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A CASE STUDY OF SCIENCE TEACHERS' PERCEPTIONS OF SELF-EFFICACY IN TEACHING THE SCIENCE AND ENGINEERING PRACTICES

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By

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A CASE STUDY OF SCIENCE TEACHERS' PERCEPTIONS OF SELF-EFFICACY IN TEACHING THE SCIENCE AND ENGINEERING PRACTICES

by

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DEDICATION

I dedicate this dissertation to God. I know that I could not have completed this dissertation without God guiding my every step. I owe everything that I am and everything that I will become to Him. I pray that this dissertation will bring glory and honor to God as it impacts those who labor alongside me in the field of education.

Thank you, Mom and Dad. Your love and support provided the foundation that allowed me to dream big dreams. You helped me develop the boldness I needed to follow my dreams and instilled within me the work ethic to complete this dissertation. I know you are looking down on me from Heaven with love and pride. I did it, Mom and Dad! I became a doctor! I cannot wait to see you and Gene again someday. I love you, and I miss you dearly.

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ABSTRACT

This case study examined South Carolina public school science teachers' perceptions of self-efficacy related to planning and executing STEM-centric lessons. The adoption of the *South Carolina Academic Standards and Performance Indicators for Science* in 2014 required science teachers to make substantial pedagogical shifts in their instructional practices, which influenced their self-efficacy. The standards included science and engineering practices (SEPs) embedded in the standards. Understanding how science teachers' perceptions of self-efficacy influence their instructional competence for planning and executing SEP-integrated lessons might guide schools and districts to create focused instructional support for the teachers designed to meet their unique pedagogical needs. An examination of 10 South Carolina teachers' lived experiences and their STEM-centric lesson plans provided insights into what type of professional development they needed to make the necessary pedagogical shifts to integrate the SEPs successfully. The insights gained from the teachers' interview and lesson plan data revealed that they preferred one-on-one mentoring from expert-teachers who model SEP integration. The findings from this study may be valuable for school and district level educators as they explore alternative professional development options for science teachers. The information may also expand the types of professional development offered by the South Carolina Department of Education.

Key Words: self-efficacy, South Carolina Academic Standards and Performance Indicators for Science, science and engineering practices, science teachers, STEM-centric lessons, pedagogical shifts, instructional competence, alternative professional development, mentoring

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I. INTRODUCTION

In 2012, the National Research Council developed *A Framework for K-12 Science Education* (*Framework*) outlining the specific science concepts students need to learn before graduating high school to be successful in college or career fields. Historically, science content standards focused on factual content rather than using an inquiry approach that allows students to develop a deeper, more sophisticated understanding of science concepts. The *Framework* recognized the problem and called for science education standards designed to engage students in three dimensions of learning: disciplinary core ideas, science and engineering practices, and crosscutting concepts. The three dimensions of learning encompass the scientific concepts that are important to the disciplines of science, the behaviors and skills scientists engage in as they practice their scientific discipline, and the concepts that unify the disciplines (NRC, 2013). The *Framework* purposefully identified fewer disciplinary core ideas that all students should learn in depth in contrast to the previous standards that were broad and shallow (NRC, 2013).

The development of the *Framework* gave rise to the Next Generation Science Standards (NGSS), which were released in April 2013 (NRC, 2013). Many states adopted the NGSS either in their original form or a new iteration based upon the unique needs of the state (NGSS, 2019; NRC, 2012). The development of the NGSS provided states with standards that were "rich in content and practice and arranged in a coherent manner across disciplines and grades to provide all students an internationally-benchmarked science education" (NGSS, 2019, para. 2). The NGSS standards and state iterations of the standards were explicitly designed to allow students to learn disciplinary core ideas through the science and engineering practices (NRC, 2013).

In 2013, a committee of educators and policymakers from South Carolina began a comprehensive revision of the *South Carolina Academic Standards and Performance Indicators for Science 2005* (Zais, 2014). The committee intended to update the state science content standards to reflect national trends and to enhance the rigor of the standards. The outcome of the committee's year-long efforts resulted in the creation and subsequent adoption of the *South Carolina Academic Standards and Performance Indicators for Science 2014*, which included the science and engineering practices (SEPs) embedded in the standards (South Carolina Department of Education, 2014).

