive continuous support to develop an understanding of science and engineering practices and the appropriate instructional strategies to deliver quality instruction aligned to the vision of the *Frameworks* (NRC, 2012). In this regard, principals were positioned to play a critical role in enhancing the quality of science teachers' instruction (Banilower, Heck, & Weiss, 2007; Robinson, Lloyd, & Rowe, 2008; Whitworth & Chiu, 2015).

## Limitations of Prior Research

Existing literature on science teachers' concerns and empirical studies on science and engineering practices, especially at the secondary level, were extremely limited in number and scope. Since 2012, increasingly more studies were conducted on science teachers and their incorporation of engineering practices; however, most focused on engineering practices in the elementary education setting (Cunningham & Kelly, 2017; Lachapelle, Sargianis, &

Cunningham, 2013; Milano, 2013; Wendell & Rogers, 2013); yet, only one study focused on the topic at the secondary science level (Boesdorfer & Staude, 2016).

It was anticipated that research on the implementation of the Next Generation Science Standards (NGSS), Science Georgia Standards of Excellence (SGSE), science and engineering practices, and their impact on teachers, leaders, and student performance could be conducted and reported during the first years of implementation. Although the body of research on the topic was growing, very few studies about the standards, implementation processes, and its impact on student achievement were conducted.

## Theoretical Framework

### Concerns Theory

Frances Fuller and her colleagues at the University of Texas at Austin's Research and Development Center for Teacher Education conducted studies that were paramount to the development of theories relating to educational change and teacher concerns (Fuller, 1969; Fuller & Case, 1970; Hall, Wallace, & Dossett, 1973; George, Hall, & Rutherford, 1976). Following the launching of *Sputnik*, math and science classrooms in the United States were introduced to radical, new approaches to teaching and learning. To increase the likelihood of successful implementations, summer professional development institutes were funded. Unfortunately, one year after each new curriculum was introduced, the evaluation of the program revealed discouraging data. As a result, each program was discarded, and a new program was introduced. Frustrated with the cycle of failed implementation, developers at the National Institute of Education funded studies at the University of Texas Austin's Research and Development Center for Teacher Education to investigate the educational change and improvement process.

The notion of Concerns Theory emerged from Frances Fuller's (1969) work with student teachers. According to the Concerns Theory, at the beginning of the change process, teachers' concerns were focused on their feelings about how the instructional change impacted them personally (self). As teachers began to use new instructional practices, they expressed concerns about the task, which can be described as the feelings, thoughts, attitudes, and perceptions of their performance, their management of time and resources, and their effectiveness. Overtime, as teachers became skilled in managing the new practice, teacher were more concerned about the impact the new practice had on students and their colleagues (impact concerns) (Fuller, 1969; Hall, 1979; Hall, Hord, & George, 2014).

**Administrative Support**

Littrell, Billingsley, and Cross (1994) adapted James House's (1981) variation of the social support theory and proposed that administrative support for teachers included four behavioral domains: instrumental support, informational support, emotional support, and appraisal support. Instrumental support consisted of the principal helping teachers with work-related tasks. Informational supported was demonstrated when principals provided information that could be used to improve classroom practices. Emotional support involved the principal showing teachers that they were respected, trusted professionals, and worthy of concern. Appraisal support was demonstrated when principals provide teachers with ongoing, frequent and constructive feedback (Littrell et al., 1994).

## Summary

As science teachers shifted from teaching science as a process of inquiry to teaching science as a practice, feelings of preparedness, their knowledge and skills, support and guidance, and pedagogical beliefs were identified as concerns that impacted the teachers' ability to successfully implement science and engineering practices. Principals created conditions within schools to ensure success by cultivating a supportive learning environment for adults by developing positive relationships with teachers, participating in the learning process with teachers, providing the necessary time and resources, and by designing differentiated support for teachers as they incorporated the new practice. Educational literature was limited for science and engineering practices and even more so for the secondary educational setting.

**Conceptual Analysis Chart**

**Topic: Science and Engineering Practices**

| Study | Purpose | Participants | Design/Analysis | Outcomes |
|---|---|---|---|---|
| Nollmeyer & Bangert (2015) | To establish measures for assessing in-service educators' self-reported understanding of NGSS and readiness to implement the ideas in their science instruction<br>- To design and validate an instrument to assess the constructs | 167 K-5 Science Teachers from Montana, Wyoming, Utah, Idaho | Quantitative/ exploratory analyses and confirmatory factor analyses | "Solid" Understanding of Science and Engineering Practices,<br><br>"Solid" Readiness to implement Science and Engineering Practices |

| | | | | |
|---|---|---|---|---|
| Haag & Megowan, (2015) | To assess level of motivation to adopt NGSS science and engineering practices and their feelings of readiness to implement practices<br>To define characteristics of prepared teachers | 710 Grades 7-12 Science Teachers | Mixed Methods/ Quantitative: 2x2 factor ANOVA and independent *t*-tests<br>Qualitative: data reduction, data display, and conclusion drawing and verification | HS teachers trained in specific practices reported they were more motivated and felt better prepared.<br><br>Science teachers reported a need for preparation in engineering content |
| Trygstad, Smith, Banilower, & Nelson (2013) | To highlight data from 2012 survey that contributed to science teachers' readiness to embrace NGSS | K-5 Science Teachers from the 2012 National Survey of Science and Mathematics data set | Quantitative/ descriptive data only | Few science teachers reported having taken engineering courses in college |

**Conceptual Analysis Chart**

**Topic: Administrative Support Provided by Principals**

| Study | Purpose | Participants | Design/Analysis | Outcomes |
|---|---|---|---|---|
| Cancio, Albrecht, & Johns, 2013 | To identify contemporary factors affecting teacher longevity | 408 teachers | Quantitative/ Cronbach's Alpha, Pearson Correlations | Characteristics of administrative support significantly impacted positive view of school, extent of support, trust |

| | | | | |
|---|---|---|---|---|
| Littrell, Billingsley, & Cross, 1994 | To identify special and general teachers' perceptions of principal support<br><br>Investigated the effects of perceived principal support on teacher stress and personal health, job satisfaction, school commitment, and intent to stay in teaching | 385 special and 313 general education teachers in Virginia | Quantitative/ cross-validated regression | Specific types of support are significant predictors of job satisfaction, school commitment |

# CHAPTER III: METHODOLOGY

## Introduction

The dominant instructional approach in science education in the United States changed from inquiry to the three-dimensional learning model after the publication of *Framework* in 2012. Science and engineering practices comprised one component of the three-dimensional learning model. Researchers reported varying level of preparedness among science teachers in preliminary studies. In several studies, the science teachers reported the need for administrative support during implementation. Science teachers in Georgia began implementing the Science Georgia Standards of Excellence during the 2017- 2018 school year. The science and engineering practices were embedded in the new standards. The purpose of the study was to investigate the perceptions middle and high school science teachers had about science and engineering practices and administrative support provided by principals during the implementation of Science Georgia Standards of Excellence.

This chapter was a presentation of the research methods and procedures used to conduct the study. Sections included the research questions, research design, participants, sampling, instrumentation, validation, data collection, analysis, and reporting methods.

## Research Questions

The researcher addressed the following questions in the study: (1) To what extent are the perceptions middle and high school science teachers have about science and engineering practices during the implementation of Science Georgia Standards of Excellence different? (2) To what extent are the perceptions middle and high school science teachers have about administrative support provided by the principal during the implementation of the Science Georgia Standards of Excellence different?

## Research Design

To conduct the investigation, the researcher utilized a sequential explanatory mixed methods research design (Creswell & Plano Clark, 2011). According to Tashakkori and Creswell (as cited in Creswell & Plano Clark, 2011, p.4), a mixed methods approach was characterized as research in which the investigator collected and analyzed data, integrated the findings, and drew inferences using both quantitative and qualitative approaches in a single study. The sequential explanatory design strategy for conducting mixed methods research studies was described as a two-phase design, in which quantitative data were collected and analyzed first followed by qualitative data collection (Johnson & Christenson, 2017).

The main rationale for selecting a mixed methods design strategy was complementarity (Greene, Caraceli, & Graham, 1989). It was decided that qualitative data were needed to further explain and interpret the findings from the quantitative phase. The researcher determined that the research problem could not be best understood by using the quantitative results alone to examine the differences in perceptions (Creswell & Plano Clark, 2011). A mixed methods design provided more evidence to fully answer the research problem than either quantitative or qualitative methods alone (Creswell & Plano Clark, 2011). To further support the researcher's rationale for using this design, the two-phase structure made it easier for a single researcher to manage the data collection and analysis associated with each phase (Creswell & Plano Clark, 2011).

Consistent with the sequential explanatory mixed methods design, the researcher collected and analyzed quantitative data using a web-based survey and SPSS; then, the researcher facilitated focus group discussions to collect qualitative data to further explain the quantitative results (Creswell & Plano Clark, 2011; Johnson & Christenson, 2017). Next, qualitative data were analyzed by identifying themes and using a spreadsheet. Taken together, the researcher integrated the findings and made inferences about the data collected to answer the research questions.

## Population

The population for this study included all middle and high school science teachers in the State of Georgia who were teaching courses aligned to the Science Georgia Standards of Excellence in 2017-2018. The administration of web-based surveys and facilitation of focus group discussions to investigate the differences among the entire populations of middle and high school science teachers in Georgia was not feasible considering the time and resources available to the researcher.

To identify a subset of the population, the researcher utilized sampling techniques that were consistent with the quantitative methods for the first phase and qualitative methods for the second phase (Teddlie & Fu, 2007). Characteristically, probability sampling techniques, which aimed to achieve representativeness, were used to identify a sample for quantitative research (Teddlie & Tashakkori, 2009). To ensure the maximum breadth of quantitative information, the researcher employed the one-stage cluster sampling technique to identify a group of schools that naturally occurred in the population by selecting one regional education service agencies (RESAs) in southwestern Georgia. Cluster sampling was preferred over simple random sampling and systematic sampling because the travel costs and amount of time to conduct the study were greatly reduced as a result of using the cluster sampling technique compared to other sampling alternatives that offered the similar representativeness (Johnson & Christensen, 2017). Within the RESA cluster, there were approximately 20 middle schools and 18 high schools that served students in grades six through12.

Next, a total population sampling technique was used to invite school systems to participate in the research study. Of the 16 school systems included in the cluster, three letters were returned from school district leaders who agreed to cooperate with the terms of the study to allow their middle and high school science teachers to take a survey or participate in a focus group discussion. A total of 111 subjects were identified. More precisely, there were 60 middle school science teachers and 51 high school science teachers who taught one or more of the follow Science Georgia Standards of Excellence-based courses: $6^{th}$ grade Earth Science, $7^{th}$ grade Life Science, $8^{th}$ grade Physical Science, Biology, Physical Science, Chemistry, Environmental Science, or Physics.

One aspect of the study was based on the science teachers' perception of administrative support provided by the principal during the implementation of Science Georgia Standards of Excellence. Middle and high school principals were excluded from the study, because the purpose of the study was not to validate or show differences between science teachers' and principals' perceptions of administrative support provided to middle and high school science teachers during the implementation of the Science Georgia Standards of Excellence.

## Participants

The participants in this research study were limited to middle and high school science teachers who taught Science Georgia Standards of Excellence-based courses in three school systems within a regional education service agency (RESA) in southwestern Georgia. All eligible participants at each middle and high school were chosen to participate in the study, because the number of teachers was relatively small. Furthermore, eliminating any potential respondents negatively impacted the significance of research findings.

Participation from science teachers was expected to be high, because the topic was current, relevant to the daily work of middle and high school science teachers, and the potential findings could improve the implementation process. Although there was no incentive to participate, results from the study could improve the administrative supports provided by principals, increase the number of relevant professional learning sessions aligned to the needs of middle and high school science teachers regarding the topics, and highlight specific concerns unique to each group of science teachers that had not previously been reported in the research findings.

## Sample

To obtain a subset of the population, the researcher utilized sequential mixed methods sampling techniques (Johnson & Christensen, 2017; Teddlie & Fu, 2007). To achieve a representative sample to answer the research questions quantitatively, a one-stage cluster sampling technique was used to identify a sample of middle and high school science teachers. The State of Georgia was organized into 16 regional education service agency (RESA) areas. Through random selection, one cluster was selected from the 16 regions. Using a total population sampling technique, the researcher requested permission from each school system served by the RESA via e-mail and a letter. Three of the 16 school systems returned letters of cooperation and agreed to allow all middle and high school science teachers to participate in the study. Potential respondents indicated a desire to participate in the focus group discussion in lieu of completing the survey when answering the second question on the survey. Due to the low number of respondents who indicated a desire to participate in a focus group, a total sampling technique, instead of a purposive sampling technique, was used.

## Instrumentation

The researcher created two nearly identical web-based surveys to collect data from middle and high school science teachers on their perceptions of science and engineering practices and administrative support provided by their principal during the implementation of the Science Georgia Standards of Excellence. The unique features of each survey were the grade-band specific tasks associated with each practice found in the practices matrix; however, the questions were the same on both instruments. The sections of the instrument were informed consent and permission to participate in the focus group discussion; demographic information; science and engineering practices; and administrative support provided by the principal.

### Informed Consent Information and Focus Group Participation

The first question on the web-based survey to be answered by all participants was the informed consent. The following information was included: (1) an explanation of the research project and its purpose, (2) a description of the procedures for data collection, (3) a description of the minimal risks and potential benefits associated with the research project, (4) a statement about the lack of costs and compensation, (5) a statement explaining the maintenance of confidential records, and (6) a statement explaining the procedures for withdrawal. The participants selected the appropriate response within the web-based survey as to whether they agreed or disagreed to participate in the study. If the participant chose not to participate, the survey concluded, and the response will be recorded.  If the participant chose to participate, then the survey advanced to the next page, Focus Group Participation. If the participant chose not to participate in the focus group, the survey advanced to the next item. If the participant chose to participate in the focus group, the survey concluded, and the response will be recorded.

**Demographic Information**

Demographic information was assessed using questions about the participants' education level and major, years of experience, years of experience teaching science, number of science teachers in the school, and number of professional learning sessions attended that were sponsored by the Georgia Department of Education, the area RESA, and the local school district. Demographic information was used to identify perception data trends based on the level and area of concentration.

Education level. Respondents were asked to indicate the areas of their undergraduate major and graduate major using the options of science, education, science education, or other. On question 3, respondents who had not obtained a graduate degree can select "I do not hold a graduate degree."

Teaching experience. For questions 5 and 6, respondents answered questions about the number of years teaching and the number of years teaching science. Possible answer choices for each question were as follows: 0 – 4 years, 5 – 9 years, 10 – 14 years, 15 – 19 years, 20 – 24 years, 25 – 29 years, and 30 or more years.

Work environment. For question 7, respondents indicated the number of science teachers in their schools by selecting one of the following: 1, I am the only teacher in my school; 2 -4 science teachers; 5 – 7 science teachers; 8 – 10 science teachers; 11 – 13 science teachers; and 14 or more science teachers.

Professional learning. For questions 8, 9, and 10, respondents indicated the number of professional learning session attended offered by the Georgia Department of Education, the Regional Education Service Agency (RESA), and the local school district. Answer choices were as follows: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 or more.

**Science and Engineering Practices**

To answer the first research question, “To what extent are the perceptions middle and high school science teachers have about science and engineering practices during the implementation of Science Georgia Standards of Excellence different?”, middle and high school science teachers rated their level of concern regarding each science and engineering practice using a 4-point Likert scale. The value associated with each response was one point for not at all concerned, two points for slightly concerned, three points for somewhat concerned, and four points for extremely concerned. For items 11-18, science teachers were provided the list of grade band-appropriate tasks for each of the science and engineering practices (See Appendices C and D).

**Administrative Support Provided by the Principal**

To answer the second research question, “To what extent are the perceptions middle and high school science teachers have about administrative support provided by the principal during the implementation of the Science Georgia Standards of Excellence different?”, middle and high school science teachers rated their level of agreement with a series of statements using a 4-point Likert Scale. The value associated with each response was one point for strongly agree, two points for agree, three points for disagree, and four points for strongly disagree. For items 19 – 24, science teachers responded to the following statements (See Appendices C and D): (19) I am satisfied with the amount of support I receive to implement science and engineering practices. (20) I am satisfied with the amount of support I receive from my principal to implement science and engineering practices. (21) My principal has conversations with me about my delivery of science instruction related to science and engineering practices embedded in the Science Georgia Standards of Excellence. (22) My principal encourages the implementation of science and engineering practices. (23) My principal enhances the science program at my school by providing me with the needed materials and equipment. (24) My principal provides time for science teachers in my school to meet and share ideas about implementing science and engineering practices with one another.

**Focus Group Protocol**

A hard copy of the informed consent form was provided to focus group participants at the beginning of the focus group meeting. The researchers reminded participants of each component of the informed consent form. Special emphasis was placed on confidentiality and procedures for withdrawal.

To further explain quantitative results from the first research question, the researcher facilitated a semi-structured discussion for each of the eight practices with following questions: (1) What were your feelings about the tasks? (3) How well do you feel you were implementing the practice? (4) How has professional learning impacted the implementation of SEPs? (4) Tell me about any other concerns you have about implementing the practice. The order in which the practices were discussed were prioritized based on the quantitative findings.

To further explain quantitative results from the survey for the second research question, the researcher introduced the following questions to guide discussions had by the two groups: (1) Tell me about the type of support you receive to ensure you were implementing the science and engineering practices. (2) How was your principal supporting you during the implementation of the Science Georgia Standards of Excellence? (3) How was your principal supporting you with the science and engineering practices?

## Validation

### Web-based Survey

A draft of the survey was evaluated by a group of five science teachers from southwest Georgia who worked in middle and high schools which were not included in the study to determine face validity (Teddlie & Tashakkori, 2009). The science teachers responded to the items, provided feedback on the clarity of the items, the time it took to complete the surveys, and made suggestions for improvement. The final survey instruments reflected the recommendations of the panel of science teachers.

During the actual data collection period, respondents were allowed to review answers and revisit questions to ensure that the selected responses for each question reflects their true opinion prior to submitting the survey.

### Focus Group Discussions

To ensure trustworthiness of the data collected during focus group discussions, member checking was utilized (Johnson & Christensen, 2017). According to Lincoln and Guba (1985), member checks were “the most crucial technique for establishing credibility” (p. 314) in a study. During the discussions, the researcher used paraphrasing, summarization for clarification, and probing techniques to clarify participant responses, when it was appropriate.

## Data Collection

The procedures for collecting data in this mixed method study were consistent with a sequential explanatory design and the use of two data collection strategies. After receiving approval to conduct the research from the Institutional Review Board (IRB) from the university, the researcher emailed participants received a Survey Monkey e-mail invitation to complete a web-based survey, entitled Science and Engineering Practices: Middle School Science Teachers’ Task Concerns and Administrative Support Survey or Science and Engineering Practices: High School Science Teachers’ Task Concerns and Administrative Support Survey, via their school district e-mail account during November 2017.The first page of the web-based survey included the informed consent information. The participants selected the appropriate response within the web-based survey as to whether they agreed or disagreed to participate in the study.  If participant disagreed, the survey ended. The response was recorded. If the participant agreed, then the survey advanced to the next item.

The second item/page of the web-based survey asked respondents if they would like to participate in a focus group discussion. Respondents selected the appropriate response within the web-based survey as to whether they would or would not like to participate in a focus group discussion. If the participant did not want to participate in the focus group, then the survey advanced to the next item. If the participant wanted to participate in the focus group, then the survey ended. The responses were recorded. Three days after the initial Survey Monkey e-mail invitation was sent, non-responders received an e-mail reminder to complete a web-based survey via their school district e-mail account during November 2017. The researcher analyzed survey data using Statistical Package for the Social Sciences (SPSS) software.

Focus group participants received an e-mail with the location and options to schedule the focus group interview on a mutually agreed upon day and time. Focus group participants participated in a 45- to 60-minute semi-structured, open-ended focus group discussion with five middle school science teachers and five high school science teachers facilitated by the researcher. The order of questions was based on the quantitative findings. The researchers collected data using audio recorded using digital electronic device. Participants used their first name only and were reminded of the importance of confidentiality. The participants were e-mailed the transcript of the focus group interview for member checking purposes, if requested by participants. The transcript did not include any identifiable information. The researcher analyzed focus group data to identify themes to further understand the topic using a spreadsheet.

## Response Rate

The researcher e-mailed the online surveys using the Survey Monkey e-mail invitation tool to all middle and high school science teachers who taught Science Georgia Standards of Excellence-based courses in three school systems in the southwestern region of Georgia. Two e-mails were sent to a sample pool of 111 science teachers, of which 60 were middle school science teachers and 51 were high school science teachers. Survey responses were submitted by 60 science teachers (29 middle school science teachers and 31 high school science teachers), for an overall response rate of 54% (Dillman, Smyth, & Christian, 2009).

Middle school science teachers returned 29 surveys with responses to the survey or marked for participation in the focus group discussion, for a group response rate of 47%. Upon further investigation, the researcher determined that 18 of 60 (30%) middle school science teachers submitted a completed survey and 11 of 60 (18%) middle school science teachers indicated the desire to participate in the focus group discussion; however, only 5 of 60 (8.3%) middle school science teachers participated in the focus group discussion. In total, 38% (23 of 60) of the middle school science teachers in the sample pool participated in the study.

Thirty-one high school science teachers submitted completed responses to the survey or indicated a desire to participate in the focus group discussion among high school science teachers. Their group response rate was 61% (31 of 51). Only five of 31 respondents agreed to participate in the focus group, which they all did. One respondent did not agree to the informed consent information; as a result, the respondent was disqualified from participation. In total, there were 30 of 51 (59%) high school science teachers who participated in the research study.

Web-based surveys typically had low response rates, which increased the chance of biased results and decreased the likelihood that the results represented the sample of interest (Johnson & Christensen, 2017; Robson, 2011). To maximize the response rate, the researcher used the "personalize and repeat" approach (Morgan & Adams, 2012). The researcher e-mailed potential respondents a personalized e-mail invitation from Survey Monkey with language to show enthusiasm, demonstrate trustworthiness, appeal to the potential respondent's connection to study results, ensure confidentiality, and describe the time required to complete the survey (Dillman, Smyth, & Christian, 2009; Millar & Dillman, 2011). Three days after the original invitation, a personalized reminder e-mail was sent to non-respondents to remind them about the survey with the same persuasive language as the e-mail invitation (Morgan & Adams, 2012).

Also, administrators from each district provided an accurate list of eligible science teachers prior to the start of the research. During the study, administrators reminded teachers about the survey (Monroe & Adams, 2012).

## Data Analysis

### Web-based Surveys

There researcher analyzed data collected from the online surveys using the Statistical Package for the Social Sciences (SPSS) software. The two data sets were combined, and descriptive analyses were performed. Descriptive data generated were frequency, percent, mean, standard deviation, and standard error mean. To evaluate whether there was a significant difference between the mean scores reported by middle school science teachers and high school science teachers, two-tailed independent sample t-tests were performed at the alpha level .05 for question 11-24. Inferential data generated by Statistical Package for the Social Sciences (SPSS) software included the Levene's Test for Equality of Variances variables, $F$ – statistics and its Sig. $p$ value; $t$ values, degree of freedom, the $p$ value for the $t$ test, mean difference values, standard error difference, and the lower level and upper level values for the 95% confidence intervals.

There were two assumptions associated with $t$-test, normal distribution and equality of variances among groups in the data set. For each $t$ test analysis, the assumption of homogeneity of variance was assessed. On occasions when the Sig $p$ value for the Levene's Test was less than .05, the null hypothesis for variance, which assumed that there was no difference in the variances between two groups, was rejected and the alternative hypothesis was accepted, the results from the adjust test were used. The issue of differences in variance was corrected by Statistical Package for the Social Sciences (SPSS) software using the Welch- Satterthwaite *t*-test Method.

### Focus Group Discussions

The narrative data collected during the two focus group discussions were analyzed by the researcher using a spreadsheet. Following the interviews, the data were transcribed, chunked, and coded. Themes, patterns, and quotes relevant to the study were identified for each question.

## Reporting of Data

Data from the investigation were reported in the following order: demographic data, research question (1) – science and engineering practices, then research question (2) – administrative support, which was also the order of the questions on the survey instruments. The researcher described demographic data collected from respondents of the surveys in the text and displayed in tables.

For the first research question, “To what extent are the perceptions middle and high school science teachers have about science and engineering practices during the implementation of Science Georgia Standards of Excellence different?”, subheadings were created for quantitative results and qualitative findings. Under the quantitative results subheading, another level of subheadings was created for each of the science and engineering practices, which corresponded to items 11-18 on the surveys. For the quantitative results, data were displayed as graphs, tables, and described in the text. Under the qualitative subheading, direct quotes from participants were detailed in tables and described in text.

For the second research question, “To what extent are the perceptions middle and high school science teachers have about administrative support provided by the principal during the implementation of the Science Georgia Standards of Excellence different?", subheadings were created for quantitative results and qualitative findings. Under the quantitative results subheading, another level of subheadings was created using the question number and the statement which matched items 19-24 on the surveys. Under each subheading for questions 19-24, quantitative data were displayed as graphs, tables, and described in the text. Under the qualitative findings subheading, direct quotes from participants were detailed in tables, along with a narrative.

## Summary

To answer the research questions, the researcher used a sequential explanatory mixed methods design. First, the researcher identified the potential respondents using cluster sampling and total population sampling techniques. Once approved by superintendents and the Institutional Review Board at the university, the researcher e-mailed the 111 potential respondents web-based surveys using Survey Monkey's e-mail invitation tool. Forty-four respondents completed a 24-item survey with perception question about science and engineering practices, administrative support, and demographic information. Afterwards, data from the two surveys, one set from the middle school science teacher survey and another from high school science teacher survey, were analyzed using Statistical Package for the Social Sciences (SPSS) software. Descriptive data (i.e. frequencies, means, standard deviations,) and inferential data from a two-sided independent-sample *t*-test at an alpha level of .05 were analyzed.

During the survey, potential respondents indicated a desire to participate in a focus group discussion instead of completing a survey. Using a total sampling technique to identify participants, the researchers facilitated two semi-structured, open-ended focus group discussions at a public library on a date and time that maximized participation. A digital electronic device was used to record each of the 45- to 60-minute focus group discussions with five middle school science teachers and five high school science teachers. Audio recordings were transcribed by the researcher and e-mailed to participant for member checking. Next, spreadsheets were used to analyze qualitative data to identify themes. Afterwards, the researcher answered the research questions by integrating the quantitative results generated from the web-based surveys and qualitative findings from the focus group discussions and making inferences from the findings. The data collected were not collected for the purpose of use in future projects.

**Research Confirmation**

| Research Question | Instrumentation/ Analysis | How will strategy answer research question? |
|---|---|---|
| 1. Perceptions of Science and Engineering Practices | Survey/independent t-test at the 95% CI<br><br>Focus group discussions/coding and narrative data | A comparison of the mean score indicated significant differences between groups.<br>Narrative data and themes from the focus group discussions explained and expounded on the quantitative results. |
| 2. Perceptions of Administrative Support Provided by Principals | Survey/independent t-test at the 95% CI<br><br>Focus group discussions/coding and narrative data | A comparison of the mean score indicated significant differences between groups.<br>Narrative data and themes from the focus group discussions explained and expounded on the quantitative results. |

**Survey Item Analysis**

| Item | Research | Survey Question | Research Question |
|---|---|---|---|
| 1. Undergraduate major | Banilower, Smith, Weiss, Malzahn, Campbell, & Weis, 2013; Cunningham & Carlsen, 2014 | 3 | 1 |
| 2. Graduate Major | Banilower, et al., 2013; Cunningham & Carlsen, 2014 | 4 | 1 |
| 3. Number of years teaching | Trygstad, Smith, Banilower, & Nelson, 2013 | 5 | 1, 2 |
| 4. Number of years teaching science | Trygstad, et al, 2013 | 6 | 1, 2 |
| 5. Number of science teachers in school | Bazerman, 1988 | 7 | 1, 2 |
| 6. Georgia Department of Education professional learning sessions attended | Daily & Robinson, 2016; Haag & Megowan, 2015 | 8 | 1, 2 |
| 7. Southwest Georgia Regional Education Service Agency Professional Learning sessions attended | Daily & Robinson, 2016; Haag & Megowan, 2015 | 9 | 1, 2 |
| 8. School district professional learning session attended | Daily & Robinson, 2016; Haag & Megowan, 2015 | 10 | 1, 2 |
| 9. Asking Questions and Defining Problems | Rosenshine, Meister, & Chapman, 1996; Schmidt, 1993; NRC, 2012 | 11 | 1 |
| 10. Developing and Using Models | Haag & Megowan, 2015; NRC, 2012 | 12 | 1 |
| 11. Planning and Carrying Out Investigations | NRC, 2012 | 13 | 1 |
| 12. Analyzing and Interpreting Data | NRC, 2012 | 14 | 1 |
| 13. Using Mathematical and Computational Thinking | NRC, 2012 | 15 | 1 |
| 14. Constructing Explanations and Designing Solutions | NRC, 2012 | 16 | 1 |
| 15. Engaging in Argument with Evidence | Erduran, Ozdem, & Park, 2015; NRC, 2012 | 17 | 1 |
| 16. Obtaining, Evaluating, and Communicating Information | NRC, 2012 | 18 | 1 |
| 17. Satisfied with amount of support | Daily & Robinson, 2016 | 19 | 2 |

| | | | |
|---|---|---|---|
| 18. Satisfied with amount of support from principal | Daily & Robinson, 2016; Milner, Sondergeld, Demir, Johnson, and Czernicki, 2012 | 20 | 2 |
| 19. Principal has conversations with me about science and engineering practices | Littrell, Billingsley, & Cross, 1994 | 21 | 2 |
| 20. Principal encourages implementations of the science and engineering practices | Littrell, et al., 1994 | 22 | 2 |
| 21. Principal provides the needed materials and tools | Littrell, et al., 1994 | 23 | 2 |
| 22. Principal provides time to for science teachers to meet | Bazerman, 1988; Littrell, et al., 1994 | 24 | 2 |

**Focus Group Protocol Item Analysis**

| Item | Research | Protocol Question | Research Question |
|---|---|---|---|
| 1. What are your feelings about the tasks? (for each practice) | Hall, 1979 | 1 | 1 |
| 2. How well do you feel you are implementing the practice? (for each practice) | Haag & Megowan, 2015 | 2 | 1, 2 |
| 3. How has professional learning impacted the implementation of science and engineering practices? (for each practice) | Milner, Sondergeld, Demir, Johnson, and Czernicki, 2012 | 3 | 1, 2 |
| 4. Tell me about any concerns you have about implementing the practice. (for each practice) | Haag & Megowan, 2015; Hall, 1979 | 4 | 1, 2 |
| 5. Tell me about the type of support you receive to ensure you are implementing the science and engineering practices. | Daily & Robinson, 2016; Milner, et al., & Cross, 1994 | 5 | 2 |
| 6. How is your principal supporting you during the implementation of the Science Georgia Standards of Excellence? | Daily & Robinson, 2016; Milner, et al., 2012; Littrell, Billingsley, & Cross, 1994 | 6 | 2 |
| 7. How is your principal supporting you with the science and engineering practices? | Milner, et al., 2012; Littrell, et al., 1994 | 7 | 2 |

| | | | |
|---|---|---|---|
| 8. Is there anything else you would like to say about your concerns and the support you receive from your principals during the implementation of Science Georgia Standards of Excellence regarding the science and engineering practices? | Littrell, et al., 1994 | 9 | 1,2 |

# CHAPTER IV: REPORT OF DATA AND DATA ANALYSIS

## Introduction

The purpose of the study was to investigate the perceptions middle and high school science teachers had about science and engineering practices and the administrative support provided by their principals during the implementation of the Science Georgia Standard of Excellence in southwest Georgia. In 2012, the National Research Council (NRC) proposed a change in the way science was taught in K – 12 classrooms. One component of the three-dimensional learning model required science teachers to engage students in grade-level appropriate tasks aligned to eight science and engineering practices. The shift from teaching science as a process using inquiry methods, to teaching science as a practice using the practices, was a drastic change for science teachers. Instead of adopting the Next Generation Science Standards that followed the NRC's recommendation, the State of Georgia revised and approved the Science Georgia Standards of Excellence, which incorporated the new practices. In early studies on the implementation of the science and engineering practices in other states, science teachers voiced several concerns, one of which was the amount and lack of administrative support provided by principals. Using a sequential explanatory mixed methods design, the researcher administered web-based surveys and facilitated focus group discussions with middle and high school science teachers from three school systems in southwest Georgia.

Chapter four included the quantitative results and qualitative findings reported by middle and high school science teachers during the data collection periods. The major sections within this chapter included research questions, respondents, the demographic profile of participants, and findings organized by research questions.

## Research Questions

The researcher addressed the following questions in the study: (1) To what extent are the perceptions middle and high school science teachers have about science and engineering practices during the implementation of the Science Georgia Standards of Excellence different? (2) To what extent are the perceptions middle and high school science teachers have about administrative support provided by the principal during the implementation of the Science Georgia Standards of Excellence different?

## Research Design

A sequential explanatory mixed methods design was used to collect data to answer the research questions. First, the researcher obtained approval from superintendents to conduct the study within the school district. Once the university granted approval to conduct the study (See Appendix A), middle and high school science teachers from the school districts were emailed a personalized message and a link to access a 24-item survey (See Appendices C and D). Reminder e-mails were sent two days prior to the closing of the survey. Focus group participants indicated a desire to participate in the focus group discussion in lieu of completing the survey by marking "I Agree." on the second question of the survey.

After the data collection period for the survey closed, the researchers retrieved data and analyzed survey data using SPSS. The results were used to prioritize the questions asked during the focus group discussions. An electronic device was used to record the 45- to 60-minute discussion for each group of science teachers. For each discussion, the researcher used a semi-structured focus group protocol (See Appendix E). Afterwards, the sessions were transcribed and sent to participants for the purpose of member checking. Last, the researcher analyzed the qualitative data using a spreadsheet.

## Demographic Profile of Respondents and Participants

### Web-Based Survey Respondents

Respondents to the web-based surveys reported demographic information about their undergraduate major, graduate major, number of years teaching, number of years teaching science, number of science teachers in the science department at their school, and the number of professional learning sessions they attended offered by the Georgia Department of Education (GA DOE), the regional educational service agency (RESA), and their local school district. These factors were selected to ascertain as much information about the training background of the respondents as possible to aid in explaining trends in the data reported.

Demographic data for the 44 science teachers who responded to the web-based surveys revealed that 59% had majored in science as an undergraduate and 20% had not yet earned a graduate degree. A little over one third majored in science education during undergraduate or graduate studies, as shown in Table 1. Concerning teaching experience, nearly one half had been teaching and teaching science between five and 14 years. Very few respondents had between 15 and 19 and 30 or more years of experience; the same was true for years of experience teaching science. Additionally, 81% worked in schools with five to ten science department members.

**Table 1**

**<u>Web-based Survey Respondents' Demographic Data Summary</u>**

| Characteristic | Attribute | Middle School Science Teachers | | High School Science Teachers | |
|---|---|---|---|---|---|
| Education | | *n* | % | *n* | % |
| | Undergraduate Major | | | | |
| | Science | 13 | 72.22 | 13 | 50.00 |
| | Education | 4 | 22.22 | 8 | 30.77 |
| | Science Education | 1 | 5.56 | 5 | 19.23 |
| | Other | 0 | 0 | 0 | 0 |
| | Graduate Major | | | | |
| | Science | 5 | 27.78 | 2 | 7.69 |
| | Education | 5 | 27.78 | 6 | 23.07 |
| | Science Education | 3 | 16.67 | 10 | 38.46 |
| | Other | 3 | 16.67 | 1 | 6.25 |
| | No Graduate Degree | 2 | 11.11 | 7 | 26.92 |
| Experience | | | | | |
| | No. Years Teaching | | | | |
| | 0 – 4 | 3 | 16.67 | 3 | 11.54 |
| | 5 – 9 | 4 | 22.22 | 8 | 30.76 |
| | 10 – 14 | 4 | 22.22 | 5 | 19.23 |
| | 15 – 19 | 0 | 0 | 3 | 11.54 |
| | 20 – 24 | 3 | 16.67 | 4 | 15.38 |
| | 25 – 29 | 3 | 16.67 | 2 | 7.69 |
| | 30 or more | 1 | 5.56 | 0 | 0 |
| | No. Years Teaching Science | | | | |
| | 0 – 4 | 3 | 16.67 | 4 | 15.38 |
| | 5 – 9 | 4 | 22.22 | 11 | 42.30 |
| | 10 – 14 | 3 | 16.67 | 3 | 11.53 |
| | 15 – 19 | 1 | 5.56 | 4 | 15.38 |
| | 20 – 24 | 3 | 16.67 | 2 | 7.69. |
| | 25 – 29 | 2 | 11.11 | 2 | 7.69 |
| | 30 or more | 1 | 5.56 | 1 | 3.84 |
| Work Setting | | | | | |
| | Science Teachers at School | | | | |
| | 1, I am the only one. | 0 | 0 | 1 | 3.84 |
| | 2 – 4 | 0 | 0 | 3 | 11.53 |
| | 5 – 7 | 10 | 55.56 | 1 | 3.84 |
| | 8 – 10 | 8 | 44.44 | 17 | 65.38 |
| | 11 – 13 | 0 | 0 | 3 | 11.53 |
| | 14 or more | 0 | 0 | 0 | 0 |

*Note.* The sample size for middle school science teachers was $n$ = 18; for high school science teachers, the sample size was $n$ = 26.

As shown in Tables 2 and 3, 59% of the respondents reported that they had not attended any professional learning offered by the Georgia Department of Education or the regional education service agency in preparation for implementing the science and engineering practices. However, 75% attended between three and five professional learning sessions about the science and engineering practices offered by their local school district.

**Table 2**

**Professional Learning Attendance for Middle School Science Teachers, by Sponsor**

| | Georgia Department of Education | | Regional Education Service Agency | | Local School District | |
|---|---|---|---|---|---|---|
| No. of PL Sessions | *n* | % | *n* | % | *n* | % |
| 0 | 11 | 61.11 | 13 | 72.22 | 1 | 5.56 |
| 1 | 2 | 11.11 | 1 | 5.56 | 3 | 16.67 |
| 2 | 3 | 16.67 | 0 | 0 | 0 | 0 |
| 3 | 1 | 5.56 | 1 | 5.56 | 1 | 5.56 |
| 4 | 0 | 0 | 0 | 0 | 2 | 11.11 |
| 5 | 0 | 0 | 2 | 11.11 | 10 | 55.56 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 or more | 1 | 5.56 | 1 | 5.56 | 1 | 5.56 |

*Note.* The sample size for middle school science teachers was $n$ = 18.

**Table 3**

**Professional Learning Attendance for High School Science Teachers, by Sponsor**

| | Georgia Department of Education | | Regional Education Service Agency | | Local School District | |
|---|---|---|---|---|---|---|
| No. of PL Sessions | *n* | % | *n* | % | *n* | % |
| 0 | 15 | 57.69 | 13 | 50.00 | 1 | 3.84 |
| 1 | 7 | 26.92 | 2 | 7.69 | 3 | 11.53 |
| 2 | 0 | 0 | 3 | 11.53 | 1 | 3.84 |
| 3 | 0 | 0 | 4 | 15.38 | 12 | 46.15 |
| 4 | 1 | 6.25 | 4 | 15.38 | 4 | 15.38 |
| 5 | 3 | 11.53 | 0 | 0 | 4 | 15.38 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 or more | 0 | 0 | 0 | 0 | 0 | 0 |

*Note.* The sample size for high school science teachers was *n* = 26.

### Focus Group Participants

Five middle school science teachers and five high school science teachers participated in the separate focus group discussions. Tables 4 and 5 included information about the number of years of experience and grades taught by participants.

**Table 4**

**Middle School Focus Group Participants**

| Participants | Years of Experience | Grade Taught |
|---|---|---|
| Participant 1 | 19 | $7^{th}$ |
| Participant 2 | 5 | $8^{th}$ |
| Participant 3 | 10 | $7^{th}$ |
| Participant 4 | 2 | $6^{th}$ |
| Participant 5 | 8 | $6^{th}$ |

**Table 5**

**<u>High School Focus Group Participants</u>**

| Participants | Years of Experience | Grade Taught |
|---|---|---|
| Participant 6 | <1 | 10th |
| Participant 7 | 26 | 9th |
| Participant 8 | 14 | 12th |
| Participant 9 | 7 | 9th |
| Participant 10 | 12 | 10th |

## Findings

This section was arranged by research question and by quantitative results and qualitative findings. Under the quantitative results subheading, descriptive data, namely frequencies, percent, means, and standard deviations, and inferential data were presented in text, tables, and figures for each of the eight science and engineering practices. For each figure in the section, numbers inside the bars denoted the frequency. The percent for each frequency could be gauged using the vertical percent indicators for 0%, 20%, 40%, 60%, 80%, and 100%. The frequency and percent for each level of concern were based on responses from middle school science teachers, which was shaded gray. The frequency and percent for each level of concern were based on responses from high school science teachers, which were white. Beneath the qualitative findings subheading, major themes from each focus group discussions were presented in narrative and table formats.

Research Question 1: Perceptions of Science and Engineering Practices

To answer the first research question, “To what extent are the perceptions middle and high school science teachers have about science and engineering practices during the implementation of the Science Georgia Standards of Excellence different?”, middle and high school science teachers indicated their level of concern with regard to implementing practices associated with each of the eight practices (See Appendices C and D). The eight practices were (1) asking questions and defining problems, (2) developing and using models, (3) planning and carrying out investigations, (4) analyzing and interpreting data (5) using mathematics and computational thinking, (6) constructing explanations and designing solutions, (7) engaging in argument from evidence, and (8) obtaining, evaluating, and communicating information. The researcher used a 4-point Likert scale with values of 1 = “Not at All Concerned”, 2 = “Slightly Concerned”, 3 = “Somewhat Concerned”, and 4 = “Extremely Concerned”.

Quantitative results. The data for each question from each group were analyzed by calculating the mean score to determine the average level of concern for each group and comparing each group’s mean score using an independent-sample *t*-test at the 95% confidence interval. The comparison of means results revealed there was one significant difference in the perceptions held by middle and high school science teachers about science and engineering practices during the implementation of the Science Georgia Standards of Excellence.

On average, middle school respondents were slightly concerned about implementing the tasks associated with asking questions and defining problems. Eleven of 18 (89%) middle school science teachers reported “Slightly Concerned” and an additional 5 of 18 (28%) marked “Not at All Concerned”. There were two outliers; one middle school science teacher marked “Somewhat Concerned” and “Extremely Concerned” for each category. The mean score for levels of concerns about asking questions and defining problems among middle school science teachers was 1.89, as depicted in Table 6. On average, middle school science teachers were slightly concerned.

As displayed in Figure 2, 13 of 26 (50%) high school science teachers reported that they were somewhat concerned about implementing the performance expectations listed for the 9-12 grade band. Six of the 26 (23%) reported “Slightly Concerned.” The mean score for levels of concerns about asking questions and defining problems among high school science teachers was 2.69, as depicted in Table 6. Based on the results, on average, high school respondents were somewhat concerned about implementing the performance expectations for asking questions and defining problems. Displayed in Figure 2 was an illustration of the frequency distributions of the Likert scale answer choices by group.

An independent-sample *t*-test was conducted to evaluate whether the average level of concern about asking questions and defining problems differed significantly between middle school science teachers and high school science teachers. The test was significant: $t(42) = -3.14$, $p = .003$. The 95% confidence interval for the average level of concern was between -1.32 and -0.29 (see Table 6). According to the results of the *t*-test, on average, high school science teachers (M = 2.69, SD = 0.88) had a significantly higher level of concern than middle school science teachers (M = 1.89, SD = 0.76) about implementing the performance expectations related to asking questions and defining problems, as presented in Table 6. There were no statistically significant differences between the average level of concerns between middle and high school science teachers with regards to the remaining seven practices (see Table 6).

**Table 6**

**Summary of Descriptive and Inferential Data, by Science and Engineering Practice**

| | MS Science Teachers (*n = 18)* | | HS Science Teachers (*n = 26)* | | *t*-test Results | | 95% CI | Significant Difference |
|---|---|---|---|---|---|---|---|---|
| | M | SD | M | SD | *t* | α | | |
| Asking questions, and defining problems | 1.89 | 0.76 | 2.69 | 0.88 | -3.14 | .003 | [-1.32, -0.29] | Yes |
| Developing and using models* | 2.39 | 1.29 | 2.92 | 0.89 | -1.52 | 0.14 | [-1.25, -0.18] | No |
| Planning and carrying out investigations | 3.11 | 0.76 | 2.73 | 0.92 | 1.45 | 0.16 | [-0.15, 0.91] | No |
| Analyzing and interpreting data | 2.56 | 0.98 | 2.54 | 0.81 | 0.06 | 0.95 | [-0.53, 0.57] | No |
| Using mathematics and computational thinking | 2.89 | 1.08 | 2.62 | 1.13 | 0.80 | 0.43 | [-0.42, 0.96] | No |
| Constructing explanations and designing solutions | 2.44 | 0.86 | 2.04 | 0.82 | 1.58 | 0.12 | [-0.11, 0.96] | No |
| Engaging in argument from evidence | 3.06 | 0.73 | 3.04 | 0.92 | 0.07 | 0.95 | [-0.51, 0.54] | No |
| Obtaining, evaluating, and communicating information | 1.61 | 0.85 | 1.92 | 0.89 | -1.16 | 0.25 | [-0.85, 0.23] | No |

*Note.* CI = confidence interval. * The *F* value for Levene's test was 7.90 with a Sig. *p* value of .007. Homogeneity of variance could not be assumed.

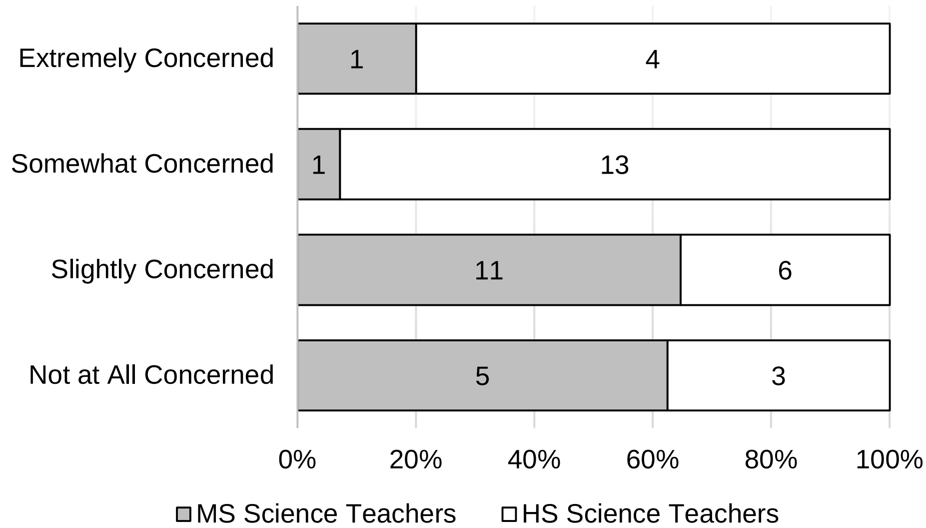


***Figure 2.*** **Frequency distribution for levels of concern regarding asking questions and defining problems by group. MS = middle school; HS = high school. The sample sizes were 18 and 26, respectively. Numbers inside the bars denoted the frequency.**

*Developing and using models.* Based on the results, on average, middle school respondents were slightly concerned about engaging students in the performance expectations associated with developing and using model. One third (6 of 18, 33%) of middle school science teachers responded to the prompt by marking "Not at All Concerned". The same number of respondents marked "Extremely Concerned". As shown in Figure 3, five of the remaining six middle school science teachers reported feeling slightly concerned and one testified "Somewhat Concerned." The mean score for middle school science teachers' level of concern about performance expectations related to developing and using models was 2.39 (see Table 6).