The new science standards were introduced to teachers and students during the 2015-2016 school year. The South Carolina Department of Education (SCDE) offered science teachers formal professional development courses designed to increase teachers' abilities to implement the new standards and SEPs (South Carolina Department of Education, 2019). Even though the new science standards have been in effect for five years, many science teachers still express concern and frustration related to implementing the SEPs in their daily science lessons. Therefore, science teachers' self-efficacy in planning and teaching the *South Carolina Academic Standards and Performance Indicators for Science* 2014 and specifically the SEPs should be analyzed, and the successes and challenges related to effectively implementing the SEPs must be identified. Subsequently, the SCDE and school districts can work toward offering more SEP-focused instructional support for science teachers.

Background of the Study

Many states adopted new science content standards designed to better prepare K-12 students for college and careers, providing a more rigorous education. New science standards, such as the Next Generation Science Standards (NGSS) and state iterations of these standards, include a new component called the science and engineering practices (SEPs). The inclusion of the SEPs in science content standards required science teachers to make major pedagogical shifts in teaching the standards and integrating the practices (Bowers & Ernst, 2018). Consequently, many teachers have had to deal with changes in their perceptions of self-efficacy, to develop new methods to engage students in the revised standards, and to refine their craft based upon the successes and challenges inherent in implementing the (Bybee, 2014).

Self-efficacy

According to Bandura (1977b), self-efficacy is an individual's perceptions of competence in a specific area. Teachers' self-efficacy would be their perception of their instructional competence. Historically, science teachers taught broad science standards that focused primarily on knowledge outcomes. The recently adopted science content standards place "a new emphasis on science and engineering practices (SEPs). These practices are both knowledge outcomes and cognitive abilities for students" (Bybee, 2014, p. 219). This pedagogical shift requires science teachers to provide students in-depth learning experiences using the SEPs (Bowers & Ernst, 2018). The new standards also call for science teachers to possess the ability to teach the revised standards using scientific inquiry, engineering design methods, and "new and unique methods, such as modeling or using evidence as the basis for arguments" (Bybee, 2014, p. 220). The fundamental competencies needed to be a successful science teacher have changed, and many teachers may experience a lower sense of self-efficacy.

A need to examine science teachers' perceptions of self-efficacy as related to executing STEM-centric lessons exists at all levels of experience.

Other researchers have built upon Bandura's theory of self-efficacy. According to Tschannen-Moran and Hoy's (2007) research on teacher self-efficacy, a teacher's self-efficacy beliefs are "most in flux early in learning and tend to become fairly stable and resistant to change once set" (p. 953). The researchers also found that novice teachers were more likely to base their self-efficacy on the approval of "administrators, colleagues, parents, and members of the community" (Tschannen-Moran & Hoy, 2007, p. 954). Whereas, veteran teachers have a higher perception of self-efficacy compared to novice teachers. Tschannen-Moran and Hoy (2007) found, "experienced teachers have apparently adapted to the typical isolation of their work lives and have learned to base their efficacy judgments on other sources" (p. 954). Guskey's (2002) research provides clarity to Tschannen-Moran and Hoy's reference to "other sources" of teacher self-efficacy by describing them as student achievement and engagement.

Engaging Students

Engaging students in sustained scientific inquiry is a crucial aspect of any science lesson. Teachers who create science lessons using the SEPs provide engaging, relevant learning experiences for their students. For example, Tomas, Jackson, and Carlisle (2014) found that when teachers shifted from traditional teaching methods to implementing design challenges for their daily science lessons, student engagement increased markedly. Compared to design challenges, the researchers found that traditional teaching methods do not always challenge students to engage in problem-solving or to use higher-order thinking (Tomas et al., 2014). Engaging students in the SEPs is also an ideal way to teach students how to apply the skills of scientists and engineers to solve real-world problems (Sias, Nadelson, Juth, & Seifert, 2017).

When students work to solve real-world problems and design solutions, their motivation and engagement in the learning experience increases (Sias et al., 2017). Providing students with opportunities to grapple with solving complex problems also allows students to learn at a deeper level (Tomas et al., 2014). By allowing students to direct their learning and providing them with opportunities to discuss the outcomes of their challenges, students learn more than a single teacher could teach alone (Tomas et al., 2014). In other words, opportunities for student-centered STEM design challenges and collaboration afford students a deeper level of cognitive learning and create engaging learning experiences for all students (Tomas et al., 2014).

Using STEM design challenges also allows teachers to differentiate the learning experience for students of various ability levels. Students who need more direction and guidance can work closely with teachers, and advanced students can pursue the design challenges using an open inquiry process with less teacher guidance (Tomas et al., 2014).