According to data from high school science teachers, 42% (11 of 26) reported they were somewhat concerned about implementing practices that engaged students in the development and use of models. Seven replied with "Extremely Concerned"; five were slightly concerned. The mean score for levels of concerns about developing and using models for high school science teachers was 2.92, as depicted in Table 6. Based on the results, on average, high school respondents were somewhat concerned about implementing the performance expectations for developing and using models.

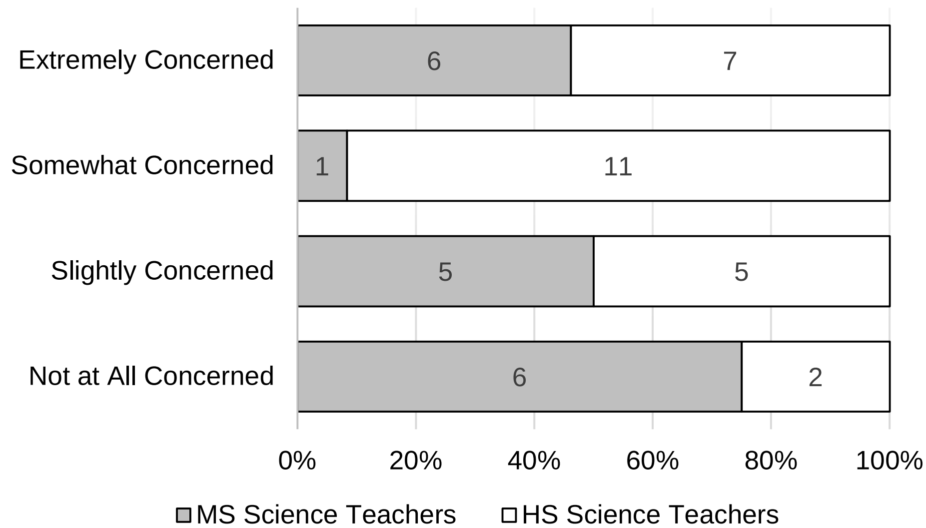


***Figure 3.* Frequency distribution for levels of concern regarding developing and using models by group. MS = middle school; HS = high school. The sample sizes were 18 and 26, respectively.**

*Planning and carrying out investigations.* According to the mean score (M = 3.11) for the level of concern for planning and carrying out investigations, middle school science teachers on average reported they were “Somewhat Concerned” about implementing the practices associated with the practice, as shown in Table 6. According to Figure 4, eight of 18 (44%) indicated they were somewhat concerned, while six of 18 (33%) stated they were extremely concerned.

Among high school science teachers, nearly half (12 of 26) marked “Somewhat Concerned” as their level of concern for planning and carrying out investigations. Five expressed that they were extremely concerned.  Also, three high school science teachers reported they had no concerns with implementing planning and carrying out investigations. The mean score for high school science teachers for question 13 was 2.73, as shown in Table 6. Illustrated in Figure 4 was a side by side comparison of the frequency distribution for the levels of concerns about implement practices related to planning and carrying out investigation reported for each group.

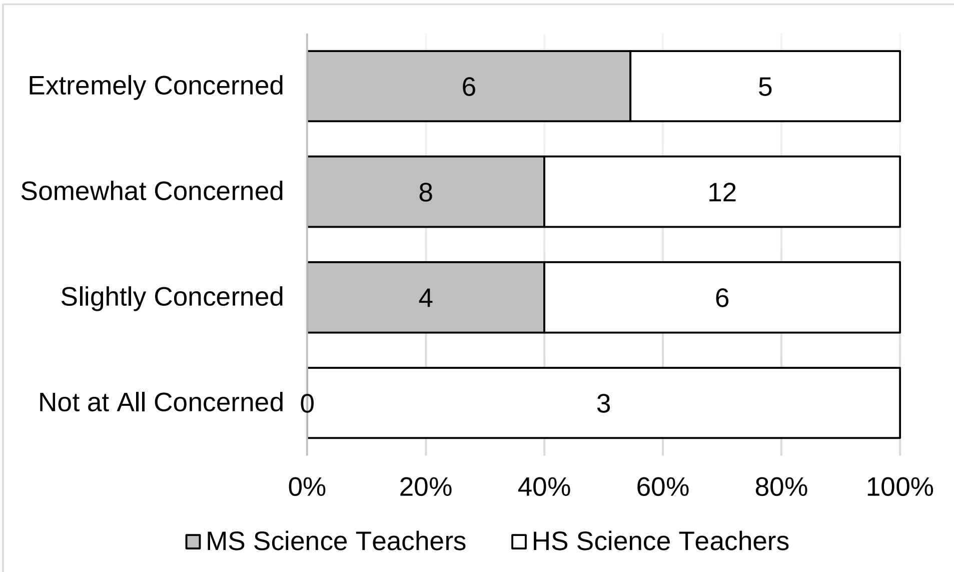


***Figure 4.* Frequency distribution for levels of concern regarding planning and carrying out investigations by group. MS = middle school; HS = high school. The sample sizes were 18 and 26, respectively.**

*Analyzing and interpreting data.* Ten teachers from both groups answered, "Somewhat Concerned". For answer choices "Slightly Concerned" and "Extremely Concerned," there were two middle school science teachers who responding accordingly, as displayed in Figure 5. Among high school science teachers, 11 of 26 (42%) expressed that they were slightly concerned. As shown in Table 6, the mean scores for the levels of concern regarding analyzing and interpreting data for middle school science teachers and high school science teachers were 2.56 and 2.54, respectively.

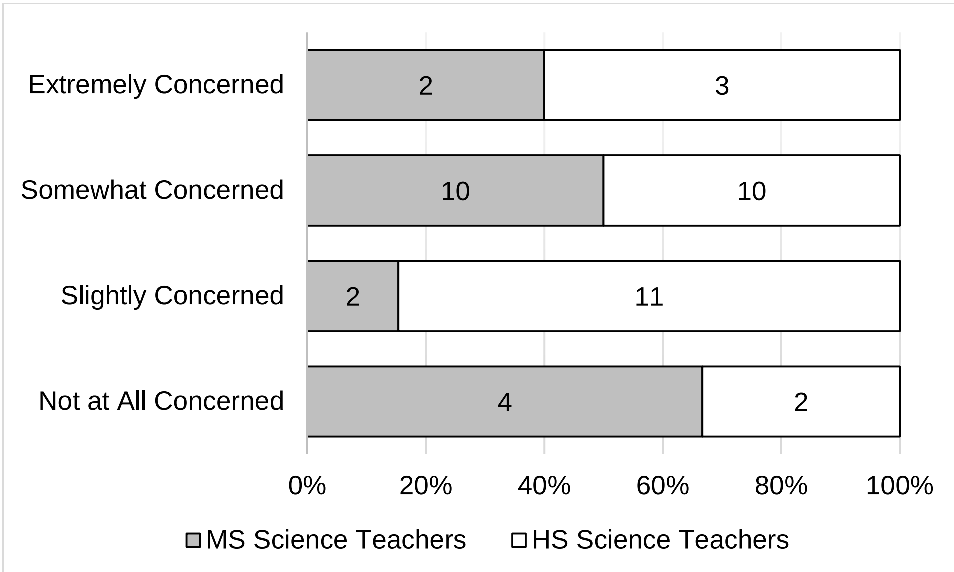


***Figure 5.*** **Frequency distribution for levels of concern regarding analyzing and interpreting data by group. MS = middle school; HS = high school. The sample sizes were 18 and 26, respectively.**

*Using mathematical and computational thinking.* Seven of 18 (39%) middle school science teachers submitted “Somewhat Concerned” as their answer to question 15 on the survey. Six (33%) middle school respondents indicated that they were extremely concerned about implementing practices associated with using mathematical and computational thinking. The mean or average score for levels of concern reported by middle school science teachers was 2.89, as shown in Table 6.  An interpretation of the mean implied that on average middle school science teachers who responded were somewhat concerned about implementing practices related to using mathematical and computational thinking.

The responses from high school science teacher were distributed as follows: 30% marked "Extremely Concerned" and "Slightly Concerned; 20% marked "Not at All Concerned" and "Somewhat Concerned." The distribution of responses from high school science teachers was illustrated in Figure 6. In Table 6, the mean value for levels of concerns about using mathematical and computational thinking reported by high school science teachers was 2.62, which was close to slightly concerned and somewhat concerned.

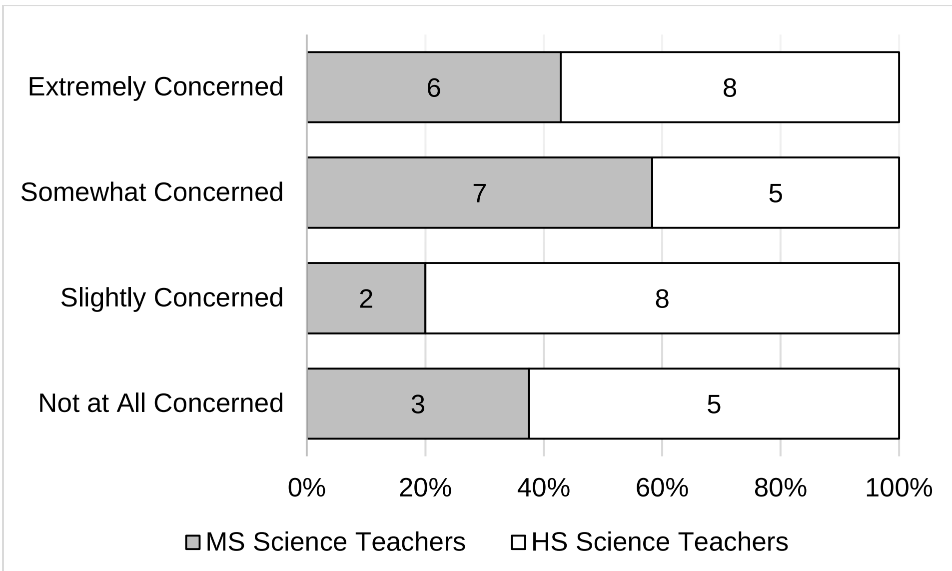


***Figure 6.*** **Frequency distribution for levels of concern regarding using mathematical and computational thinking by group. MS = middle school; HS = high school. The sample sizes were 18 and 26, respectively.**

*Constructing explanations and designing solutions.* Among middle school science teachers, 44% (8 of 18) expressed that they were slightly concerned about implementing the performance expectations associated with constructing explanations and designing solutions, and 33% (6 of 18) responded by marking "Somewhat Concern", as displayed in Figure 7. The average score for the level of concern of middle school science teachers regarding the implementation of practices associated with constructing explanations and designing solutions was 2.44, as shown in Table 6.

Nearly 60% (15 of 26) of high school science teachers reported being slightly concerned with the expectations for this practice. Six of 26 (23%) indicated they were not at all concerned about implementing the practices associated with constructing explanations and designing solutions. The mean of the levels of concerns for high school science teachers regarding their levels of concern about constructing explanations and designing solutions was 2.04, as shown in Table 6.

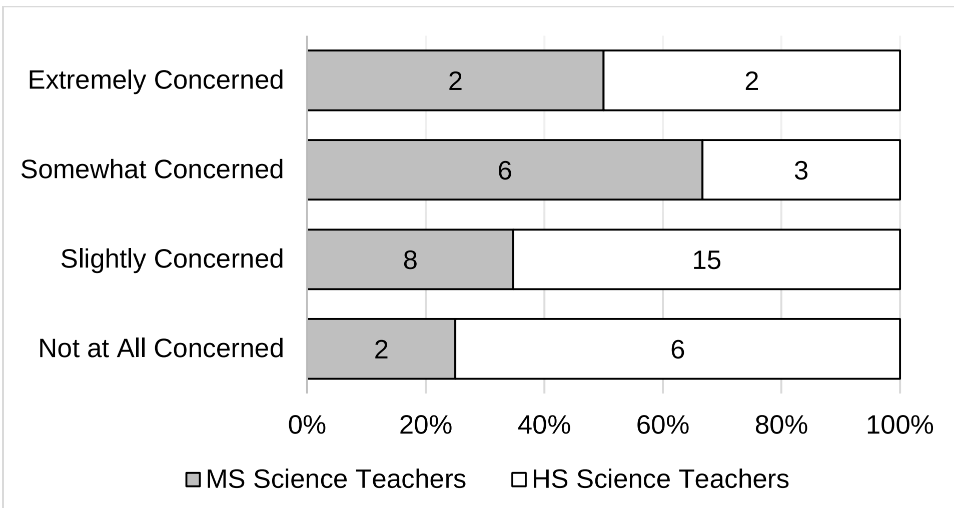


***Figure 7.*** **Frequency distribution for levels of concern regarding constructing explanations and designing solutions by group. MS = middle school; HS = high school. The sample sizes were 18 and 26, respectively.**

*Engaging in argument from evidence.* Half (9 of 18) of middle school science teachers reported that they were somewhat concerned about implementing the tasks associated with engaging in argument from evidence; Twenty-eight percent (5 of 18) submitted “Extremely Concerned” as their response to question 17. The average score for the levels of concern about implementing the performance expectations for engaging in argument from evidence reported by middle school science teachers was 3.06, as displayed in Table 6.

The average score reported by high school science teachers was 3.04, as listed in Table 6. The frequency of high school science teachers reporting "Somewhat Concerned" for the question about engaging in argument from evidence was 11. Additionally, 35% of high school science teachers (9 of 26) submitted an answer of "Extremely Concerned."

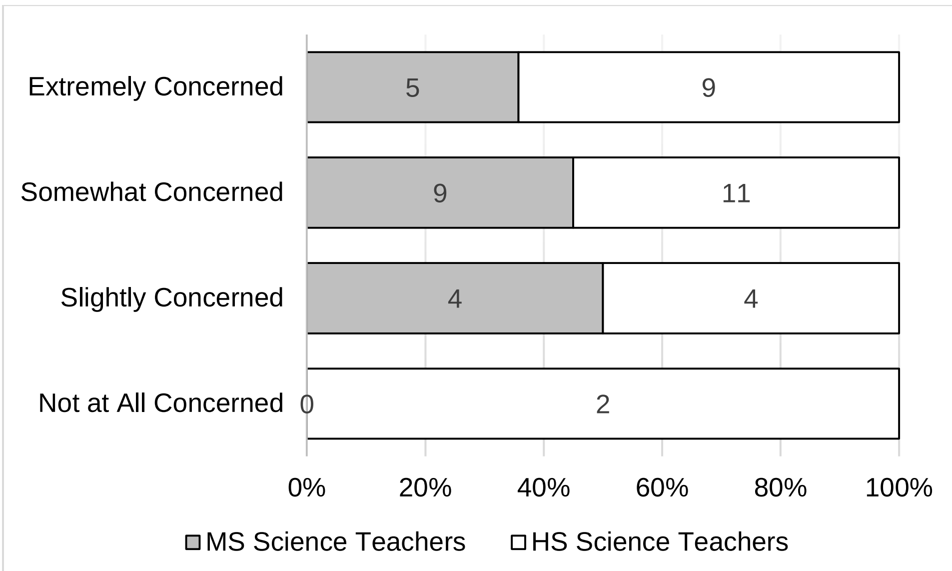


***Figure 8.*** **Frequency distribution for levels of concern regarding about engaging in argument from evidence by group. MS = middle school; HS = high school. The sample sizes were 18 and 26, respectively.**

*Obtaining, evaluation, and communicating information.* The level of concern about implementing the practices associated with obtaining, evaluating, and communicating information that was most frequently reported by middle school science teachers was "Not at All Concerned," at a rate of 56% (10 of 18). Six (33%) indicated "Slightly Concerned" as their level of concern about the tasks associated with obtaining, evaluating, and communicating information (see Figure 9).

Forty-six percent of highs school science teachers (12 of 26) reported being "Slightly Concerned," while 35% (9 of 26) reported not at all being concerned about implementing the practices associated with obtaining, evaluating, and communicating information. The mean scores of the levels of concern reported by middle school science teachers and high school science teachers were 1.61 and 1.92, respectively, as shown in Table 6.

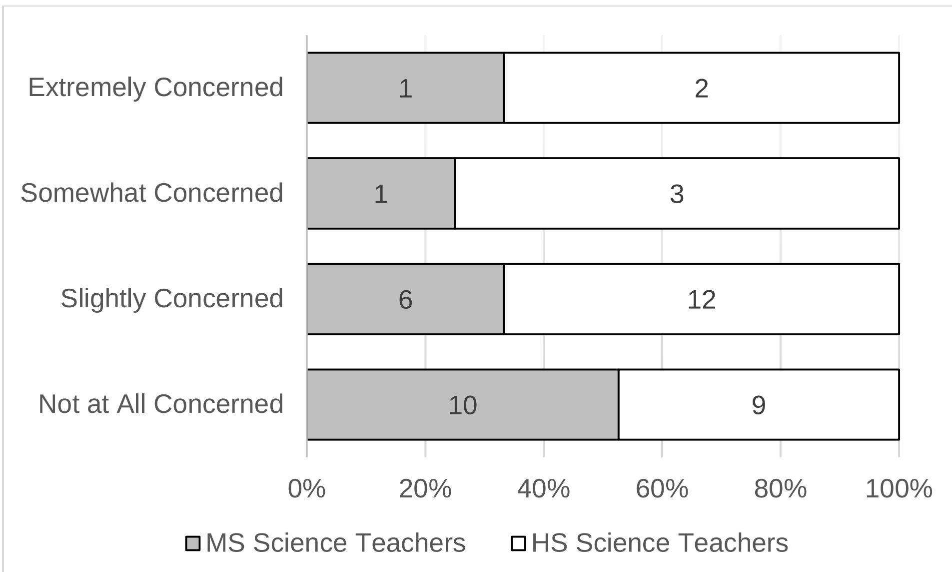


***Figure 9.*** **Frequency distribution for levels of concern regarding about obtaining, evaluating, and communicating information by group. MS = middle school; HS = high school. The sample sizes were 18 and 26, respectively.**

Qualitative findings. To further explain the differences in the levels of concern about the performance expectation for asking questions and defining problems and the similarities among other practices, the researcher conducted focus group discussions with five middle school science teachers and five high school science teachers. Prioritized discussions based on the quantitative results (see Appendix E) were recorded using an electronic device. The researcher used a spreadsheet to analyzed data that related to the practice of asking questions and defining problems (see Tables 7 and 8) and identified relevant themes from the discussions (see Table 9).

**Table 7**

**Middle School Science Teachers' Focus Group Data: Asking Questions and Defining Problems**

| Participant | Commentary |
|---|---|
| 1 | *Sometimes, I feel okay about it* [asking questions and defining problems]; *sometimes, I don't.* |
| 2 | *I don't remember it [asking questions and defining problems] being discussed or modeled in any professional learning I have attended.* |
| 3 | *This practice* [asking questions and defining problems] *require me to be more of a facilitator than an actual instructor and they* [students] *are used to being instructed. They are used to people telling them what to do, and then they just go do it.* |
| 5 | *They* [students] *are trying to push their point and don't want to ask questions to clarify during an argument.* |

**Table 8**

**High School Science Teachers' Focus Group Data: Asking Questions and Defining Problems**

| Participant | Commentary |
|---|---|
| 7 | *We are battling low readers; we expect those kids to do this—and one thing they want us to do is to help with reading. I have to help teach you how to read and then do this. You know, in order to prepare students to do this, it's a lot. I feel that I don't have time to get to this* [the performance expectations associated with asking questions and defining problems]*."* |
| 8 | *It sounds easy, but it is hard to get students to think beyond the text.* |

| | |
|---|---|
| 10 | *The students ask lots of questions when obtaining information about assignments and content; however, they struggle with asking other students questions when engaging in argument.* |

**Table 9**

**Comparison of the prominent themes and their frequency during focus group discussions**

| Middle School Science Teachers Frequency | Themes | High School Science Teachers Frequency |
|---|---|---|
| 8 | Professional Development | 15 |
| 9 | Support and Guidance | 12 |
| 6 | Students' Abilities | 5 |
| 3 | Resources | 2 |
| 1 | Pedagogical Beliefs | 0 |

Three major themes emerged from the focus group discussions about the differences in the perceptions middle school science teachers and high school science teachers had about science and engineering practices.

*Professional development.* In both focus group meetings, science teachers made statements related to how the quality and lack of professional development specific to the practices had impacted their implementation of science and engineering practices. Tables 10 and 11 displayed direct quotes from participants.

*Limited support and guidance.* Both middle and high school science teachers expressed concerns about limited feedback, resources, and feelings of certainty about how they were implementing the practices. Displayed in Tables 12 and 13 are comments made by middle and high school science teachers during the focus groups discussions related to limited support and guidance.

**Table 10**

**Middle School Focus Group Data on Professional Development**

| Participant | Commentary |
|---|---|
| 1 | *Math is not my strong point either. I mean, I can do a graph. I can do simple computations. If it requires more than that, I might be a little lost. I would have to teach myself to make sure I give it to them [the students] correctly, as well. That's my main issue.* |
| 2 | *We talk about it* [implementing the practices]. *We say, "Can we get people to come in and show us?" There was a lady that came over the summer for two days. She did give examples for life science, earth science, and physical science. It was great, but two days was not enough to help with a whole school term.* |
| 5 | *For me, it* [professional learning] *has not impacted the implementation. I would go to our workshops off campus. Those workshops were more about what the standards were and why the standards changed. We looked at the crosscutting concepts a lot, the science and engineering practices a lot, but we did not ever get to a point where we put it into practice. We never actually brought lessons and vetted our lessons and had experienced people say, "Okay, this is good. Change this… change that…". We didn't have a chance to try a lesson out with anybody else, to say teach it to a group to see how it worked. We never got what I would call "hands-on" experiences to see these things.* |

**Table 11**

**High School Focus Group Data on Professional Development**

| Participant | Commentary |
|---|---|
| 6 | *We took the chart that you have, and we had to sort them bases on where we thought each one should be placed. Other activities we did in PL were jigsaw with an article, more card sorting, and talk to your neighbor type activities.* |
| 7 | *The department chairperson is the only person from my school that goes to training. I can't receive the training I need to teach the standards, because I am not allowed to attend training. We were told that the district wanted to reduce the number of days teachers were away from the classroom.* |

| | |
|---|---|
| 8 | *You leave feeling like I could have been at work instead of being here.* |
| 10 | *There was an article we read on rigor. We talked about information, but we never put it into to practice.* |

**Table 12**

**<u>Middle School Focus Group Data on Limited Support and Guidance</u>**

| Participant | Commentary |
|---|---|
| 1 | *When it comes to life science, life science and engineering don't match to me. I think about physical science when it comes to engineering. I struggle to find resource to build lessons that incorporate engineering. When I think about food chains and food webs, I think, "how does that relate to engineering?" When we talk about biomes, how does that relate to engineering? I don't know. That's the hard part.* |
| 2 | *My concern is that, in my attempts, am I doing it right? I don't expect to get it right 100% of the time, but in my attempts, what am I doing right, what I am doing wrong? And there isn't anybody around to tell me what those things are. I am not trying to give it to them incorrectly.* |
| 2 | *The person who went to Science Ambassador training from my system is not helping, because that person is confused, too.* |
| 3 | *I had to sign off on my formative just the other day. The feedback was generic and not aligned to the Science Georgia Standards of Excellence.* |
| 4 | *I am not sure if I am doing it correctly. I see my practices being over here more towards 3-5* [the grade-band for grades 3-5 on the practices matrix]. |

**Table 13**

**<u>High School Focus Group Data on Limited Support and Guidance</u>**

| Participant | Commentary |
|---|---|
| 6 | *When it comes to qualitative and quantitative data, we don't have a lot of digital tools to do real labs.* |
| 7 | *They* [other participants] *mentioned technological tools and we are not equipped with those tools to complete the tasks.* |

| | |
|---|---|
| 8 | *I am not implementing the practice well. Simply not knowing how to or what's expected; we have no real examples. There are examples for grade levels that are tested, but my subject isn't tested.* |
| 9 | *We receive feedback from other science teachers when we create lessons together. Academic coaches and the science content coordinator offer feedback on how I implemented some lessons. Even assistant principals do sometimes, but my principal never does.* |
| 10 | *I don't feel like I know what I am doing that helps them* [students] *meet these goals.* |

*Students' abilities.* During the discussion of each practice, participants from both groups made mention of their students' abilities to meet the performance expectations. Commentary on students' abilities are presented in Tables 14 and 15.

**Table 14**

**Middle School Focus Group Data on Students' Abilities**

| Participant | Commentary |
|---|---|
| 2 | *I get it. I know what they want them to do and why they want them to do it, but the issue we have where I am is the kids don't have the ability to do this, even those kids who are gifted.* |
| 4 | *As far as the arguments, students can see the differences in two different points of view. That's not the issue. The issue is how they argue. They are argumentative people. They don't know how to argue effectively. They say things like "You're stupid." and "That's wrong." That's not the biggest issue to me. When it gets down to writing it, the writing is…, the writing is… They don't know how to put it on paper. They can argue and say it, but when comes down to putting it on paper, …then it becomes difficult.* |
| 5 | *They* [practices associated with developing and using models] *are a little heavy, especially to evaluate the limitations of a model. If I gave them a model to revise to show relationships among variables, they would not be able to do that.* |

**Table 15**

**High School Focus Group Data on Students' Abilities**

| Participant | Commentary |
|---|---|
| 6 | *When it comes to making a graph, they forget how to make the graphs. You know, they forget the x-axis and y-axis.* |
| 7 | *We are battling low readers; we expect those kids to do this—and one thing they want us to do is to help with reading. I have to help teach you how to read and then do this. You know, in order to prepare students to do this, it's a lot."* |
| 8 | *They* [students] *don't want to know why another person thinks differently*. |
| 9 | *Students don't like to ask questions during argumentation.* |
| 10 | *The students ask lots of questions when obtaining information about assignments and content; however, they struggle with asking other students questions when engaging in argument.* |

Research Question 2: Perceptions of Administrative Support Provided by Principals

To answer the second research question, "To what extent are the perceptions middle and high school science teachers had about administrative support provided by their principal during the implementation of the Science Georgia Standard of Excellence different?", middle and high school science teachers to indicate their level of agreement with regards to six statements about administrative support and participated in focus group discussions (See Appendices C, D, and E).

Quantitative results. For questions 19 – 24 on the surveys, middle and high school science teachers provided responses to indicate their level of agreement with regard statements about administrative support using a 4-point Likert scale. The values for answer choices were as follows: 1 = "Strongly Agree", 2 = "Agree", 3 = "Disagree", and 4 = "Strongly Disagree". After the quantitative data collection period closed, the researcher analyzed data by determining the average level of agreement for each group and comparing the differences in the mean scores for each statement using an independent *t*-test at the 95% confidence interval for each of the statements related to administrative support.

Based on the t-test results, there were statistically significant differences between the level of agreement for the following statements: Question 21 "*My principal has conversations with me about my delivery of science instruction related to science and engineering practices embedded in the Science Georgia Standards of Excellence.*" and Question 23. "*My principal enhances the science program at my school by providing me with the needed materials and equipment*." In both cases, on average, high school science teachers disagreed, whereas middle school science teachers agreed with the statements.

*Question 21. My principal has conversations with me about my delivery of science instruction related to science and engineering practices embedded in the Science Georgia Standards of Excellence.* In response to the statement, 72% (13 of 18) of middle school science teachers agreed with the statement; as for the remainder of the group, 17% (3 of 18) and 11% (2 0f 18) rated the statement "Disagree" and "Strongly Disagree," respectively. As shown in Table 17, the means scores for levels of agreement were 2.39 and 2.81 for middle school science teachers and high school science teachers, respectively. Among high school science teachers, 65% (17 of 26) disagreed and 8% (2 of 26) strongly disagreed. Seven (26%) of high school science teachers agreed that their principal had conversations with them about their delivery of science instruction related to the science and engineering practices. No science teachers strongly agreed with the statement. The frequency distribution was displayed in Figure 10.

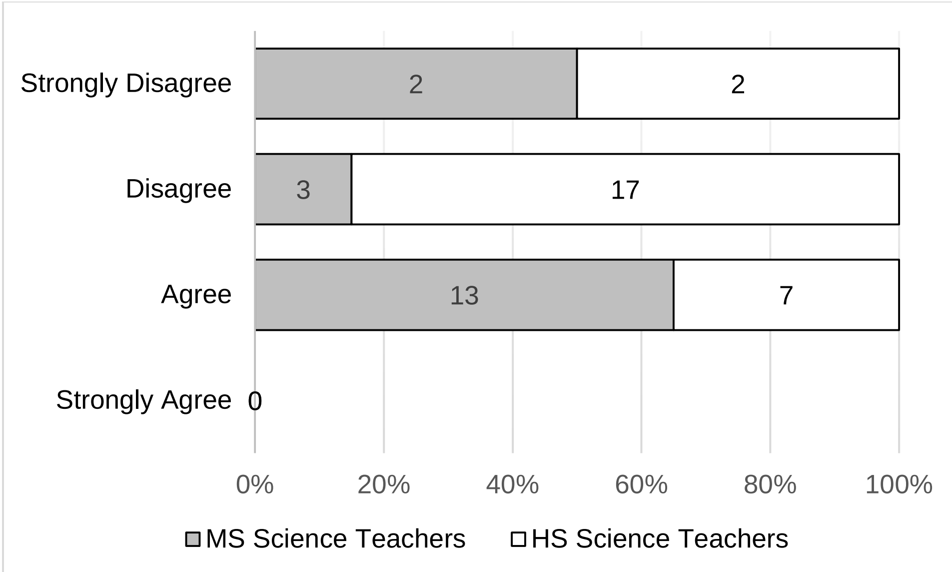


***Figure 10.* Frequency of science teachers' perceptions of principals conversing about instruction related to science and engineering practices. MS = middle school; HS = high school. The sample sizes were 18 and 26, respectively.**

An independent-sample *t*-test was conducted to evaluate whether the average level of agreement about principals having conversations with science teachers about science and engineering practices differed significantly between middle school science teachers and high school science teachers. The test was significant, $t(42) = -2.19$, $p = .03$. The 95% confidence interval for the average level of concern was between -0.80 and -0.03, as displayed in Table 16. An examination of the mean scores indicated that middle school science teachers (M = 2.39, SD = 0.70) on average agree more than high school science teachers (M = 2.81, SD = 0.57) that principals had conversations with them about their delivery of science instruction related to science and engineering practices.

*Question 23: "My principal enhances the science program by provided me the needed materials and equipment."* In response to the question, no science teachers from middle schools and high schools reported “Strongly Disagree.” Forty-six percent (12 of 26) of high school science teachers indicated that they disagreed with the statement. Eleven percent (2 of 18) of their counterparts indicated the same. Of the science teachers who reported “Agree,” 13 worked at middle schools and 12 worked at high schools. Five science teachers reported “Strongly Agree.” Three were from middle schools and two were from high schools. Figure 11 was a visual depiction the summary for question 23. The average mean scores for middle school science teachers and high school science teachers were 1.94 and 2.38, respectively.

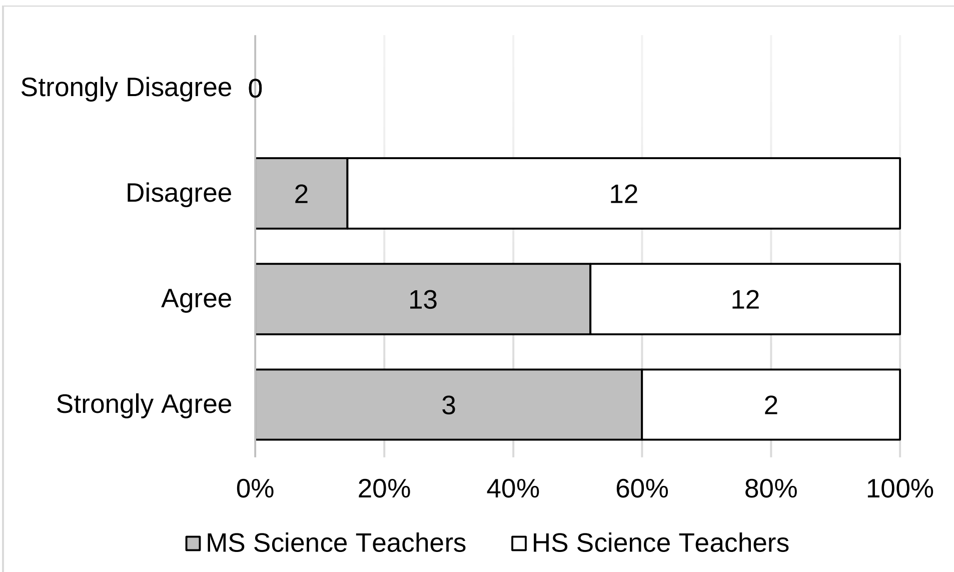


***Figure 11.* Frequency of science teachers’ perceptions of principals providing needed materials and equipment. MS = middle school; HS = high school. The sample sizes were 18 and 26, respectively.**

The independent-sample *t*-test comparing the mean level of agreement of the statement about principal supporting the implementation of the science and engineering practices by providing instructional support by providing adequate resources between middle school science teachers and high school science teachers was significant, $t(40) = -2.47$, $p = 0.02$. The 95%

confidence interval for the average level of agreement for question 23 ranged from -0.80 to -0.08, as shown in Table 16.

**Table 16**

**Summary of Descriptive and Inferential Data about Administrative Support, by Statement**

| | MS Science Teachers (*n = 18)* | | HS Science Teachers (*n = 26)* | | *t*-test Results | | 95% CI | Significant Difference |
|---|---|---|---|---|---|---|---|---|
| | M | SD | M | SD | *t* | α | | |
| Q19. Satisfied with amount of support | 2.67 | 0.84 | 2.69 | 0.68 | -0.11 | 0.91 | [-0.49, 0.44] | No |
| Q20. Satisfied with amount of support from principal | 2.67 | 0.60 | 2.73 | 0.67 | -0.33 | 0.75 | [-0.46, 0.33] | No |
| Q21. Principal has conversations with me about science and engineering practices | 2.39 | 0.70 | 2.81 | 0.57 | -2.91 | 0.03 | [-0.80,-0.03] | Yes |
| Q22. Principal encourages implementations of the science and engineering practices* | 2.00 | 0.60 | 1.62 | 0.80 | 1.82 | 0.08 | [-0.41, 0.81] | No |
| Q23. Principal provides the needed materials and tools** | 1.94 | 0.54 | 2.38 | 0.64 | -2.47 | 0.02 | [-0.80,-0.08] | Yes |
| Q24. Principal provides time to for science teachers to meet | 1.39 | 0.70 | 1.58 | 0.58 | -0.98 | 0.34 | [-0.58, 0.20] | No |

*Note.* * The *F* value for Levene's test was 8.80 with a Sig. *p* value of .01. Homogeneity of variance could not be assumed. ** The *F* value for Levene's test was 5.82 with a Sig. *p* value of .02. Homogeneity of variance could not be assumed.

The quantitative results for the other statements were as follows:

*Question 19: "I am satisfied with the amount of support I receive to implement science and engineering practices."* Middle school science teachers responded to the question in the following manner: 56% (10 of 18) disagreed with the statement, 22% (4 of 18) agreed, and 11% (2 of 18) indicated "Strongly Agree" and "Strongly Disagree" (see Figure 12). High school science teachers' responses were as follows: 46% (12 of 26) marked "Disagree", 42% (11 of 26) selected "Agree", and 12% (3 of 26) responded with "Strongly Disagree." An illustration of the frequencies was shown in Figure 12.

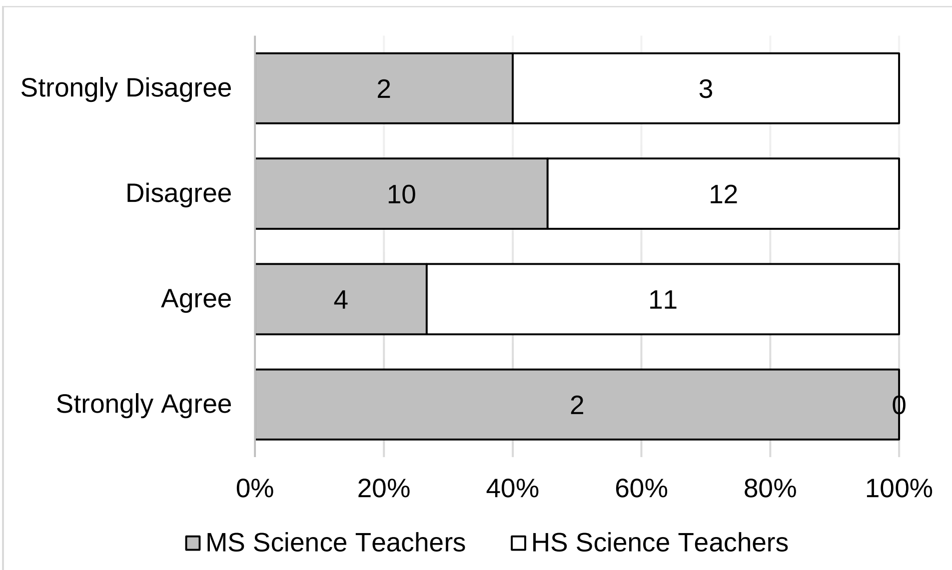


***Figure 12.* Frequency distribution for science teachers' satisfaction with the amount of support. The numbers inside the bars denoted the frequency. MS = middle school; HS = high school. The sample sizes were 18 and 26, respectively.**

*Question 20: I am satisfied with the amount of support I receive from my principal to implement science and engineering practices.* In response to the statement "I am satisfied with the amount of support I receive from my principal to implement science and engineering practices.," over 60% of middle school science teachers reported a level of disagreement with the statement. Ten of 18 (56%) rated the statement “Disagree,” while one of 18 (6%) answered with “Strongly Disagree.” Half of high school science teachers (13 of 26) responded by selecting “Disagree”. The other half were split between “Agree” (10 of 26, 38%) and “Strongly Disagree” (3 of 26, 12%). No science teachers reported “Strongly Agree” in response to the prompt, as shown in Figure 13.

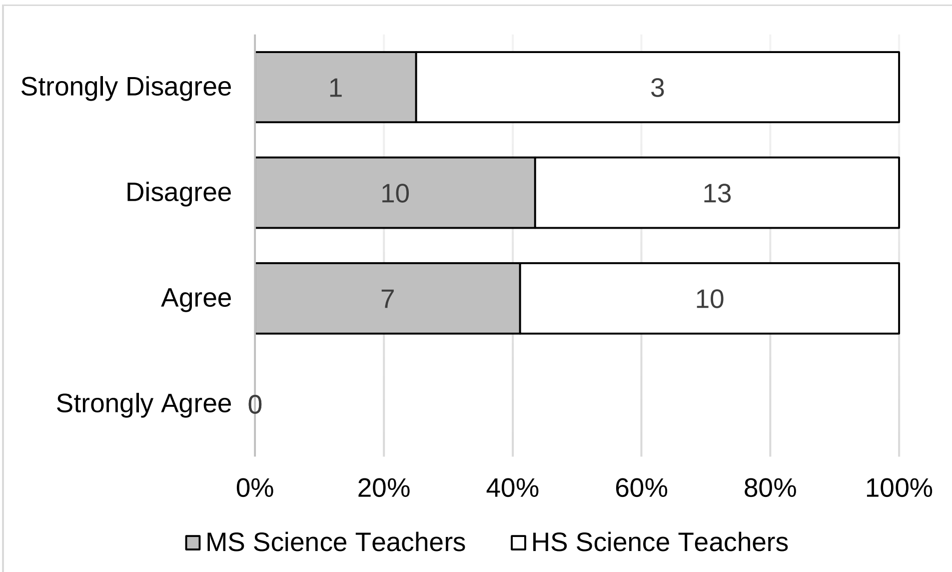


***Figure 13.* Frequency distribution for the level of agreement about science teachers’ perceptions of satisfaction with amount of support from principal. The numbers inside the bars denoted the frequency. MS = middle school; HS = high school. The sample sizes were 18 and 26, respectively.**

*Question 22: “My principal encourages the implementation of science and engineering practices.”* In response, 83% (15 or 18) of middle school science teachers reported “Agree.” Indicating the same answer were 35% (9 of 26) of high school science teachers. As shown in Figure 13, 14 of 26 (54%) high school science teachers strongly agreed with the statement; eleven percent (2 of 18) of middle school science teachers responded the same. Of the remaining respondents, two high school science teachers disagreed, one science teacher from each group responded with “Strongly Disagree.” The average scores or mean for each group were 2.00 and 1.62 for middle school science teachers and high school science teachers, respectively.

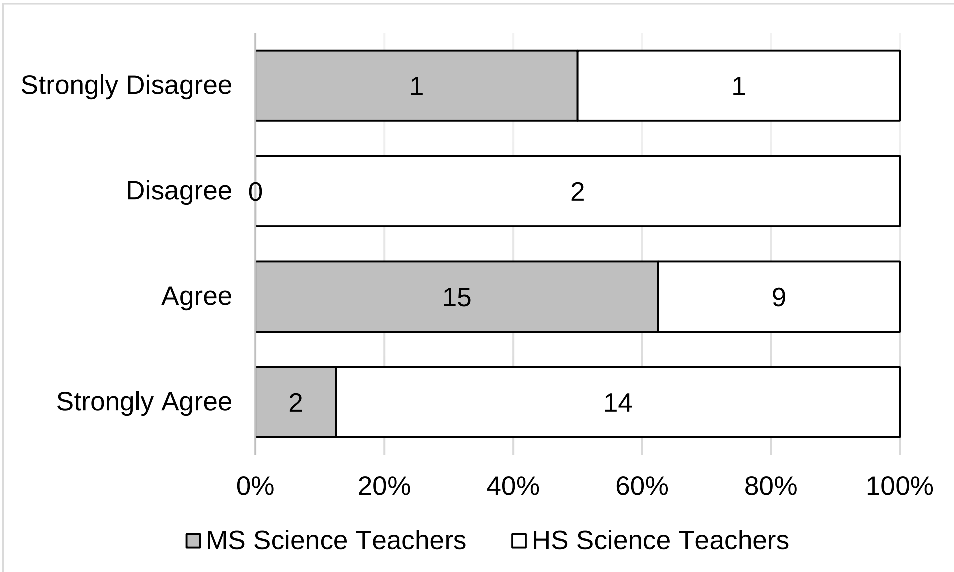


***Figure 14.*** **Frequency distribution for the level of agreement with principal encourages the implementation of science and engineering practices. The numbers inside the bars denoted the frequency. MS = middle school; HS = high school. The sample sizes were 18 and 26, respectively.**

*Question 24: “My principal provides time for science teachers in my school to meet and share ideas about implementing science and engineering practices with one another.”* In response to this prompt, no respondents disagreed strongly with this statement. Most from each group indicated “Agree” or “Strongly Agree.” For middle school science teachers, 72% (13 of 18) responded with “Strongly Agree.” Fifty percent (13 0f 26) of high school science teachers reported that they “Agree” with the statement, while 46% (12 0f 26) strongly agreed. The remaining two middle school science teachers and one high school science teacher reported that they disagreed with the statement. Figure 15 was an illustration of the data reported for question 24.

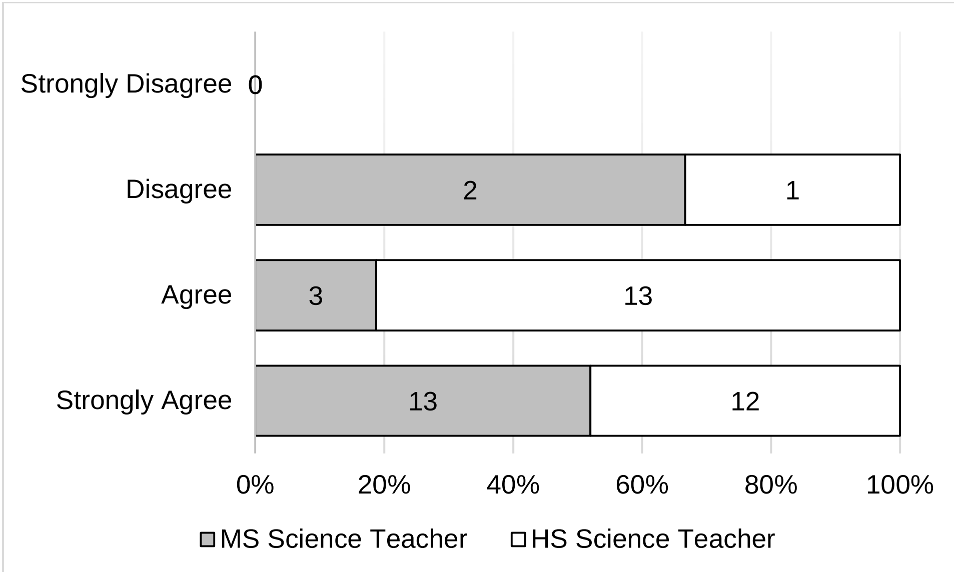


***Figure 15.* Frequency distribution for Science Teachers' Perceptions of Principals Providing Time to Meet and Share Ideas. The numbers inside the bars denoted the frequency. MS = middle school; HS = high school. The sample sizes were 18 and 26, respectively.**

Qualitative findings. According to Littrell et al., (1994), administrative support for teachers includes four behavioral areas: instrumental support, informational support, emotional support, and appraisal support. Themes from middle and high school science teachers' focus group meetings were coded and grouped based on the four support behaviors proposed by Littrell and colleagues (1994) by the researcher using a spreadsheet.

During the focus group discussions, participants from middle schools and high schools had discussions to expound on their level of agreement or disagreement with the statements attached to questions 21 and 23 (see Tables 17 and 18).

**Table 17**

**<u>Focus Group Data for Principals have Conversations with the Science Teacher about the Science and Engineering Practices</u>**

| Participant | Commentary |
|---|---|
| 1 | *Administrators don't understand it; I don't think it is deliberate; I don't think they don't care. They just don't know.* |
| 2 | *Our administrators don't know what these things are either. So, I feel like if they don't understand it themselves, they can't possibly get us the proper support during this implementation.* |
| 9 | *We talk about the new standards in our department meetings. The principal has been present.* |

**Table 18**

**<u>Focus Group Data from Science Teachers on Principals provides the necessary materials and supplies</u>**

| Participant | Commentary |
|---|---|
| 3 | *We have a grant now. We purchased STEMSCOPES. We could order other materials to help with that program.* |
| 5 | *Basically, whatever we need to do, the principal goes with it as long as we all agree. At my school, we tell the principal about the new standards and what we have to do differently.* |
| 6 | *When it comes to qualitative and quantitative data, we don't have a lot of digital tools to do real labs.* |

The frequency for comments related to each theme was presented in Table 19.

**Table 19**

**Comparison of the Frequency of Administrative Support Domains, by Focus Group Discussions**

| Middle School Science Teachers Frequency | Themes | High School Science Teachers Frequency |
|---|---|---|
| 10 | Instrumental Support | 12 |
| 6 | Informational Support | 7 |
| 5 | Emotional Support | 6 |
| 1 | Appraisal Support | 0 |

*Instrumental support.* According to focus group participants from both groups, principals had shown varying levels of support to science teacher during the implementation of science and engineering practices. Commentary that were examples of principals providing instrumental support were displayed in Table 20.