Design challenges can also hold transformative power for students and teachers. Students in Tomas, Jackson, and Carlisle's (2014) study self-reported more positive attitudes toward science and an increased understanding of scientific concepts. Teachers in the study also reported a shift in their pedagogical mindset and increased perceptions of self-efficacy in teaching science and the SEPs.

Opportunities

STEM-centric lessons that implement the SEPs create opportunities for students and teachers to experience transformative learning. Researchers Lesseig, Nelson, Slavit, and Seidel (2016) point out the benefits of transformational STEM-centric learning opportunities such as Problem Based Learning (PBL) and STEM design challenges. PBL lessons and design challenges are primarily student-driven, allowing students to "recognize their roles as active members, contributors to, and possible change agents in their communities" (Lesseig et al., 2016, p. 178).

Lesseig et al. (2016) conducted a case study of middle school teachers and low socio-economic students using STEM-centric PBL design challenges. According to the study results, teachers found value in using PBLs as they noted increases in students' ability to implement STEM practices. Students also willingly engaged in the SEPs with limited prompting and were "motivated and empowered by the complex, open-ended design challenges" (Lesseig et al., 2016, p. 181). Students of all ability levels also were observed being engaged in "collaboration, creativity, communication, responsibility, research, and critical thinking" (Lesseig et al., 2016, p. 181). Overall, teachers found PBL design challenges worthwhile because students engaged and persevered through each design challenge to reach successful outcomes.

Another opportunity teachers experience in implementing the SEPs is planning design challenges with fellow teachers. Lesseig et al. (2016) found that teachers' perceptions of self-efficacy increased related to the new pedagogical approaches they used during the study. The new sense of an increased ability to plan and implement design challenges due to the collaborative process of developing and implementing PBL activities empowered the teachers. The teachers discovered that collegial collaboration was vital to the success of each design challenge (Lesseig et al., 2016). However, study participants pointed out that the typical isolation that content area teachers experience in public schools is not always conducive to interdisciplinary work (Lesseig et al., 2016).

Challenges

Several challenges may play a role in limiting the implementation of the SEPs in K-12 education. According to Bybee (2011), "substantial barriers exist for the realization of the

[SEPs] in national and state education policies, school programs, and classroom practices" (p. 26). These challenges exist "in the form of federal laws, state standards and assessments, teachers' conceptual understanding and personal beliefs, instructional strategies, budget priorities, parental concerns, college and university teacher preparation programs, [and] teacher unions" (Bybee, 2011, p. 26). The introduction of new innovative programs is often grant-funded. Unfortunately, when grant funding ends, school districts do not always have the resources to sustain the programs, and teachers "become frustrated and demotivated" (Filippi & Agarwal, 2017, p. 266) to continue with the innovative programs. Their frustration leads them to return to traditional teaching methodologies that are less beneficial to students rather than embracing the pedagogical shifts required of STEM-centric lessons incorporating the SEPs (Filippi & Agarwal, 2017).

When teachers implement inquiry-based lessons that incorporate the SEPs, they must embrace a pedagogical shift in their teaching methods as their students struggle, fail, and steer design challenges in unanticipated directions. Giving students the freedom to grapple with the PBLs and make meaning from their mistakes and successes without the teacher guiding students step-by-step toward the correct solutions or answers can be challenging for some teachers (Lesseig et al., 2016). Another challenge teachers must deal with is determining the degree to which they should help struggling students. Many teachers do not know how much support and scaffolding students needed to reach the desired outcomes of design challenges.

Teachers also find the nonalignment of design challenges with mandated state content standards to be problematic (Lesseig et al., 2016). Additional challenges related to state content standards and some school district course scope and sequence timelines, compounded by the limited time available for extended inquiry due to class schedules, limit how much students can accomplish in one class setting (Lesseig et al., 2016).

The educational infrastructure that exists within the state may also impede SEPs implementation (Bybee, 2011). An example of an infrastructure barrier is the financial situation of any given school district. Limited funds result in inadequate resources for school science budgets (Bybee, 2011). Science teachers may not receive adequate training or may not have sufficient equipment and materials (Bybee, 2011). Such an unfortunate situation does not support the significant instructional changes in curriculum and instruction required by the SEPs (Bybee, 2011).

According to Filippi and Agarwal (2017), many teachers of all levels of experience have to work additional jobs to earn secondary sources of income "rather than focusing on their professional development as a teacher" (p. 266). The limited time available to teachers who work second jobs may lead to a lack of interest in making the major pedagogical shifts needed to implement the SEPs despite the benefits related to student achievement (Filippi & Agarwal, 2017).