**Table 20**

**Focus Group Data from Science Teachers on Instrumental Support**

| Participant | Commentary |
|---|---|
| 1 | *Administrators don't understand it; I don't think it is deliberate; I don't think they don't care. They just don't know.* |
| 2 | *Our administrators don't know what these things are either. So, I feel like if they don't understand it themselves, they can't possibly get us the proper support during this implementation.* |
| 2 | *We have time to have meetings, but the time is rarely used to plan together.* |
| 3 | *We have a grant now. We purchased STEMSCOPES. We could order other materials to help with that program.* |
| 5 | *Basically, whatever we need to do, the principal goes with it as long as we all agree. At my school, we tell the principal about the new standards and what we have to do differently.* |

| | |
|---|---|
| 6 | *Once when I didn't have my lesson plan finished. My principal talked with me about why I had not submitted them. He gave me more time to complete the lesson. He did know how much more time it took to plan lessons.* |
| 6 | *We do have and share Chromebook, we are encouraged to use Google Classroom. We were about to purchase digital textbooks that have student workbooks; however, we could only get a few, which was not enough for all students. Our principal did fight for more, but we were told we could not afford to purchase more.* |
| 7 | *My principal does not provide any support. The focus is on English and math.* |
| 8 | *I felt like there was a lack of support when we could not go to professional learning we felt we needed.* |
| 8 | *We have a paraprofessional who works with the science department, laptops, and software programs, too. I could use more training on implementing labs.* |
| 9 | *We talk about the new standards in our department meetings. The principal has been present. We talked about how our current lesson plan template might not be the best. We are currently working on developing a unit plan template for lessons.* |

*Informational support.* A sample of comments made by middle and high school science teachers that were examples of informational support mentioned during the focus group discussion were listed in Tables 21.

**Table 21**

**Focus Group Data from Science Teachers on Informational Support**

| Participant | Commentary |
|---|---|
| 1 | *Administrators don't understand it; I don't think it is deliberate; I don't think they don't care. They just don't know.* |
| 2 | *Our administrators don't know what these things are either.* |
| 2 | *My concern is that, in my attempts, am I doing it right? I don't expect to get it right 100% of the time, but in my attempts, what am I doing right, what I am doing wrong? And there isn't anybody around to tell me what those things are. I am not trying to give it to them incorrectly.* |
| 9 | *We talk about the new standards in our department meetings. The principal has been present.* |

*Emotional support.* Science teachers gave few accounts of their principal providing emotional support. Commentary were listed in Tables 22.

**Table 22**

**<u>Focus Group Data: Emotional Support</u>**

| Participant | Commentary |
|---|---|
| 6 | *Once when I didn't have my lesson plan finished. My principal talked with me about why I had not submitted them. He gave me more time to complete the lesson. He did know how much more time it took to plan lessons.* |

*Appraisal support.* Evidence of appraisal support mentioned during the middle school science teachers' focus group discussions were displayed in Table 23. There was no evidence of appraisal support was collected during the high school science teachers' discussions.

**Table 24**

**<u>Focus Group Data: Appraisal Support</u>**

| Participant | Commentary |
|---|---|
| 3 | *I haven't gotten any feedback. I just signed off on my formative evaluation a few days ago. I think she saw that what I was doing was aligned to the standard, but there was no specific feedback, really generic.* |

Science teachers reported that principals completed both formal and informal evaluation; however, the feedback and recommendations were not specifically related to the science and engineering practices. During the discussions, only one science teacher talked about receiving a formal evaluation that were positive; however, she did not feel that the principal knew enough about the standards and practices to fairly evaluate the instructional strategies.

## Other Relevant Findings

### Research Question 1: Perceptions of Science and Engineering Practices

For the first research question, the results from the survey revealed areas of most concern and least concern, in addition to the differences between middle and high school science teachers. Middle science teachers reported high levels of concern about the tasks related to planning and carrying out investigations (M = 3.11, SD = 0.76), engaging students in argument from evidence (M =3.06, SD = 0.73), and using mathematics and computational thinking (M = 2.89, SD = 1.08). High school science teachers who responded to the survey were most concerned about the tasks related to engaging students in argument from evidence (M = 3.04, SD = 0.92), developing and using models (M = 2.92, SD = 0.89), and planning and carrying out investigations (M = 2.73, SD = 0.92). The data analysis revealed that both middle school and high school science teachers have higher levels of concerns about implementing the performance expectations associated with planning and carrying out investigations and engaging students in argument from evidence.

Middle school science teachers reported being least concerned about obtaining, evaluating, and communicating information (M = 1.61, SD =0.85) and asking questions and designing problems (M = 1.89, SD = 0.76). High school science teachers were least concerned about obtaining, evaluating, and communicating information (M = 1.92, SD = 0.89) and constructing explanations and designing solutions (M =2.04, SD = 0.82). In summary, both middle school and high school science teachers reported being slightly concerned about implementing the performance expectations associated with the practice of obtaining, evaluating, and communicating information.

During focus group discussions, middle and high school science teachers reported being most concerned about the quality of professional development, limited support and guidance, and their students' abilities when implementing the science and engineering practices. These themes were common among both groups of science teachers. It was also worth noting that engineering practices were neglected from the conversations had by science teachers during both focus group meetings. Science teachers tended to speak about traditional science practices only.

## Summary

The researcher presented quantitative results and qualitative findings that were revealed after the data analysis. Bases on the results of *t*-test analyses, there were significant differences in the perceptions middle and high school science teachers had about the level of concern regarding the implementation of asking questions and designing problems, the level of agreement with the statements about principals conversing with science teachers about the implementation of the science and engineering practices, and the principal providing the necessary materials and equipment to implement the science and engineering practices. The themes from the qualitative findings associated with the first research question were professional development, limited support and guidance, and students' abilities.

# CHAPTER V: SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Chapter five was a synopsis of the investigation into the perceptions middle and high school science teachers had about science and engineering practices and administrative support provided by principals during the implementation of the Science Georgia Standards of Excellence. The major sections included in this chapter were the summary, the analysis of research findings, conclusions, relationship to previous research studies, implications, recommendations, and dissemination.

## Summary

In A *Framework for K – 12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (National Research Council [NRC], 2012), the NRC introduced new goals and a new learning model for science education in the United States. The three-dimensional learning model was comprised of science and engineering practices, crosscutting concepts, and disciplinary core ideas.

To achieve the new goals of science education, science teachers were expected to shift from teaching science as a process of inquiry to teaching science as a practice using the eight science and engineering practices: (1) asking questions and defining problems; (2) developing and using models; (3) planning and carrying out investigations; (4) analyzing and interpreting data; (5) using mathematics and computational thinking; (6) constructing explanations and designing solutions; (7) engaging in argument from evidence; and (8) obtaining, evaluating, and communicating information (NGSS Lead States, 2013; NRC, 2012).

The National Research Council (2012, 2015) anticipated the change would be drastic for science teachers. Reminiscent of the barriers to implementing of inquiry in the 1950s through the

2000s, the council incorporated evidence-based strategies about how students learn science best to develop the new model. Science teachers and other stakeholders had multiple opportunities to give input during the developmental stages. Science teachers and those who support their work were invited to participate in professional development prior to the implementation; a common language and clear definitions of the practices were communicated in print material, webinars, and professional development sessions.

Students were expected to engage in specific tasks aligned to each of the eight practices throughout their K – 12 education; however, as grade bands increased, the complexity and sophistication of the performance expectations increased, also (NRC, 2012). The practices provided science teachers a structure to engage students in performances that build scientific knowledge by thinking, acting, talking, and interacting with peers like scientists and engineers (Duncan & Cavera, 2015; NRC, 2012). The specific tasks associated with the science and engineering practices were performance expectations, which had been described for students by grade bands, K – 2, 3 – 5, 6 – 8, and 9 – 12 in a chart called practices matrix (NRC, 2012).

In earlier studies on the implementation of the science and engineering practices in other states, science teachers revealed the following concerns: feelings of preparedness, knowledge and skills to teach engineering, support and guidance, and pedagogical beliefs. According to Haag and Megowan (2015), science teachers who attended more training reported feeling more prepared to implement modeling practices. Nollmeyer and Banquet (2015) reported that there was a significant difference between the science teachers' understanding of the framework and their levels of readiness to use it due to the difference in the grouping of particular ideas. Science teachers reported concerns about not having the knowledge and skills to implement engineering practices (Cunningham & Carlsen, 2014). Parsley and colleagues (2016) found that published literature offered little assistance to science teachers about ways to make the science and engineering practices accessible to all students. Boesdorfer and Staude (2016) reported that the high school chemistry teachers mostly had positive, accurate beliefs about engineering but had naïve thoughts about the concepts of engineering. Science teachers testified that they hold pedagogical beliefs that were not aligned to evidence-based research on how students learn science best (Trygstan et al., 2013).

In several of the earlier studies, science teachers reported the need for administrative support during implementation. According to Hall and Hord (1987), for change to be successful, the perceptions of the teacher must be understood by themselves and the change facilitator, in this case, the principal. By understanding teacher concerns, the principal can be more certain that the planned actions to support change were relevant to the perceived needs of teachers (Hall & Hord, 1987). To guide principals through the change, the National Research Council (NRC) published a one-page document that explained what the standards are, how their adoption will change science education, and offered suggestions for how principals can support the implementation (NRC, 2015). By adapting a variation of the social support theory, Littrell and colleagues (1994) constructed a theory of administrative support, which suggested that there were four behavioral domains in his principals engage when supporting teachers. The four behavioral domains were instrumental support, informational support, emotional support, and appraisal support. In a study about the concerns elementary science teachers had about the SEPs, Dailey and Robinson (2016) concluded that although concerns may not be eliminated, with extensive support from administrators, science teachers can lessen their focus on self and eventually focus more on the impact their practices had on students.

In Georgia, the three-dimensional learning model was incorporated into the newly revised standards, the Science Georgia Standards of Excellence (SGSE). Science teachers in Georgia enacted the science and engineering practices for the first time during 2017-2018 school year. Considering the literature from the preliminary studies and research on the importance of administrative support, the researcher prosed to investigate the perceptions middle and high school science teachers had about science and engineering practices and administrative support provided by principals during the implementation of the Science Georgia Standards of Excellence (SGSE). Using a cluster sampling technique, the researcher selected one regional education service agency (RESA) service area to identify potential respondents. Using a total sampling technique, the researcher contacted superintendents at each of the school to request participation from their teachers. It was determined that all middle and high school science teachers who worked in three school systems in southwest Georgia would be the sample

Using a sequential explanatory mixed methods design, the researcher administered web-based surveys and facilitated focus group discussions with middle and high school science teachers from three school systems in southwest Georgia to answer the following research questions: (1) To what extent are the perceptions middle and high school science teachers have about science and engineering practices during the implementation of Science Georgia Standards of Excellence different? (2) To what extent are the perceptions middle and high school science teachers have about administrative support provided by the principal during the implementation of the Science Georgie Standards of Excellence different?

The researchers used Survey Monkey's email invitation tool to contact 111 middle and high school science teachers. Fifty-four percent of the sample responded with either a completed survey or with a survey that indicated interest in participating in a focus group discussion.

Among middle and high school science teachers, 18 and 26 completed surveys were returned, respectively; five middle and five high school science teachers participated in focus group discussions.

For the first research question, the results from the survey revealed areas of most concern, least concern, and similarities and differences among and between middle and high school science teachers. Middle science teachers revealed high levels of concern about the tasks related to planning and carrying out investigations (M = 3.11, SD = 0.76), engaging students in argument from evidence (M =3.06, SD = 0.73), and using mathematics and computational thinking (M = 2.89, SD = 1.08). High school science teachers who responded to the survey were most concerned about the tasks related to engaging students in argument from evidence (M = 3.04, SD = 0.92), developing and using models (M = 2.92, SD = 0.89), and planning and carrying out investigations (M = 2.73, SD = 0.92).

Middle school science teachers reported being least concerned about obtaining, evaluating, and communicating information (M = 1.61, SD =0.85) and asking questions and designing problems (M = 1.89, SD = 0.76). High school science teachers were least concerned about obtaining, evaluating, and communicating information (M = 1.92, SD = 0.89) and constructing explanations and designing solutions (M =2.04, SD = 0.82).

There was significant difference between the average levels of concern of middle school science teachers (M = 1.89, SD = 0.76) and high school science teachers (M = 2.69, SD = 0.88) with regards to the performance expectations associated with asking questions and defining problems. Middle school science teachers were only slightly concerned whereas high school science teachers were somewhat to extremely concerned.

Themes that emerged during the focus group discussions about the perceptions middle and high school science teachers had about the science and engineering practices were professional development, feedback, and students’ abilities.

For the second research question, the results from the survey revealed levels of agreement, disagreement, similarities, and differences among and between middle and high school science teachers. The highest levels of agreement among middle school science teachers was for the statements “*My principal provides time for science teachers in my school to meet and share ideas about implementing science and engineering practices with one another*.” (M = 1.39, SD = 0.70), “*My principal enhances the science program at my school by providing me with the needed materials and equipment.*” (M = 1.94, SD = 0.54), and “*My principal encourages the implementation of science and engineering practices.”* (M = 2.00, SD = 0.59). High school science teachers, on average, agreed most with the statements “*My principal provides time for science teachers in my school to meet and share ideas about implementing science and engineering practices with one another.*” (M = 1.58, SD = 0.58) and “*My principal encourages the implementation of science and engineering practices.*” (M = 1.62, SD = 0.80).

Middle school respondents reported average levels of disagreement with the statements, “*I am satisfied with the amount of support I receive to implement science and engineering practices.*” (M = 2.67, SD = 0.84) and “*I am satisfied with the amount of support I receive from my principal to implement science and engineering practices.*” (M = 2.67, SD = 0.59). High school science teachers disagreed most with “*My principal has conversations with me about my delivery of science instruction related to science and engineering practices embedded in the Science Georgia Standards of Excellence.*” (M = 2.81, SD =0.70), “*I am satisfied with the amount of support I receive from my principal to implement science and engineering practices.*”

(M = 2.73, SD = 0.67), and "*I am satisfied with the amount of support I receive to implement science and engineering practices.*" (M = 2.69, SD = 0.68).

Based on results from an analysis of the means, there were significant differences between the average levels of agreement of middle school science teachers (M = 2.39, SD = 0.70; M = 1.94, SD = 0.53) and high school science teachers (M = 2.81, SD = 0.57; M= 2.38, SD = 0.64) about the statements "*My principal has conversations with me about my delivery of science instruction related to science and engineering practices embedded in the Science Georgia Standards of Excellence" and "My principal enhances the science program at my school by providing me with the needed materials and equipment.", correspondingly.*

Qualitative data gathered during the focus group meeting were framed by the four behavioral support domains: instrumental, informational, emotional, and appraisal. Most reports from both middle and high school science teachers related to instrumental and informational support.

## Analysis of Research Findings

### Research Question 1: Perceptions of Science and Engineering Practices

Web-based surveys and focus group discussions were used to collect data on the perceptions middle and high school science teachers had about the science and engineering practices during the implementation of the Science Georgia Standards of Excellence. Overall, there were differences in the perceptions of science and engineering practices between middle and high school science teachers, based on quantitative and qualitative data. On average, high school science teachers reported higher levels of concern; however, there was a statistically significant difference in the average level of concern between the two groups for one practice, asking questions and defining problems.

The quality of and access to professional development impacted science teachers' perceptions of their implementation of the practices. Nearly 60% of survey respondents had not had attended professional learning offered directly by the Georgia Department of Education or the RESA. In April 2016, the Georgia Department of Education's Science Ambassador Program was enacted to support the implementation and professional development needs associated with the new approach to instruction (Peacock, 2016). According to an official with the Georgia Science Teacher Association (GSTA), science teachers, science curriculum specialists, RESA science specialists, science academic coaches and instructors, and other science educators who support professional development for their local school districts could be permitted to participate in trainings to augment their leadership capacity (Peacock, 2016). There were reports that science teachers who had been identified as Science Ambassadors were sure if they were implementing the practices well. Using this trickled down approach to professional learning has not been beneficial, according to science teachers in the focus groups.

Cunningham and Carlsen (2014) suggested that teachers participate in professional development that allows them to engage in the practices, to model pedagogies that support the practices, which give them experiences as learners and teachers, and aid in the development of teachers' understandings of the fundamentals of engineering and the interconnections between engineering and science. The researchers also urged that the professional learning be designed in ways that allow teachers to understand science and engineering as a social practice, which echoed the observations of Thomas Kuhn (Cunningham & Carlsen, 2014). Instead, science teachers stated that they engage in activities like sorting cards and jigsaw, and had not had an opportunity to create, vet, or practice lessons based on the practices.

Research Question 2: Perceptions of Administrative Support Provide by Principals

The researcher administered web-based surveys and facilitated focus group discussions to collect data on the perceptions middle and high school science teachers had about administrative support provided by principals during the implementation of the Science Georgia Standards of Excellence. Based on the findings from the survey and focus group discussions, there were differences in the perceptions held by middle and high school science teachers with regard to administrative support provided by the principal. On average, high school science teachers reported higher levels of disagreement with statements about satisfaction with support in general, support provided by the principal, principals conversing with science teachers about the implementation,  and principals providing materials and tools; however, the difference between the two group was statistically significant for statements about the principal conversing with the science teacher about the implementation of the science and engineering practices and the principal providing the needed materials and tools to implement the Science Georgia Standards of Excellence.

## Discussion of Research Findings

### Research Question 1: Perceptions of Science and Engineering Practices

Based on the findings, there was one significant difference in the perceptions held by middle and high school science teachers about science and engineering practices during the implementation of the Science Georgia Standards of Excellence. With regard to the performance expectations for asking questions and defining problems, middle school science teachers, on average, were slightly concerned (M = 1.89, SD = 0.76), whereas high school science teachers were somewhat to extremely concerned (M = 2.69, SD = 0.88), as shown in Tables 1 and 37. In the focus group discussion with high school science teachers, participants explained their perceptions about the tasks associated with asking questions and defining solutions with statements that reflected their feelings and concerns with commentary about students' inabilities to engage in the practices. According to researchers, engaging students in asking questions and defining problems was beneficial for activating their prior knowledge, focusing, and expounding on their learning (Osborne, 2014; Rosenshine, Meister, & Chapman, 1996; Schmidt, 1993).

The findings from this study were not consistent with the results from a related study conducted by Haag and Megowan (2015). Haag and Megowan (2015) concluded that high school science teachers reported a higher degree of motivation to use science and engineering practices, felt more prepared to implement the practices, and enacted modeling instruction at higher rates than middle school teachers. The increased motivation among high school science teachers was credited to them attending more days of training than middle school science teachers (Haag & Megowan, 2015).

Based on demographic information about professional learning, high school science teachers reported attending professional learning sessions from all three sponsors at higher rates than middle school science teachers (see Tables 3 and 4). To be specific, 42% (versus 39% of middle school science teachers) of high school science teachers reported that they had attended one or more session sponsored by the Georgia Department of Education; 50% had attended sessions sponsored by the RESA, compared to 28% of middle school science teachers; and 96% had attended trainings within their school district, compared to 94% of middle school science teachers.

According to statements made by both middle and high school science teachers during focus group discussions, the professional learning sessions were not viewed positively (See Tables 15 and 16). Cunningham and Carlsen (2014) suggested that teachers participate in professional development that allows them to engage in the practices, to model pedagogies that support the practices, which give them experiences as learners and teachers, and aid in the development of teachers' understandings of the fundamentals of engineering and the interconnections between engineering and science. The researchers also urged that the professional learning be designed in ways that allow teachers to understand science and engineering as a social practice, which echoed the observations of Thomas Kuhn (Cunningham & Carlsen, 2014). Instead, science teachers stated that they engaged in activities such as sorting cards and jigsaw articles but had not had an opportunity to create, vet, or practice lessons based on the science and engineering practices.

One goal of teaching science as a practice using science and engineering practices was for students to comprehend how the scientific community worked to build content knowledge overtime by using more than one method while thinking, acting, talking, and interacting with their peers like scientists (Duncan & Cavera, 2015). Unique to this study was the emergence of the theme of student abilities being viewed as a barrier to implementing the science and engineering practices. According to Trygstan and colleagues (2013), science teachers reported that they held pedagogical beliefs that were not aligned to research on how students learned science best. Their finding was likely the reason for teachers reporting student abilities as barriers to implementation. Several researchers concluded that teachers had the most significant impact on student achievement (Day, Gu, & Sammons, 2016; Hallinger, 2005; Leithwood, Louis, Anderson, & Wahlstrom, 2004; Osborne-Lampkin, Folsom, & Herrington, 2015;

Robinson, Lloyd & Rowe, 2008; Spillane & Hunt, 2010; Waters, Marzano, & McNulty, 2003). Unfortunately, there was little existing guidance for science teachers on how students could experience the practices in K-12 classrooms (Trygstad et al., 2013). This, however, was consistent with the qualitative data collected from science teachers during the focus group discussions.

**Research Question 2: Perceptions of Administrative Support Provided by Principals**

Prominent themes that emerged from the focus group discussion with high science teachers were their concerns the support and guidance provided during the implementation of Science Georgia Standards of Excellence, in addition to professional learning. According to the National Research Council (2012), it was essential for science teachers to receive continuous support to develop an understanding of science and engineering practices and the appropriate instructional strategies to deliver quality instruction aligned to the vision of *Framework*. Based on the reviewed literature, principals positively impacted the change process when they participated in the process of learning with teachers (Robinson et al., 2008), differentiated supports based on teachers' needs to facilitate teacher voice and encourage participation in the change process (Brezicha, Bergmark, & Mitra, 2015), established a positive relationship and a positive school climate (Brezicha et al., 2015; Price, 2011).

Qualitative findings revealed a mixture of perceptions about administrative support provided by principals consistent with the two of the four domains of administrative support, instrumental and informational support (Littrell et al., 1994). According to the accounts of middle and high school science teachers, feedback from principals about teaching practices was a concern. Even though conversations were reported by middle school science teachers, science teachers did not perceive the principal was providing informational support. Based on the description, middle school science teachers reported conversing with their principals to help principals understand how to support them. At the high school level, some science teachers reported that the principals were not having conversations about the implementation of the practices; however, academic coaches, department chairpersons, and content coordinators provided were conversing with them regularly and provided feedback specific to the practices.

Within the context of the administrative support domain of informational support, principals provide practical information on effective teaching strategies, and provided suggestions to improve classroom instruction, classroom management, and work-related stressors (Cancio et al., 2013; Littrell et al., 1994). As lead learners, principals were to lead teachers in a process of learning and development to improve their teaching (Robinson, Lloyd, & Rowe, 2008). According to the accounts of middle and high school science teachers, feedback from principals about teaching practices was a concern. Even though conversations were reported among middle school science teachers, science teachers did not perceive the principal was providing informational support. Based on the description, middle school science teachers reported conversing with their principals to help principals understand how to support them. At the high school level, some science teachers reported that the principals were not having conversations about the implementation of the practices; however, academic coaches, department chairpersons, and in a few cases, content coordinators provided were conversing with them regularly and provided feedback specific to the practices.

Instrumental support behaviors exhibited by principals included providing necessary resources, space, and materials to teachers (Cancio, Albrecht, & Johns, 2013; Littrell et a., 1994). With regards to providing the needed materials and resources, on average, high school science teachers disagreed that principals provided them with the needed materials and resources to implement the practices. In the practices matrix, “tools” were mentioned frequently. High school science teachers stated during the focus group discussions that they did had an abundance of resources, ranging from software programs to textbooks and support from paraprofessionals; however, high school teachers reported that they lacked resources to engage in the practices on the matrix. Middle school science teachers reported being satisfied with their resources.

**Conclusions**

Decades of subpar K – 12 student outcomes in science provoked the Carnegie Corporation and the National Research Council (NRC) to propose drastic changes to science education in the United States. Based on the findings from this study, the researcher concluded that principals and middle and high school science teachers in southwest Georgia are not working together to successfully make the instructional shift required to teaching science as a practice during the implementation the Science Georgia Standards of Excellence. Principals impacted the change process positively when they participate in the process of learning with teachers, differentiate supports based on teachers’ needs, establish a positive relationship and a positive school climate (Brezicha et al., 2015; Price, 2011; Robinson et al., 2008). Hence, it was essential for science teachers to receive continuous support to develop an understanding of science and engineering practices and the appropriate instructional strategies to deliver quality instruction aligned to the vision of the *Frameworks* (NRC, 2012).

The data collected from middle school and high school science teachers during the survey revealed that the levels of concern for seven practices were mostly similar and correlated to slightly concern or higher. As a result, both groups of science teachers could benefit from administrative support strategies that relate to professional development, feedback and guidance on implementing the new standards, and ways to help students become better prepared to engage in the practices at the appropriate grade level, as reported during the focus group discussions.

Overwhelmingly, middle and high school participants in the focus group discussions reported how their principals were not knowledgeable of the new standards and practices and offered little to no assistance with improving their instructional practices. However, the teachers reported varying levels of support from principals in the area of instrumental support, but not informational support and appraisal support. Principals in southwest Georgia were not perceived as a knowledgeable source of support by their middle or high school science teachers.

To further support the previous point, science teachers need feedback and guidance specific to the new standards to prevent science teachers from using old practices. In search of explanations for the differences between the two groups, the researcher inquired with participants in the focus group discussions about their concerns regarding the implementation of the performance expectations associated with the asking questions and defining problems on the practices matrix (see Appendix B). It was likely that science teachers were not fully aware of the performance expectations. Three of the 10 focus group participants had not seen the practice matrix prior to session. Science teachers from both groups failed to address the engineering practices for most of the eight practices; comments were only made about traditional science practices.

In summary, science teachers and principals must work together and have a common understanding of the knowledge, needs, and actions to make the change. Based on science teachers' perceptions of science and engineering practices and administrative support provided by their principals collected during this study, science teachers and principals are not working together to ensure that science teachers are certain that they are implementing the new standards effectively.

The Practices and Support Conceptual Framework was revised to reflect the findings of the two research questions, as shown in Figure 17. The framework displayed relationships between key concepts and groups. The overlapping ovals forming a Venn Diagram represented the similarities and differences in the level of concerns about the science and engineering practices as reported by middle and high school science teachers in the study. The overlapping rectangular bases represented the similarities and differences in the level of agreement about administrative support provided by the principal as reported by middle and high school science teachers participating in the study. The differences and the values for mean (M) and standard deviation (SD) had been added.

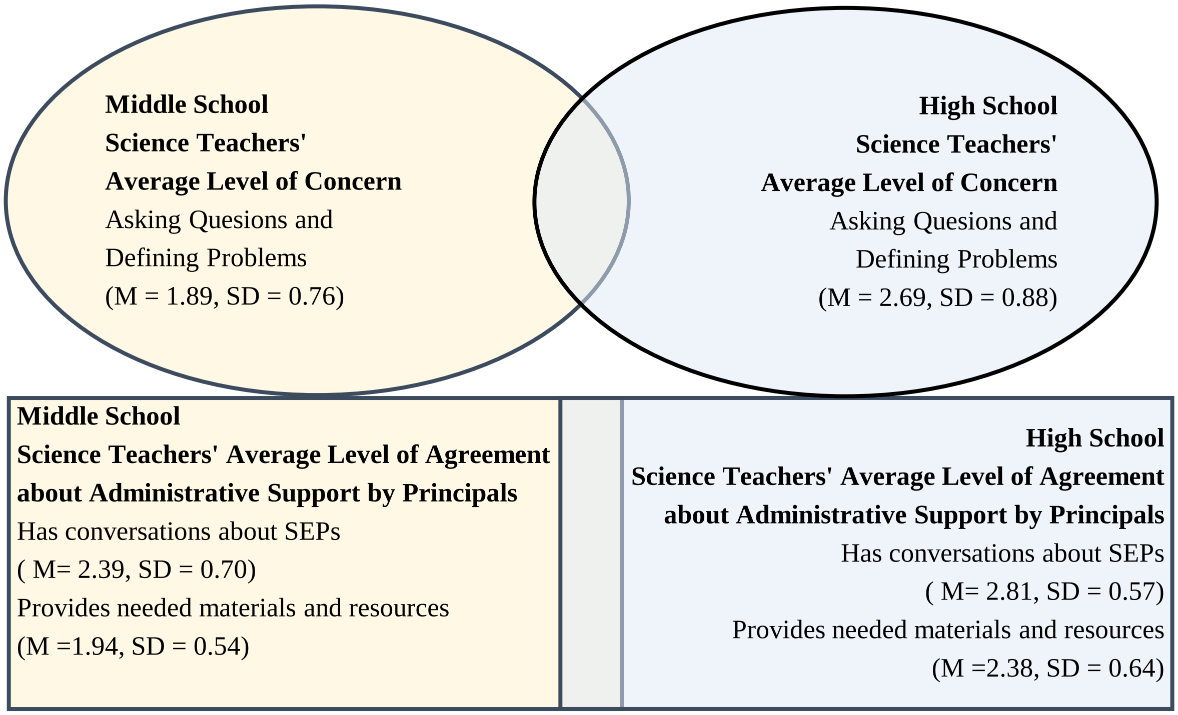


**Figure 17. Revised Practices and Supports Framework.**

## Implications

The purpose of investigating the concerns was best explained by Hall and Hord (1987), who suggested that by understanding teacher concerns, the principal can be more certain that the planned actions to support change were relevant to the perceived needs of teachers. Beyond the answers to the research questions, this study provided valuable information for administrators who want to support science teachers during the implementation of the Science Georgia Standards of Excellence.

First, science teachers and principals must work together to achieve the successful implementation of the Science Georgia Standards of Excellence and shift from teaching science as a process of inquiry to teaching science as a practice. If they fail to work to together, science teachers have concerns and the need for materials and tools that are not addressed. On the other hand, principals would not be aware of the concerns. Ultimately, the number of ineffective science teachers, according to the new expectations, would increase.

Second, science teachers who participated in the study reported that they received most of their professional development at the school district level, not from the regional education service agency or directly from the state. If science teachers do not implement the new standards and change instructional methods, then students will be negatively impacted. As a result, students in Southwest Georgia will not be prepared for future educational endeavors in the field of science, jobs in the fastest growing industries, and impact the global competitiveness of the State of Georgia.

## Recommendations

Based on the methodology and conclusions, the researcher suggested the following:

1. Regional education service agencies and school systems should work together to improve the quality of professional learning offered for both science and engineering practices.

   On average, survey respondents from middle schools and high schools in southwest Georgia reported being somewhat concerned about implementing the performance expectations for six of the eight science and engineering practices. Science teachers who participated in the focus group discussions recalled their lack of engagement and their dissatisfaction with the quality of the professional learning. Additionally, consistently science teachers focused more on the science components of the practices and not the engineering. Based on the recommendations made by Cunningham and Carlsen (2014), professional learning facilitators should consider the following: allow science teachers to engage in the practices, model pedagogies that support the practices when leading professional learning sessions, design sessions so that science teachers engage in experiences as learners and teachers, aid in the development of science teachers' understandings of the fundamentals of engineering and the interconnections between engineering and science, and  allow teachers to understand science and engineering as a social practice. As a whole, the professional development provided for science teachers and their principals must be relevant to the implementation of both the science practices and engineering practices. Based on their recommendation, science content specialists from the regional education service agency need to venture into the schools to led and monitor job-embedded professional learning for science teachers who are implementing the Science Georgia Standards of Excellence for the first time.

2. School systems must work with principals to ensure that they are knowledgeable of the changes in the science standards and expectations for science teachers and their instruction.

According to Littrell, et al., (1994), information support from principals is needed to support a change in teachers' behaviors. Principals are to be knowledge and lead the charge for change within the school. Science teachers who participated in the focus group discussion reported that they informed the principal of the new practices and other requirements for the changes to be made in instruction. Because the job of the principal is demanding, both science teachers and principals must work together during the implementation phase; however, principals must be knowledgeable in order to provide informational support to science teachers during the implementation of the Science Georgia Standards of Excellence.

3. If this study was duplicated, adjustments to the focus group questions should be considered to better inform the presence or absence of the four behavioral domains related to administrative support.

   Science teachers had rich discussions in response to the focus group protocol written and approved for this study; however, most questions related to instrumental and informational support in accordance with the research questions, rather than emotional and appraisal support. Some data related to emotional and appraisal support were collected during the course of the discussion; however, more intentional questioning could have potentially provided greater incite on those domains. Future researcher could further investigate administrative support based on all the four behavioral domains.

## Dissemination

The researcher planned to share the findings from the dissertation study with science teachers and those who support their efforts to implement the Science Georgia Standards of Excellence by submitting articles to educational magazines and requesting to present at a national science conference hosted within the state. The Association for Supervisors and Curriculum Development published articles monthly in *Educational Leadership* that were timely and relevant to current trends in education. In May 2018, the topic, *Bolstering the Teacher Pipeline*, included a request for articles that explored how school leaders leveraged and adapted to new models of teacher development and support. The findings from the second research question could be expanded to provide suggestions for principals and other school leaders.

The National Science Teacher Association published monthly magazines tailored to topics of interest for middle and high school science teachers, among others. The researcher outlined key points from the findings and results to answer the first research question, which will be used in an article that will be submitted to *Science Scope* and *The Science Teacher*, respectively, in spring 2018.

Also anticipated in spring 2018 was the united Georgia Science Teacher Association and National Science Teacher Association's Spring conference. The researcher planned a timeline to submit a request to present the results from the dissertation study to science educational leaders.

## Concluding Thoughts

The improvement of science achievement in Georgia and the United States has hinged on the recommendations from the national level and implementation at the classroom level through many cycles of instructional change since the 1960s. Science teachers and principals were left to develop their own sense of coherence that may or may not have accurately reflected the original vision of the change. Science and engineering practices are new and different but worth the collective effort to improve the global opportunities for students and the future workforce. Although the outcome of this study was no surprise to the researcher, the researcher remains hopeful of the successful collaboration between science teachers and principals to implement the Science Georgia Standards of Excellence.

## REFERENCES


ACT (2017a). *The condition of college & career readiness 2017: National*. American College Testing.

ACT (2017b). *The condition of college & career readiness 2017: Georgia*. American College Testing.

Allen, C. D., & Penuel, W. R. (2015). Studying teachers' sensemaking to investigate teachers' responses to professional development focused on new standards. *Journal of Teacher Education*, *66*(2), 136-149.

Anderson, R. D. (2002). Reforming science teaching: What research says about inquiry. *Journal of Science Teacher Education, 13*(1), 1-12.

Banilower, E. R., Gess-Newsome, J., & Tippins, D. (2014). Supporting the implementation of NGSS through research: Professional development. *National Association for Research in Science Teaching*.

Banilower, E. R., Smith, P. S., Weiss, I. R., Malzahn, K. A., Campbell, K. M., & Weis, A. M. (2013). *Report of the 2012 National Survey of Science and Mathematics Education*. Chapel Hill, NC: Horizon Research, Inc.

Barrow, L. H. (2006). A brief history of inquiry: From Dewey to standards. *Journal of Science Teacher Education*, *17*(3), 265-278.

Boesdorfer, S. B., & Staude, K. D. (2016). Teachers' practices in high school chemistry just prior to the adoption of the next generation science standards. *School Science and Mathematics*, *116*(8), 442-458.

Brezicha, K., Bergmark, U., & Mitra, D. L. (2015). One size does not fit all: Differentiating leadership to support teachers in school reform. *Educational Administration Quarterly, 5*(1), 96-132.

Bryk, A. S., Sebring, P. B., Allensworth, E., Easton, J. Q., & Luppescu, S. (2010). *Organizing schools for improvement: Lessons from Chicago*. Chicago, IL: University of Chicago Press.

Bybee, R. W. (1995). Science curriculum reform in the United States. In R. Bybee & J. McInerney (Eds.), *Redesigning the science curriculum*, (pp. 12-20). Colorado Springs, CO: Biological Sciences Curriculum Study.

Bybee, R. W. (2010). Fulfilling national aspirations through curriculum reform. In R.W. Bybee (Ed.), *The teaching of science: 21st century perspectives* (pp. 115-126). Arlington, VA: NSTA Press.

Bybee, R. W. (2011). Scientific and engineering practices in K-12 classrooms. *Science Teacher, 78*(9), 34-40.

Bybee, R. W. (2014). NGSS and the next generation of science teachers. *Journal of Science Teacher Education, 25*(2), 211-221.

Capps, D. K. & Crawford, B. A. (2013). Inquiry-based instruction and teaching about nature of science: Are they happening? *Journal of Science Teacher Education, 24*(3), 497-526.

Carr, R. L., Bennett, L. D., & Strobel, J. (2012). Engineering in the K-12 STEM standards of the 50 United States: An analysis of presence and extent, *Journal of Engineering Education, 101*(3), 1-26.

Castle, M. A. & Ferreira, M. M. (2015). Middle school science teachers' perspectives and practices related to science as inquiry: A case study. *Journal of Ethnographic & Qualitative Research, 10*(1), 13-28.

Cohen, D. K., & Hill, H. C. (2008). *Learning policy: When state education reform works*. New Haven, CT:Yale University Press.

Cook, C., Heath, F., & Thompson, R. L. (2000). A meta-analysis of response rates in web-or internet-based surveys. *Educational and Psychological Measurement, 60*(6), 821-836.

Creswell, J. W. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (4th ed.). Boston, MA: Pearson Education, Inc.

Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research*. Los Angeles: SAGE Publications.

Crismond, D. (2013). Design practices and misconceptions. *The Science Teacher, 80*(1), 50-54.

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

Cunningham, C. M., & Kelly, G. J. (2017). Epistemic practices of engineering for education. *Science Education, 101*(3), 486-505.

Dailey, D., & Robinson, A. (2016). Elementary teachers: Concerns about implementing a science program. *School Science and Mathematics, 116*(3), 139-147.

DiBiase, W. & McDonald, J. R. (2015). Science teacher attitude toward inquiry-based teaching and learning. *The Clearing House, 88*(2), 29-38.

Dillman, D. A., Smyth, J. D., & Christian, L. M. (2009). *Internet, mail, and mixed-mode surveys: The tailored design method* (3rd ed.). New York, NY: John Wiley & Sons.

Duncan, R. G., & Cavera, V. L. (2015). DCIs, SEPs, and CCs, oh my! Understanding the three dimensions of the NGSS. *Science Scope, 82*(7), 50-57.

Erduran, S., Ozdem, Y., & Park, J. Y. (2015). Research trends on argumentation in science education: A journal content analysis from 1998–2014. *International Journal of STEM Education, 2*(1), 5.

Evans, J. R., & Mathur, A. (2005). The value of online surveys. *Internet Research, 15*(2), 195-219.

Evans, Z. (2015, April 16). Georgia Science Teachers Association - FAQs. Retrieved June 24, 2016, from http://www.georgiascienceteacher.org/Next-Gen-FAQs/#FAQ2

Evans, Z. (2016, April 19). Georgia Science Teachers Association: Moving Science Education Forward. Retrieved June 24, 2016, from http://www.georgiascienceteacher.org/Next-Gen-Science

Fullan, M. (2014). *The principal: Three keys to maximizing impact.* San Francisco, CA: Jossey-Bass.

Fullan, M. (2016). *The new meaning of educational change, fifth edition*. New York: Teachers College Press.

Fuller, F. (1969). Concerns of teachers: A developmental conceptualization. *American Educational Research Journal, 6*(2), 207-226.

Fuller, F., & Case, C. (1969). Concerns of teachers, a manual for teacher educators: Increasing teacher satisfaction with professional preparation by considering teachers' concerns when planning preservice and inservice education. Austin, TX: Texas University Research and Development Center for Teacher Education. Retrieved from http://files.eric.ed.gov/fulltext/ED040143.pdf.

Gilbert, J. K., Boulter, C. J., & Elmer, R. (2000). Positioning models in science education and in design and technology education. In *Developing Models in Science Education* (pp. 3-17). Springer Netherlands.

Gonzales, P., Williams, T., Jocelyn, L., Roey, S., Kastberg, D., & Brenwald, S. (2008). *Highlights from TIMSS 2007: Mathematics and science achievement of US fourth-and eighth-grade students in an international context*. NCES 2009-001. Washington, DC: National Center for Education Statistics.

Governor's Office of Student Achievement (2017). State level data 2017. Retrieved from https://schoolgrades.georgia.gov/dataset/state-level-data/resource/10839738-e592-4172-a442-b3b41d676584#.

Griffiths, P., & Cahill, M. (2009). *The opportunity equation: Transforming mathematics and science education for citizenship and the global economy*. New York, NY: Carnegie Corporation of New York and Institute for Advanced Study.

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.

Hall, G. E. (1979). The concerns-based approach to facilitating change. *Educational Horizons, 57*(4), 202-208.

Hall, G. E., & Hord, S. M. (1987). *Change in schools: Facilitating the process*. New York, NY: SUNY Press.

Hall, G. E., Wallace, R. C., & Dossett, W. F. (1973). *The concerns-based adoption model: A developmental conceptualization of the adoption process within educational institutions*. (Report No. 3006). Austin, TX: The University of Texas at Austin, Research and Development Center for Teacher Education.

Harrison, A. G., & Treagust, D. F. (2002). The particulate nature of matter: Challenges in understanding the submicroscopic world. In *Chemical education: Towards research-based practice* (pp. 189-212). Netherlands: Springer.

Hurd, P. D. (1986). Perspectives for the reform of science education. *Phi Delta Kappan, 67*(5), 353-358.

Johnson, B. & Christensen, L. B. (2017). *Educational research: Quantitative, qualitative, and mixed approaches.* Thousand Oaks, CA: SAGE.

Kelly, P. (2006). What is teacher learning? A socio-cultural perspective. *Oxford Review of Education, 32*(4), 505-519.

Kessinger, T. A. (2011). Efforts toward educational reform in the United Stated since 1958: A review of seven major initiatives. *American Educational History Journal, 38*(2), 263-276.

Klahr, D., & Dunbar, K. (1988). Dual space search during scientific reasoning. *Cognitive science A multidisciplinary journal, 12 (1),* 1-48.

Lachapelle, C. P., Sargianis, K., & Cunningham, C. M. (2013). Engineer it, learn it: science and engineering practices in action. *Science and Children, 51*(3), 70-76.

Lam, S. F., Cheng, R. W. Y., & Choy, H. C. (2010). School support and teacher motivation to implement project-based learning. *Learning and Instruction, 20*(6), 487-497.

Latour, B. (1999). *Pandora's hope: Essays on the reality of science studies*. Cambridge, MA: Harvard University Press.

Latour, B., and Woolgar, S. (1986). *Laboratory life: The construction of scientific facts.* Princeton, NJ: Princeton University Press.

Lehrer, R., & Schauble, L. (2006). Cultivating model-based reasoning in science education. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences,* (pp. 371-387). Cambridge, MA: Cambridge University Press.

Leithwood, K. & Seashore-Louis, K. (2012). *Linking leadership to student learning*. San Francisco, CA: Jossey-Bass.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry* (Vol. 75). Thousand Oaks, CA: SAGE.

Littrell, P. C., Billingsley, B. S., & Cross, L. H. (1994). The effects of principal support on special and general educators' stress, job satisfaction, school commitment, health, and intent to stay in teaching. *Remedial and Special Education*, *15*(5), 297-310.

Lochner, B., Conrad, R., & Graham, E. (2015). Secondary teachers' concerns in adopting learning management systems: A U. S. perspective. *TechTrends: Linking Research and Practice to Improve Learning*, *59*(5), 62-70.

Martin, M. O., Mullis, I. V. S., Foy, P., & Hooper, M. (2016). TIMSS 2015 international results in science. Retrieved from Boston College, TIMSS & PIRLS International Study Center website: http://timssandpirls.bc.edu/timss2015/international-results/.

Milano, M. (2013). The next generation science standards and engineering for young learners: Beyond bridges and egg drops. *Science and Children*, *51*(2), 10-16.

National Academies of Sciences, Engineering, and Medicine. (2015). *Science teachers learning: Enhancing opportunities, creating supportive contexts.* Committee on Strengthening Science Education through Teacher Learning Continuum. Board on Science Education and Teacher Advisory Council, Division of Behavioral and Social Science and Education. Washington, DC: The National Academies Press.

National Education Association (1894). *Report of the committee of ten on secondary school studies with the reports of the conferences arranged by the committee*. New York, NY: The American Book Company. Retrieved from https://books.google.com/books

National Research Council. (1996). *National science education standards*. Washington, DC: The National Academies Press. https://doi.org/10.17226/4962.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: National Academy Press.

National Research Council. (2015). *Guide to implementing the next generation science standards*. Committee on Guidance on Implementing the Next Generation Science Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education, Washington, DC: The National Academies Press.

Nercessian, N. (2008). Model-based reasoning in scientific practice. In R.A. Duschl and R.E. Grandy (Eds.), *Teaching scientific inquiry: Recommendations for research and implementation* (pp. 57-79). Rotterdam, the Netherlands: Sense.

NGSS Lead States. (2013). *Next generation science standards: For states, by states*. Washington, DC: The National Academies Press.

Nollmeyer, G. E., & Bangert, A. (2015). Assessing K-5 elementary teachers understanding and readiness to teach the new framework for science education. *The Researcher, 27*(2), 7-13.

OECD (2016). Science performance (PISA) (indicator). doi: 10.1787/91952204-en

Osborne, J. (2014). Teaching scientific practices: Meeting the challenge of change. *Journal of Science Teacher Education*, *25*(2), 177-196.

Osborne-Lampkin, L., Folsom, J. S., & Herrington, C. D. (2015). *A systematic review of the relationships between principal characteristics and student achievement* (REL 2016–091). Washington, DC: U.S. Department of Education, Institute of Education Sciences, National Center for Education Evaluation and Regional Assistance, Regional Educational Laboratory Southeast. Retrieved from http://ies.ed.gov/ncee/edlabs.

Pasley, J. D., Trygstad, P. J., & Banilower, E. R. (2016). Towards engagement with the science and engineering practices for all students. Presented at the 2016 NARST Annual International Conference, Baltimore, MD.

Peacock, J. (2016, April 19). GaDOE launches science ambassadors program to support professional learning. Retrieved June 24, 2016, from http://www.georgiascienceteacher.org/Next-Gen-Updates

Peacock, J. S. (2014). Science instructional leadership: The role of the department chair. *Science Educator*, *23*(1), 36-48.

Pinar, W. F., Reynolds, W. M., Slattery, P., & Taubman, P. M. (2008) *Understanding curriculum: An introduction to the study of historical and contemporary curriculum discourses*. New York, NY: Peter Lang.

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

Robinson, V. M., Lloyd, C. A., & Rowe, K. J. (2008). The impact of leadership on student outcomes: An analysis of the differential effects of leadership types. *Educational Administration Quarterly*, *44*(5), 635-674.

Robson, C. (2011). *Real World Research*. Third edition. New York, NY: John Wiley and Sons.

Rosenshine, B., Meister, C., & Chapman, S. (1996). Teaching students to generate questions: A review of the intervention studies. *Review of Educational Research*, *66*(2), 181-221.

Rudolph, J. L. (2014). Dewey's "science as method" a century later: Reviving science education for civic ends. *American Educational Research Journal*, *51*(6), 1056-1083.

Rudolph, J. L., & Meshoulam, D. (2014). Science education in American high schools. In *The Oxford Encyclopedia of the History of American Science, Medicine, and Technology*, (pp. 503-523). New York, NY: Oxford University Press.

Rutherford, W. L., Hord, L. L., Huling, L., & Hall, G. E. (1983). *Change facilitators: In search of understanding their role*. Alington, TX: University of Texas, Research and Development Centre for Teacher Education.

Schmidt, H. G. (1993). Foundations of problem-based learning: Some explanatory notes. *Medical Education, 27*(5), 422-432.

Schubert, W. H. (1993). Curriculum reform. In G. Cawelti, *Challenges and achievements of American Education* (pp. 80-115). Alexandria, VA: Association for Supervision and Curriculum Development.

Spillane, J. P. (2004). *Standards deviation: How schools misunderstand education policy.* Cambridge, MA: Harvard University Press.

Spring, J. (1970). Education and progressivism. *History of Education Quarterly*, *10*(1), 53-71.

Teddlie, C., & Tashakkori, A. (2009). *Foundations of mixed methods research: Integrating quantitative and qualitative approaches in the social and behavioral sciences*. Thousand Oaks, SAGE.

Teddlie, C., & Yu, F. (2007). Mixed methods sampling: A typology with examples. *Journal of Mixed Methods Research, 1*(1), 77-100.

Trygstad, P., Banilower, E., & Parsley, J. (2016). *Operationalizing the science and engineering practices.* Chapel Hill, NC: Horizon Research, Inc.

Trygstad, P., Smith, P., Banilower, E., & Nelson, M. (2013). *The status of elementary science education: Are we ready for the Next Generation Science Standards?* Chapel Hill, NC: Horizon Research, Inc.

Tschaepe, M. D. (2012). The student as philosopher-Scientist: Dewey's conception of scientific explanation in science education, *Education and Culture*, *28*(2), 70-79.

Venkatesh, V., Brown, S. A., & Bala, H. (2013). Bridging the qualitative-quantitative divide: Guidelines for conducting mixed methods research in information systems. *MIS quarterly*, *37*(1), 21-54.

Waters, T., Marzano, R., & McNulty, B. (2003). *Balanced leadership: What 30 years of research tells us about the effect of leadership on student achievement.* Aurora, CO: Mid-Continent Research for Education and Learning.

Watson, J., Swain, J. R., & McRobbie, C. (2004). Students' discussions in practical scientific inquiries. *International Journal of Science Education*, *26*(1), 25-45.

Webster, A., McNeish, D., Scott, S., Maynard, L., & Haywood, S. (2012). *What influences teachers to change their practice? A rapid research review* (No. 12/07). Bristol, United Kingdom: University of Bristol.

Wilcox, J., Kruse, J. W., & Clough, M. P. (2015). Teaching science through inquiry. *The Science Teacher, 82*(6), 62-67.

Yager, R. E. (2000). The history and future of science education reform. *The Clearing House: A Journal of Educational Strategies, Issues and*

# APPENDIX A

## IRB APPROVAL E-MAIL

Exempt Approval Protocol 18-041
1 message

CSU IRB <irb@columbusstate.edu> Wed, Nov 8, 2017 at 1:24 PM

To: Shereca Harvey <harvey_shereca@columbusstate.edu>, Pamela Lemoine <lemoine_pamela@columbusstate.edu>

Cc: CSU IRB <irb@columbusstate.edu>, Institutional Review Board <instituional_review@columbusstate.edu>

Institutional Review Board

Columbus State University

Date: 11/8/17

Protocol Number: 18-041

Protocol Title: Implementing Science and Engineering Practices in Southwest Georgia: A Mixed Method Study of Science Teachers' Task Concerns and Administrative Support

Principal Investigator: Shereca Harvey Co-Principal Investigator: Pamela Lemoine

Dear Shereca Harvey:

The Columbus State University Institutional Review Board or representative(s) has reviewed your research proposal identified above. It has been determined that the project is classified as exempt under 45 CFR 46.101(b) of the federal regulations and has been approved. You may begin your research project immediately. Please note any changes to the protocol must be submitted in writing to the IRB before implementing the change(s). Any adverse events, unexpected problems, and/or incidents that involve risks to participants and/or others must be reported to the Institutional Review Board at irb@columbusstate.edu or (706) 5078634.If you had further questions, please feel free to contact the IRB.

Sincerely,

Amber Dees, IRB Coordinator

Institutional Review Board

Columbus State University

# APPENDIX B

# PRACTICES MATRIX

**Science & Engineering Practices**

# Asking Questions and Defining Problems

A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world(s) works and which can be empirically tested. Engineering questions clarify problems to determine criteria for successful solutions and identify constraints to solve problems about the designed world. Both scientists and engineers also ask questions to clarify ideas.

| K–2 Condensed Practices | 3–5 Condensed Practices | 6–8 Condensed Practices | 9–12 Condensed Practices |
|---|---|---|---|
| Asking questions and defining problems in K–2 builds on prior experiences and progresses to simple descriptive questions that can be tested. | Asking questions and defining problems in 3–5 builds on K–2 experiences and progresses to specifying qualitative relationships. | Asking questions and defining problems in 6–8 builds on K–5 experiences and progresses to specifying relationships between variables, clarify arguments and models. | Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. |
| • Ask questions based on observations to find more information about the natural and/or designed world(s). | • Ask questions about what would happen if a variable is changed. | • Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.<br>• Ask questions to identify and/or clarify evidence and/or the premise(s) of an argument.<br>• Ask questions to determine relationships between independent and dependent variables and relationships in models.<br>• Ask questions to clarify and/or refine a model, an explanation, or an engineering problem. | • Ask questions that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.<br>• Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships.<br>• Ask questions to determine relationships, including quantitative relationships, between independent and dependent variables.<br>• Ask questions to clarify and refine a model, an explanation, or an engineering problem. |
| • Ask and/or identify questions that can be answered by an investigation. | • Identify scientific (testable) and non-scientific (non-testable) questions.<br>• Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships. | • Ask questions that require sufficient and appropriate empirical evidence to answer.<br>• Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles. | • Evaluate a question to determine if it is testable and relevant.<br>• Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory. |
| | | • Ask questions that challenge the premise(s) of an argument or the interpretation of a data set. | • Ask and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of the design. |

| | | | |
|---|---|---|---|
| • Define a simple problem that can be solved through the development of a new or improved object or tool. | • Use prior knowledge to describe problems that can be solved.<br>• Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost. | • Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions. | • Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical and/or environmental considerations. |



**Science & Engineering Practices**

# Developing and Using Models

A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations. Modeling tools are used to develop questions, predictions and explanations; analyze and identify flaws in systems; and communicate ideas. Models are used to build and revise scientific explanations and proposed engineered systems. Measurements and observations are used to revise models and designs.

| K–2 Condensed Practices | 3–5 Condensed Practices | 6–8 Condensed Practices | 9–12 Condensed Practices |
|---|---|---|---|
| Modeling in K–2 builds on prior experiences and progresses to include using and developing models (i.e., diagram, drawing, physical replica, diorama, dramatization, or storyboard) that represent concrete events or design solutions. | Modeling in 3–5 builds on K–2 experiences and progresses to building and revising simple models and using models to represent events and design solutions. | Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems. | Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). |
| • Distinguish between a model and the actual object, process, and/or events the model represents.<br>• Compare models to identify common features and differences. | • Identify limitations of models. | • Evaluate limitations of a model for a proposed object or tool. | • Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism, or system in order to select or revise a model that best fits the evidence or design criteria.<br>• Design a test of a model to ascertain its reliability. |

| | | | |
|---|---|---|---|
| • Develop and/or use a model to represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed world(s). | • Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regular occurring events.<br>• Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution.<br>• Develop and/or use models to describe and/or predict phenomena. | • Develop or modify a model—based on evidence – to match what happens if a variable or component of a system is changed.<br>• Use and/or develop a model of simple systems with uncertain and less predictable factors.<br>• Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena.<br>• Develop and/or use a model to predict and/or describe phenomena.<br>• Develop a model to describe unobservable mechanisms. | • Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.<br>• Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations. |
| • Develop a simple model based on evidence to represent a proposed object or tool. | • Develop a diagram or simple physical prototype to convey a proposed object, tool, or process.<br>• Use a model to test cause and effect relationships or interactions concerning the functioning of a natural or designed system. | • Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. | • Develop a complex model that allows for manipulation and testing of a proposed process or system.<br>• Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. |

**Science & Engineering Practices**

# Planning and Carrying Out Investigations

Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters. Engineering investigations identify the effectiveness, efficiency, and durability of designs under different conditions.

| K–2 Condensed Practices | 3–5 Condensed Practices | 6–8 Condensed Practices | 9–12 Condensed Practices |
|---|---|---|---|
| Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions. | Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions. | Planning and carrying out investigations in 6-8 builds on K-5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or solutions. | Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. |
| • With guidance, plan and conduct an investigation in collaboration with peers (for K).<br>• Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence to answer a question. | • Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. | • Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.<br>• Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation. | • Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible variables or effects and evaluate the confounding investigation's design to ensure variables are controlled.<br>• Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.<br>• Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts. |
| • Evaluate different ways of observing and/or measuring a phenomenon to determine which way can answer a question. | • Evaluate appropriate methods and/or tools for collecting data. | • Evaluate the accuracy of various methods for collecting data. | • Select appropriate tools to collect, record, analyze, and evaluate data. |
| • Make observations (firsthand or from media) and/or measurements to collect data that can be used to make comparisons.<br>• Make observations (firsthand or from media) and/or measurements of a proposed object or tool or solution to determine if it solves a problem or meets a goal.<br>• Make predictions based on prior experiences. | • Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.<br>• Make predictions about what would happen if a variable changes.<br>• Test two different models of the same proposed object, tool, or process to determine which better meets criteria | • Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.<br>• Collect data about the performance of a proposed object, tool, process, or system under a range of conditions. | • Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated.<br>• Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables. |

| | | | |
|---|---|---|---|
| | for success. | | |

**Science & Engineering Practices**

# Analyzing and Interpreting Data

Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis. Engineering investigations include analysis of data collected in the tests of designs. This allows comparison of different solutions and determines how well each meets specific design criteria— that is, which design best solves the problem within given constraints. Like scientists, engineers require a range of tools to identify patterns within data and interpret the results. Advances in science make analysis of proposed solutions more efficient and effective.

| K–2 Condensed Practices | 3–5 Condensed Practices | 6–8 Condensed Practices | 9–12 Condensed Practices |
|---|---|---|---|
| Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations. | Analyzing data in 3–5 builds on K–2 experiences and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations. When possible and feasible, digital tools should be used. | Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. | Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. |
| • Record information (observations, thoughts, and ideas).<br>• Use and share pictures, drawings, and/or writings of observations.<br>• Use observations (firsthand or from media) to describe patterns and/or relationships in the natural and designed world(s) in order to answer scientific questions and solve problems.<br>• Compare predictions (based on prior experiences) to what occurred (observable events). | • Represent data in tables and/or various graphical displays (bar graphs, pictographs, and/or pie charts) to reveal patterns that indicate relationships. | • Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships.<br>• Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships.<br>• Distinguish between causal and correlational relationships in data.<br>• Analyze and interpret data to provide evidence for phenomena. | • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. |
| | • Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and/or computation. | • Apply concepts of statistics and probability (including mean, median, mode, and variability) to analyze and characterize data, using digital tools when feasible. | • Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. |
| | | • Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials). | • Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data. |
| | • Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings. | • Analyze and interpret data to determine similarities and differences in findings. | • Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations. |

| | | | |
|---|---|---|---|
| • Analyze data from tests of an object or tool to determine if it works as intended. | • Analyze data to refine a problem statement or the design of a proposed object, tool, or process.<br>• Use data to evaluate and refine design solutions. | • Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success. | • Evaluate the impact of new data on a working explanation and/or model of a proposed process or system.<br>• Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success. |

**Science & Engineering Practices**

## Using Mathematics and Computational Thinking

In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks such as constructing simulations; solving equations exactly or approximately; and recognizing, expressing, and applying quantitative relationships.
Mathematical and computational approaches enable scientists and engineers to predict the behavior of systems and test the validity of such predictions.

| K–2 Condensed Practices | 3–5 Condensed Practices | 6–8 Condensed Practices | 9–12 Condensed Practices |
|---|---|---|---|
| Mathematical and computational thinking in K–2 builds on prior experience and progresses to recognizing that mathematics can be used to describe the natural and designed world(s). | Mathematical and computational thinking in 3–5 builds on K–2 experiences and progresses to extending quantitative measurements to a variety of physical properties and using computation and mathematics to analyze data and compare alternative design solutions. | Mathematical and computational thinking in 6–8 builds on K–5 experiences and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments. | Mathematical and computational thinking in 9-12 builds on K-8 and experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. |
| | | • Decide when to use qualitative vs. quantitative data. | • Decide if qualitative or quantitative data are best to determine whether a proposed object or tool meets criteria for success. |
| • Use counting and numbers to identify and describe patterns in the natural and designed world(s). | • Organize simple data sets to reveal patterns that suggest relationships. | • Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends. | • Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. |
| • Describe, measure, and/or compare quantitative attributes of different objects and display the data using simple graphs. | • Describe, measure, estimate, and/or graph quantities such as area, volume, weight, and time to address scientific and engineering questions and problems. | • Use mathematical representations to describe and/or support scientific conclusions and design solutions. | • Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. |

| | | | |
|---|---|---|---|
| • Use quantitative data to compare two alternative solutions to a problem. | • Create and/or use graphs and/or charts generated from simple algorithms to compare alternative solutions to an engineering problem. | • Create algorithms (a series of ordered steps) to solve a problem.<br>• Apply mathematical concepts and/or processes (such as ratio, rate, percent, basic operations, and simple algebra) to scientific and engineering questions and problems.<br>• Use digital tools and/or mathematical concepts and arguments to test and compare proposed solutions to an engineering design problem. | • Apply techniques of algebra and functions to represent and solve scientific and engineering problems.<br>• Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model "makes sense" by comparing the outcomes with what is known about the real world.<br>• Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.). |

**Science & Engineering Practices**

# Constructing Explanations and Designing Solutions

The end-products of science are explanations and the end-products of engineering are solutions. The goal of science is the construction of theories that provide explanatory accounts of the world. A theory becomes accepted when it has multiple lines of empirical evidence and greater explanatory power of phenomena than previous theories. The goal of engineering design is to find a systematic solution to problems that is based on scientific knowledge and models of the material world. Each proposed solution results from a process of balancing competing criteria of desired functions, technical feasibility, cost, safety, aesthetics, and compliance with legal requirements. The optimal choice depends on how well the proposed solutions meet criteria and constraints.

| K–2 Condensed Practices | 3–5 Condensed Practices | 6–8 Condensed Practices | 9–12 Condensed Practices |
|---|---|---|---|
| Constructing explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence and ideas in constructing evidence-based accounts of natural phenomena and designing solutions. | Constructing explanations and designing solutions in 3–5 builds on K–2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems. | Constructing explanations and designing solutions in 6– 8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories. | Constructing explanations and designing solutions in 9– 12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. |
| • Use information from observations (firsthand and from media) to construct an evidence-based account for natural phenomena. | • Construct an explanation of observed relationships (e.g., the distribution of plants in the back yard). | • Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena.<br>• Construct an explanation using models or representations. | • Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. |
| | • Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem. | • Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.<br>• Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real- world phenomena, examples, or events. | • Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.<br>• Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. |
| | • Identify the evidence that supports particular points in an explanation. | • Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion. | • Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. |

| | | | |
|---|---|---|---|
| • Use tools and/or materials to design and/or build a device that solves a specific problem or a solution to a specific problem.<br>• Generate and/or compare multiple solutions to a problem. | • Apply scientific ideas to solve design problems.<br>• Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution. | • Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system.<br>• Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.<br>• Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re-testing. | • Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. |

**Science & Engineering Practices**

## Engaging in Argument from Evidence

Argumentation is the process by which evidence-based conclusions and solutions are reached. In science and engineering, reasoning and argument based on evidence are essential to identifying the best explanation for a natural phenomenon or the best solution to a design problem. Scientists and engineers use argumentation to listen to, compare, and evaluate competing ideas and methods based on merits. Scientists and engineers engage in argumentation when investigating a phenomenon, testing a design solution, resolving questions about measurements, building data models, and using evidence to evaluate claims.

| K–2 Condensed Practices | 3–5 Condensed Practices | 6–8 Condensed Practices | 9–12 Condensed Practices |
|---|---|---|---|
| Engaging in argument from evidence in K– 2 builds on prior experiences and progresses to comparing ideas and representations about the natural and designed world(s). | Engaging in argument from evidence in 3–5 builds on K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world(s). | Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world(s). | Engaging in argument from evidence in 9–12 builds on K– 8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. |
| • Identify arguments that are supported by evidence.<br>• Distinguish between explanations that account for all gathered evidence and those that do not.<br>• Analyze why some evidence is relevant to a scientific question and some is not.<br>• Distinguish between opinions and evidence in one's own explanations. | • Compare and refine arguments based on an evaluation of the evidence presented.<br>• Distinguish among facts, reasoned judgment based on research findings, and speculation in an explanation. | • Compare and critique two arguments on the same topic and analyze whether they emphasize similar or different evidence and/or interpretations of facts. | • Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues.<br>• Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. |
| • Listen actively to arguments to indicate agreement or disagreement based on evidence, and/or to retell the main points of the argument. | • Respectfully provide and receive critiques from peers about a proposed procedure, explanation or model.by citing relevant evidence and posing specific questions. | • Respectfully provide and receive critiques about one's explanations, procedures, models and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail. | • Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining what additional information is required to resolve contradictions. |

| | | | |
|---|---|---|---|
| • Construct an argument with evidence to support a claim. | • Construct and/or support an argument with evidence, data, and/or a model.<br>☐ ⍰ Use data to evaluate claims about cause and effect. | • Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. | • Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence. |
| • Make a claim about the effectiveness of an object, tool, or solution that is supported by relevant evidence. | • Make a claim about the merit of a solution to a problem by citing relevant evidence about how it meets the criteria and constraints of the problem. | • Make an oral or written argument that supports or refutes the advertised performance of a device, process, or system, based on empirical evidence concerning whether or not the technology meets relevant criteria and constraints.<br>• Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. | • Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student- generated evidence.<br>• Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations). |

**Science & Engineering Practices**

## Obtaining, Evaluating, and Communicating Information

Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity. Communicating information and ideas can be done in multiple ways: using tables, diagrams, graphs, models, and equations as well as orally, in writing, and through extended discussions. Scientists and engineers employ multiple sources to obtain information that is used to evaluate the merit and validity of claims, methods, and designs.

| K–2 Condensed Practices | 3–5 Condensed Practices | 6–8 Condensed Practices | 9–12 Condensed Practices |
|---|---|---|---|
| Obtaining, evaluating, and communicating information in K–2 builds on prior experiences and uses observations and texts to communicate new information. | Obtaining, evaluating, and communicating information in 3–5 builds on K–2 experiences and progresses to evaluating the merit and accuracy of ideas and methods. | Obtaining, evaluating, and communicating information in 6–8 builds on K–5 experiences and progresses to evaluating the merit and validity of ideas and methods. | Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. |
| • Read grade-appropriate texts and/or use media to obtain scientific and/or technical information to determine patterns in and/or evidence about the natural and designed world(s). | • Read and comprehend grade-appropriate complex texts and/or other reliable media to summarize and obtain scientific and technical ideas and describe how they are supported by evidence.<br>• ompare and/or combine across complex texts and/or other reliable media to support the engagement in | • Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s). | • Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. |

| | | | |
|---|---|---|---|
| | other scientific and/or engineering practices. | | |
| • Describe how specific images (e.g., a diagram showing how a machine works) support a scientific or engineering idea. | • Combine information in written text with that contained in corresponding tables, diagrams, and/or charts to support the engagement in other scientific and/or engineering practices. | • Integrate qualitative and/or quantitative scientific and/or technical information in written text with that contained in media and visual displays to clarify claims and findings. | • Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. |
| • Obtain information using various texts, text features (e.g., headings, tables of contents, glossaries, electronic menus, icons), and other media that will be useful in answering a scientific question and/or supporting a scientific claim. | • Obtain and combine information from books and/or other reliable media to explain phenomena or solutions to a design problem. | • Gather, read, synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence.<br>• Evaluate data, hypotheses, and/or conclusions in scientific and technical texts in light of competing information or accounts. | • Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.<br>• Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. |
| • Communicate information or design ideas and/or solutions with others in oral and/or written forms using models, drawings, writing, or numbers that provide detail about scientific ideas, practices, and/or design ideas. | • Communicate scientific and/or technical information orally and/or in written formats, including various forms of media and may include tables, diagrams, and charts. | •<br>• ▯ Communicate scientific and/or technical information (e.g. about a proposed object, tool, process, system) in writing and/or through oral presentations. | • Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). |

# APPENDIX C

# MIDDLE SCHOOL SCIENCE TEACHER SURVEY

**Science and Engineering Practices: Middle School Science Teachers' Task Concerns and Administrative Support Survey**

**INFORMED CONSENT INFORMATION**

You are being asked to participate in a research project conducted by Shereca R. Harvey, a doctoral student in the College of Education and Health Professions at Columbus State University under the supervision of Dr. Pamela Lemoine, a faculty member.

I. Purpose: The purpose of this project is to investigate the differences between middle and high school science teachers task concerns regarding science and engineering practices (SEPs) and their perceptions of administrative support provided by principal during the implementation of Science Georgia Standard of Excellence.

II. Procedures: If you agree to be in the study, you will complete a web-based survey or participate in focus group discussion. The web based survey consists of 24 items that assess the participant's level of concern associated with each of the eight SEPs, level of agreement with statements about administrative support provided by their principal, and demographic questions. The survey will require no more than 30 minutes to complete. Participants in the focus group will discuss the same topics in a 45 to 60-minute discussion with six to eight science teachers from southwest Georgia after school hours at a public library. The interview will be recorded using an electronic device to accurately capture what is said. After the interview, a transcript of the focus group interview will be emailed without identifying information for members to check for accuracy. The data collected will not be used for future projects.

III. Possible Risks or Discomforts: There are minimal risks when participating in the study. There is the potential loss of confidentiality, because the researcher cannot guarantee that participants will not share information discussed during the focus group. The researcher will take the following precautions to minimize the level of social risks by allowing participants to withdraw or limit their participation if they become uncomfortable, allowing participants to request that the audio recording be paused at any time there is a feeling of discomfort, asking participants to agree to the importance of keeping information discussed during the focus group confidential, reminding participants to respect the privacy of fellow participants, and instructing participants to use only first names during the focus group discussion

IV. Potential Benefits: Although there are no direct benefits to the participant for being in the study, there are potential benefits to science teachers and educators who support science teachers at the state, regional, district, and school levels.

V. Costs and Compensation: Participants will not be compensated for responding to the web-based survey or participating in a focus group. Focus group participants will be expected to provide their own transportation to the focus group meeting.

VI. Confidentiality: The researcher will ensure that participants' data remain confidential in the following manner: (1) storing confidential data in password-protected files, encrypted and password-protected databases (Survey Monkey), and in locked filing cabinets to limit access to the researcher only; (2) limiting the collection of information that can be used to identify a participant to the email and IP addresses; (3) removing e-mail and IP addresses from the raw data file before Statistical Package for the Social Sciences (SPSS) software analysis; (4) properly deleting, shredding, and disposing of all documents, reports, and electronic files with identifiable information five years after the completion of the study.

VII. Withdrawal: Your participation in this research study is voluntary. You may withdraw from the study at any time, and your withdrawal will not involve penalty or loss of benefits.



For additional information about this research project, you may contact the Principal Investigator, Shereca Harvey at (229) 869-9983 or harvey_shereca@columbusstate.edu or the supervising faculty, Dr. Pamela Lemoine at lemoine_pamela@columbusstate.edu. If you have questions about your rights as a research participant, you may contact Columbus State University Institutional Review Board at

| FOCUS GROUP PARTICIPATION |
|---|
| 2. Would you like to participate in a focus group with six to eight high school science teachers who teach in southwest Georgia to discuss task related concerns and administrative support provided during the implementation of science and engineering practices in southwest Georgia? If you select “I would like to participate in a focus group.”, then click Next to submit your survey. You will not be allowed to answer questions 3 - 24 in the survey. *<br><br>☐ I would like to participate in a focus group.<br>☐ I do not wish to participate in a focus group. |
| **DEMOGRAPHICS: EXPERIENCE AND WORK ENVIRONMENT** |

3. What was your undergraduate major?
   - O Science
   - O Education
   - O Science Education
   - O Other

4. What was your graduate major?
   - O Science
   - O Education
   - O Science Education
   - O Other
   - O I do not hold a graduate degree

5. Please indicate the number of years you have been teaching.
   - O 0 to 4 years
   - O 5 to 9 years
   - O 10 to 14 years
   - O 15 to 19 years
   - O 20 to 24 years
   - O 25 – 29 years
   - O 30 or more years

6. Please indicate the number of years you have been teaching science.
   - O 0 to 4 years
   - O 5 to 9 years
   - O 10 to 14 years
   - O 15 to 19 years
   - O 20 to 24 years
   - O 25 – 29 years
   - O 30 or more years

7. Please indicate the number of science teachers in your school.
   - O 1; I am the only science teacher in my school
   - O 2 to 4 science teachers
   - O 5 to 7 science teachers
   - O 8 to 10 science teachers
   - O 11 to 13 science teachers
   - O 14 or more science teachers

8. About how many Georgia Department of Education professional development sessions have you attended with the intent to prepare to implement the Science Georgia Standards of Excellence?



9. About how many Southwest RESA professional development sessions have you attended with the intent to prepare to implement the Science Georgia Standards of Excellence?

## ASKING QUESTIONS AND DEFINING PROBLEMS

A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed worlds work. A practice of engineering is to ask questions that clarify problems to determine criteria for successful solutions and identify constraints to solve problems about the designed world. Both scientist and engineers ask questions to clarify ideas.

11. Middle school science teachers are expected to design and deliver lessons that teach students to things like:
    - Ask questions that require sufficient and appropriate empirical evidence to answer.
    - Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.
    - Ask questions to identify and/or clarify evidence and/or the premise(s) of an argument.
    - Ask questions to determine relationships between independent and dependent variables and relationships in models.
    - Ask questions to clarify and/or refine a model, an explanation, or an engineering problem.
    - Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles.
    - Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions. Ask questions that challenge the premise(s) of an argument or the interpretation of a data set.

Please indicate your level of concern with regards to implementing the practices associated with asking questions and defining problem.

O Not at All Concerned
O Slightly Concerned
O Somewhat Concerned
O Extremely Concerned

## DEVELOPING AND USING MODELS

A practice of science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations. Modeling tools are used to develop questions, predictions, and explanations; analyze and identify flaws in the system; and communicate ideas. Models are used to build and revise scientific explanations and proposed engineered systems. Measurements and observations are used to revise models and designs.

12. Middle school science teachers are expected to design and deliver lessons that teach students to do things like:
    - Evaluate limitations of a model for a proposed object or tool.
    - Develop or modify a model—based on evidence – to match what happens if a variable or component of a system is changed.
    - Use and/or develop a model of simple systems with uncertain and less predictable factors.
    - Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena.
    - Develop and/or use a model to predict and/or describe phenomena.
    - Develop a model to describe unobservable mechanisms.
    - Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scale.

Please indicate your level of concern with regards to implementing the practices associated with developing and using models.

- O Not at All Concerned
- O Slightly Concerned
- O Somewhat Concerned
- O Extremely Concerned

**PLANNING AND CARRYING OUT INVESTIGATIONS**

A practice of science and engineering is to plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Investigations are systematic and require clarifying what counts as data and identifying variables or parameters.

13. Middle school science teachers are expected to design and deliver lessons that teach students to do things like:
    - Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.
    - Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation. Evaluate the accuracy of various methods for collecting data.
    - Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.
    - Collect data about the performance of a proposed object, tool, process, or system under a range of conditions.

Please indicate your level of concern with regards to implementing the practices associated with developing and using models.

O Not at All Concerned
O Slightly Concerned
O Somewhat Concerned
O Extremely Concerned

**ANALYZING AND INTERPRETING DATA**

Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools— including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis.

14. Middle school science teachers are expected to design and deliver lessons that teach students to do:
    - Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships.
    - Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships.
    - Distinguish between causal and correlational relationships in data.
    - Analyze and interpret data to provide evidence for phenomena.
    - Apply concepts of statistics and probability (including mean, median, mode, and variability) to analyze and characterize data, using digital tools when feasible. Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials).
    - Analyze and interpret data to determine similarities and differences in findings.
    - Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success.

Please indicate your level of concern with regards to implementing the practices associated with analyzing and interpreting data to students in your classes.

O Not at All Concerned
O Slightly Concerned
O Somewhat Concerned
O Extremely Concerned

**USING MATHEMATICAL AND COMPUTATIONAL THINKING**

A practice of science and engineering is to use mathematical and computational thinking to construct simulations, statistically analyze data, and recognize, express and apply quantitative relationships of physical variables. Scientists and engineers use mathematical and computational approaches to predict the behavior of systems and test the validity of such predictions.

15. Middle school science teachers are expected to design and deliver lessons that enable students to do:
    - Decide when to use qualitative vs. quantitative data. Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends.
    - Use mathematical representations to describe and/or support scientific conclusions and design solutions.
    - Create algorithms (a series of ordered steps) to solve a problem.
    - Apply mathematical concepts and/or processes (such as ratio, rate, percent, basic operations, and simple algebra) to scientific and engineering questions and problems.
    - Use digital tools and/or mathematical concepts and arguments to test and compare proposed solutions to an engineering design problem.

Please indicate your level of concern with regards to implementing the practices associated with using mathematical and computational thinking.

O Not at All Concerned
O Slightly Concerned
O Somewhat Concerned
O Extremely Concerned

**CONSTRUCTING EXPLANATIONS AND DESIGNING SOLUTIONS**

The end products of science are explanations; the end products of engineering are solutions. The goal of science is the construction of the theories that provide explanatory accounts of the world. A theory becomes accepted when it has multiple lines of empirical evidence and greater explanatory power of phenomena than previous theories. The goal of engineering design is to find a systematic solution to problems that is based on scientific knowledge and models of the material world. Each proposed solution results from a process of balancing competing criteria of desired functions, technically feasibility, cost, safety, aesthetics, and compliance with legal requirements. The optimal choice depends on how well the proposed solutions meet criteria and constraints.

16. Middle school science teachers are expected to design and deliver lessons that enable students to do:
    - Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena.
    - Construct an explanation using models or representations.
    - Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.
    - Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.
    - Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion.
    - Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system.
    - Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.
    - Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re-testing.

Please indicate your level of concern with regards to implementing the practices associated with using mathematical and computational thinking.

O Not at All Concerned
O Slightly Concerned
O Somewhat Concerned
O Extremely Concerned

**ENGAGING IN ARGUMENT WITH EVIDENCE**

Argumentation is the process by which explanations and solutions are reached. A practice of science and engineering is to use argumentation to listen to, compare, and evaluate competing ideas and methods based on merits. Scientists and engineers use reasoning and argument based on evidence to identify the best explanation for a natural phenomenon or the best solution to a design problem when investigating a phenomenon, testing a design solution, resolving questions about measurements, building data models, and using evidence to evaluate claims.

17. Middle school science teachers are expected to design and deliver lessons that enable students to do:
    - Compare and critique two arguments on the same topic and analyze whether they emphasize similar or different evidence and/or interpretations of facts.
    - Respectfully provide and receive critiques about one's explanations, procedures, models and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail.
    - Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.
    - Make an oral or written argument that supports or refutes the advertised performance of a device, process, or system, based on empirical evidence concerning whether or not the technology meets relevant criteria and constraints.
    - Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.

Please indicate your level of concern with regards to implementing the practices associated with engaging in argument.

- O Not at All Concerned
- O Slightly Concerned
- O Somewhat Concerned
- O Extremely Concerned

**OBTAINING, EVALUATING, AND COMMUNICATING INFORMATION**

Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity. Communicating information and ideas can be done in multiple ways: using tables, diagrams, graphs, models, and equations as well as orally, in writing, and through extended discussions. Scientists and engineers employ multiple sources to obtain information that is used to evaluate the merit and validity of claims, methods, and designs.

18. Middle school science teachers are expected to design and deliver lessons that enable students to do:
    - Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s).
    - Integrate qualitative and/or quantitative scientific and/or technical information in written text with that contained in media and visual displays to clarify claims and findings.
    - Gather, read, synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence.
    - Evaluate data, hypotheses, and/or conclusions in scientific and technical texts in light of competing information or accounts.
    - Communicate scientific and/or technical information (e.g. about a proposed object, tool, process, system) in writing and/or through oral presentation.

Please indicate your level of concern with regards to implementing the practices associated with obtaining, evaluating, and communicating information.

O Not at All Concerned
O Slightly Concerned
O Somewhat Concerned
O Extremely Concerned

| **ADMINISTRATIVE SUPPORT** | | | |
|---|---|---|---|
| 19. I am satisfied with the amount of support I receive to implement science and engineering practices. | | | |
| O Strongly Agree | O Agree | O Disagree | O Strongly Disagree |
| 20. I am satisfied with the amount of support I receive from my principal to implement science and engineering practices. | | | |
| O Strongly Agree | O Agree | O Disagree | O Strongly Disagree |
| 21. My principal has conversations with me about my delivery of science instruction related to science and engineering practices embedded in the Science Georgia Standards of Excellence. | | | |
| O Strongly Agree | O Agree | O Disagree | O Strongly Disagree |
| 22. My principal encourages the implementation of science and engineering practices. | | | |
| O Strongly Agree | O Agree | O Disagree | O Strongly Disagree |

| |
|---|
| 23. My principal enhances the science program at my school by providing me with the needed materials and equipment. |
| O Strongly Agree O Agree O Disagree O Strongly Disagree |
| 24. My principal provides time for science teachers in my school to meet and share ideas about implementing science and engineering practices with one another. |
| O Strongly Agree O Agree O Disagree O Strongly Disagree |

# APPENDIX D

# HIGH SCHOOL SCIENCE TEACHER SURVEY

| Science and Engineering Practices: High School Science Teachers' Task Concerns and Administrative Support Survey |
| --- |
| **INFORMED CONSENT INFORMATION** |

You are being asked to participate in a research project conducted by Shereca R. Harvey, a doctoral student in the College of Education and Health Professions at Columbus State University under the supervision of Dr. Pamela Lemoine, a faculty member.

VIII. Purpose: The purpose of this project is to investigate the differences between middle and high school science teachers task concerns regarding science and engineering practices (SEPs) and their perceptions of administrative support provided by principal during the implementation of Science Georgia Standard of Excellence.

IX. Procedures: If you agree to be in the study, you will complete a web-based survey or participate in focus group discussion. The web based survey consists of 24 items that assess the participant's level of concern associated with each of the eight SEPs, level of agreement with statements about administrative support provided by their principal, and demographic questions. The survey will require no more than 30 minutes to complete. Participants in the focus group will discuss the same topics in a 45 to 60-minute discussion with six to eight science teachers from southwest Georgia after school hours at a public library. The interview will be recorded using an electronic device to accurately capture what is said. After the interview, a transcript of the focus group interview will be emailed without identifying information for members to check for accuracy. The data collected will not be used for future projects.

X. Possible Risks or Discomforts: There are minimal risks when participating in the study. There is the potential loss of confidentiality, because the researcher cannot guarantee that participants will not share information discussed during the focus group. The researcher will take the following precautions to minimize the level of social risks by allowing participants to withdraw or limit their participation if they become uncomfortable, allowing participants to request that the audio recording be paused at any time there is a feeling of discomfort, asking participants to agree to the importance of keeping information discussed during the focus group confidential, reminding participants to respect the privacy of fellow participants, and instructing participants to use only first names during the focus group discussion

XI. Potential Benefits: Although there are no direct benefits to the participant for being in the study, there are potential benefits to science teachers and educators who support science teachers at the state, regional, district, and school levels.

XII. Costs and Compensation: Participants will not be compensated for responding to the web-based survey or participating in a focus group. Focus group participants will be expected to provide their own transportation to the focus group meeting.

XIII. Confidentiality: The researcher will ensure that participants' data remain confidential in the following manner: (1) storing confidential data in password-protected files, encrypted and password-protected databases (Survey Monkey), and in locked filing cabinets to limit access to the researcher only; (2) limiting the collection of information that can be used to identify a participant to the email and IP addresses; (3) removing e-mail and IP addresses from the raw data file before Statistical Package for the Social Sciences (SPSS) software analysis; (4) properly deleting, shredding, and disposing of all documents, reports, and electronic files with identifiable information five years after the completion of the study.



XIV. Withdrawal: Your participation in this research study is voluntary. You may withdraw from the study at any time, and your withdrawal will not involve penalty or loss of benefits.

| FOCUS GROUP PARTICIPATION |
| --- |
| 2. Would you like to participate in a focus group with six to eight high school science teachers who teach in southwest Georgia to discuss task related concerns and administrative support provided during the implementation of science and engineering practices in southwest Georgia? If you select “I would like to participate in a focus group.”, then click Next to submit your survey. You will not be allowed to answer questions 3 - 24 in the survey. * <br><br> ☐ I would like to participate in a focus group. <br> ☐ I do not wish to participate in a focus group. |
| **DEMOGRAPHICS: EXPERIENCE AND WORK ENVIRONMENT** |

3. What was your undergraduate major?
   - O Science
   - O Education
   - O Science Education
   - O Other

4. What was your graduate major?
   - O Science
   - O Education
   - O Science Education
   - O Other
   - O I do not hold a graduate degree

5. Please indicate the number of years you have been teaching.
   - O 0 to 4 years
   - O 5 to 9 years
   - O 10 to 14 years
   - O 15 to 19 years
   - O 20 to 24 years
   - O 25 – 29 years
   - O 30 or more years

6. Please indicate the number of years you have been teaching science.
   - O 0 to 4 years
   - O 5 to 9 years
   - O 10 to 14 years
   - O 15 to 19 years
   - O 20 to 24 years
   - O 25 – 29 years
   - O 30 or more years

7. Please indicate the number of science teachers in your school.
   - O 1; I am the only science teacher in my school
   - O 2 to 4 science teachers
   - O 5 to 7 science teachers
   - O 8 to 10 science teachers
   - O 11 to 13 science teachers
   - O 14 or more science teachers



8. About how many Georgia Department of Education professional development sessions have you attended with the intent to prepare to implement the Science Georgia Standards of Excellence?

## ASKING QUESTIONS AND DEFINING PROBLEMS

A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed worlds work. A practice of engineering is to ask questions that clarify problems to determine criteria for successful solutions and identify constraints to solve problems about the designed world. Both scientist and engineers ask questions to clarify ideas.

11. High school science teachers are expected to design and deliver lessons that teach students to things like:
    - Ask questions that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.
    - Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships.
    - Ask questions to determine relationships, including quantitative relationships, between independent and dependent variables.
    - Ask questions to clarify and refine a model, an explanation, or an engineering problem. Evaluate a question to determine if it is testable and relevant.
    - Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.
    - Ask and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of the design.
    - Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical and/or environmental considerations.
    - Analyze complex real-world problems by specifying criteria and constraints for successful solutions.

Please indicate your level of concern with regards to implementing the practices associated with asking questions and defining problem.

O Not at All Concerned
O Slightly Concerned
O Somewhat Concerned
O Extremely Concerned

## DEVELOPING AND USING MODELS

A practice of science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations. Modeling tools are used to develop questions, predictions, and explanations; analyze and identify flaws in the system; and communicate ideas. Models are used to build and revise scientific explanations and proposed engineered systems. Measurements and observations are used to revise models and designs.

12. High school science teachers are expected to design and deliver lessons that teach students to do things like:
    - Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism, or system in order to select or revise a model that best fits the evidence or design criteria.
    - Design a test of a model to ascertain its reliability.
    - Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.
    - Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations.
    - Use a model to provide mechanistic accounts of phenomena.
    - Develop a complex model that allows for manipulation and testing of a proposed process or system.
    - Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.

Please indicate your level of concern with regards to implementing the practices associated with developing and using models.

O Not at All Concerned
O Slightly Concerned
O Somewhat Concerned
O Extremely Concerned

**PLANNING AND CARRYING OUT INVESTIGATIONS**

A practice of science and engineering is to plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Investigations are systematic and require clarifying what counts as data and identifying variables or parameters.

13. High school science teachers are expected to design and deliver lessons that teach students to do things like:
    - Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism, or system in order to select or revise a model that best fits the evidence or design criteria.
    - Design a test of a model to ascertain its reliability.
    - Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.
    - Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations.
    - Use a model to provide mechanistic accounts of phenomena.
    - Develop a complex model that allows for manipulation and testing of a proposed process or system.
    - Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.

Please indicate your level of concern with regards to implementing the practices associated with developing and using models.

O Not at All Concerned
O Slightly Concerned
O Somewhat Concerned
O Extremely Concerned

**ANALYZING AND INTERPRETING DATA**

Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools— including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis.

14. High school science teachers are expected to design and deliver lessons that teach students to do:
    - Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.
    - Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.
    - Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data.
    - Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations.
    - Evaluate the impact of new data on a working explanation and/or model of a proposed process or system.
    - Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success.

Please indicate your level of concern with regards to implementing the practices associated with analyzing and interpreting data to students in your classes.

O Not at All Concerned
O Slightly Concerned
O Somewhat Concerned
O Extremely Concerned

**USING MATHEMATICAL AND COMPUTATIONAL THINKING**

A practice of science and engineering is to use mathematical and computational thinking to construct simulations, statistically analyze data, and recognize, express and apply quantitative relationships of physical variables. Scientists and engineers use mathematical and computational approaches to predict the behavior of systems and test the validity of such predictions.

15. High school science teachers are expected to design and deliver lessons that enable students to do:
    - Decide if qualitative or quantitative data are best to determine whether a proposed object or tool meets criteria for success.
    - Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.
    - Apply techniques of algebra and functions to represent and solve scientific and engineering problems.
    - Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model "makes sense" by comparing the outcomes with what is known about the real world.
    - Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.).

Please indicate your level of concern with regards to implementing the practices associated with using mathematical and computational thinking.

O Not at All Concerned
O Slightly Concerned
O Somewhat Concerned
O Extremely Concerned

**CONSTRUCTING EXPLANATIONS AND DESIGNING SOLUTIONS**

The end products of science are explanations; the end products of engineering are solutions. The goal of science is the construction of the theories that provide explanatory accounts of the world. A theory becomes accepted when it has multiple lines of empirical evidence and greater explanatory power of phenomena than previous theories. The goal of engineering design is to find a systematic solution to problems that is based on scientific knowledge and models of the material world. Each proposed solution results from a process of balancing competing criteria of desired functions, technically feasibility, cost, safety, aesthetics, and compliance with legal requirements. The optimal choice depends on how well the proposed solutions meet criteria and constraints.

16. High school science teachers are expected to design and deliver lessons that enable students to do:
    - Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.
    - Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.
    - Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.
    - Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.
    - Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

Please indicate your level of concern with regards to implementing the practices associated with using mathematical and computational thinking.

O Not at All Concerned
O Slightly Concerned
O Somewhat Concerned
O Extremely Concerned

**ENGAGING IN ARGUMENT WITH EVIDENCE**

Argumentation is the process by which explanations and solutions are reached. A practice of science and engineering is to use argumentation to listen to, compare, and evaluate competing ideas and methods based on merits. Scientists and engineers use reasoning and argument based on evidence to identify the best explanation for a natural phenomenon or the best solution to a design problem when investigating a phenomenon, testing a design solution, resolving questions about measurements, building data models, and using evidence to evaluate claims.

17. High school science teachers are expected to design and deliver lessons that enable students to do:
    - Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues.
    - Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
    - Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining what additional information is required to resolve contradictions.
    - Construct, use, and/or present an oral and written argument or counterarguments based on data and evidence.
    - Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student-generated evidence.
    - Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations).

Please indicate your level of concern with regards to implementing the practices associated with engaging in argument.

O Not at All Concerned
O Slightly Concerned
O Somewhat Concerned
O Extremely Concerned

**OBTAINING, EVALUATING, AND COMMUNICATING INFORMATION**

Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity. Communicating information and ideas can be done in multiple ways: using tables, diagrams, graphs, models, and equations as well as orally, in writing, and through extended discussions. Scientists and engineers employ multiple sources to obtain information that is used to evaluate the merit and validity of claims, methods, and designs.

18. High school science teachers are expected to design and deliver lessons that enable students to do:
    - Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
    - Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.
    - Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.
    - Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.
    - Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).

Please indicate your level of concern with regards to implementing the practices associated with obtaining, evaluating, and communicating information.

O Not at All Concerned
O Slightly Concerned
O Somewhat Concerned
O Extremely Concerned

**ADMINISTRATIVE SUPPORT**

19. I am satisfied with the amount of support I receive to implement science and engineering practices.

| | | | |
|---|---|---|---|
| O Strongly Agree | O Agree | O Disagree | O Strongly Disagree |

20. I am satisfied with the amount of support I receive from my principal to implement science and engineering practices.

| | | | |
|---|---|---|---|
| O Strongly Agree | O Agree | O Disagree | O Strongly Disagree |

| | | | |
|---|---|---|---|
| 21. My principal has conversations with me about my delivery of science instruction related to science and engineering practices embedded in the Science Georgia Standards of Excellence. | | | |
| O Strongly Agree | O Agree | O Disagree | O Strongly Disagree |
| 22. My principal encourages the implementation of science and engineering practices. | | | |
| O Strongly Agree | O Agree | O Disagree | O Strongly Disagree |
| 23. My principal enhances the science program at my school by providing me with the needed materials and equipment. | | | |
| O Strongly Agree | O Agree | O Disagree | O Strongly Disagree |
| 24. My principal provides time for science teachers in my school to meet and share ideas about implementing science and engineering practices with one another. | | | |
| O Strongly Agree | O Agree | O Disagree | O Strongly Disagree |

# APPENDIX E

# FOCUS GROUP PROTOCOL

FOCUS GROUP PROTOCOL

Dissertation Topic: Science Georgia Standards of Excellence: A Mixed Method Study of Science Teachers' Perceptions of Science and Engineering Practices Administrative Support

A. Welcome Participants
    a. Test audio recording
    b. Introductions with first name only

B. Purpose
    a. *The purpose of this study is to investigate the perceptions middle and high school science teachers have regarding the science and engineering practices (SEPs) and administrative support provided by principal during the implementation of Science Georgia Standard of Excellence.*
    b. You were asked to come because…

C. Review Informed Consent Form and Guidelines
    a. Procedures
    b. Privacy
    c. Confidentiality
        i. Use first names only
        ii. Discussion will be transcribed without names.
    d. Withdrawal
    e. Audio Recording Guidelines
        i. One person speaks at a time
        ii. Participants may request that the audio recording be paused if there are interruptions or feelings of discomfort.

D. Open-Ended Questions
    1. For each of the eight science and engineering practices, the researcher will ask the following questions. The science and engineering practices are:
        - Asking Questions and Defining Problems
        - Developing and Using Models
        - Planning and Carrying Out Investigations
        - Analyzing and Interpreting Data
        - Using Mathematics and Computational Thinking
        - Constructing Explanations and Designing Solutions

- Engaging in Argument from Evidence
- Obtaining, Evaluating, and Communicating Information

Take a moment to review the performance expectations that middle school/high school science teachers do to incorporate [insert name of SEP from above].

a. What are your feelings about the tasks?
b. How well do you feel you are implementing the practice?
c. How has professional learning impacted the implementation of SEPs?
d. Tell me about any concerns you have about implementing the practice.

2. On the topic of administrative support, the researcher will ask the following questions.
    a. Tell me about the type of support you receive to ensure you are implementing the science and engineering practices.
    b. How is your principal supporting you during the implementation of the Science Georgia Standards of Excellence?
    c. How is your principal supporting you with the science and engineering practices?

3. Closing Question
    a. Is there anything else you would like to say about your concerns and the support you receive from your principals during the implementation of Science Georgia Standards of Excellence regarding the science and engineering practices?

E. Thank Participants

F. Adjourn