Conclusion

Based on a review of the literature, a clear need exists to examine science teachers' perceptions of self-efficacy as related to planning and executing science technology engineering and mathematics lessons. The 2014 science standards contain the SEPs and require a radical change from how science instruction was delivered to students over the past several decades. All K-12 science teachers must ensure they implement the SEPs with fidelity. An evaluation of science teachers serving in public schools is needed to assess the degree of SEPs implementation and to illuminate the next steps necessary to move teachers to higher levels of self-efficacy that will ultimately benefit all students' future success.

Conceptual Framework

The theoretical underpinnings of this study relate to Dewey's social constructivist theory in which learners must construct meaning rather than passively receive new learning (Dewey, 1916). Building upon Dewey's work, Albert Bandura developed the social learning theory, which includes three essential constructs: observational learning, self-regulation, and self-efficacy (Bandura, 1977b). The leading theory governing this study was Bandura's social learning theory with a focus on the self-efficacy aspects of the theory as it applied to teachers' perceptions of how well they engage students in authentic learning experiences with the SEPs. According to Bandura (1982), self-efficacy includes four areas: performance attainments, vicarious experiences, verbal persuasion, and physiological states. As such, teachers' perceptions of self-efficacy can be positively and negatively impacted by a variety of experiences and feelings, which in turn affect their effectiveness in planning and executing science, technology, engineering, and mathematics (STEM) focused or STEM-centric lessons.

Significance of the Study

The *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs required a significant pedagogical shift from the 2005 science content standards. The 2005 science standards did not include any embedded SEPs, and the standards limited student interactions with science content to the lower levels of Bloom's Taxonomy (South Carolina Department of Education, 2005). The need to assess current science teachers' perceptions of self-efficacy in planning and teaching the SEPs as well as identifying the opportunities and challenges related to implementing the SEPs in their daily lessons was paramount. Gathering data in these areas and analyzing it provided insights into the next steps the South Carolina Department of Education and school districts might take as they create future professional development training and state educational policies.

To date, no formal review of South Carolina science teachers' perceptions of self-efficacy in implementing the SEPs exists. Therefore, this study provided a window of insight into the state of science standards and SEPs implementation in South Carolina and added to the existing body of knowledge related to science teaching in an era of standards reform.

Purpose Statement

The purpose of this case study was to examine science teachers' perceptions of self-efficacy as related to planning and executing STEM-centric lessons. For the purpose of this study, science teacher self-efficacy was generally defined as a teacher's perception of how well they engage students in authentic learning experiences with the SEPs.

Overview of Methodology

The study used a qualitative case study methodology (Creswell, 2013; Yin, 2009). The case study generated data regarding science teachers' perceptions of self-efficacy, student engagement, and the opportunities and challenges associated with implementing the SEPs. Interview questions and lesson plan analysis were used to gather the data. The study also highlighted the substantial pedagogical shift a science teacher must undergo to teach the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs, which require lesson plans designed to engage students and take them into deeper levels of knowledge and understanding.

Research Design

The case study participants were science teachers who teach K-12 science in public schools in South Carolina. To protect the confidentiality of the study's participants, pseudonyms were used. An interview elucidated the science teachers' perceptions of self-efficacy and provided insight into the opportunities and challenges they encounter as they plan lessons to engage students in the SEPs (Creswell, 2013; Yin, 2009). Lesson plans were collected to provide evidence of SEPs planning and intended classroom implementation, which strengthened the construct validity of the study (Yin, 2009). The lesson plans served as physical artifacts and were analyzed using the Educators Evaluating the Quality of Instructional Products Rubric-Version 3.0 (EQuIP Rubric 3.0; NSTA, 2016; Yin, 2009).

Research Questions

The research questions for this case study focused on the analysis of (a) the science teachers' self-efficacy in teaching the SEPs, (b) their ability to engage students in lessons that integrate the SEPs, and (c) the opportunities and challenges that impact the implementation of the SEPs. The following research questions were addressed in this case study:

1. How does science teachers' self-efficacy influence their teaching of the 2014 science standards and SEPs?
2. How do teachers engage students in the SEPs?
3. What are the opportunities and challenges teachers experience when implementing the SEPs?

Data Collection

A purposive sampling technique was used for this case study as the participants are known to be middle, elementary, and high school science teachers working in public schools in

South Carolina. The teachers' willingness to participate in the case study provided insightful data related to the research questions (Gay, Mills, & Airasian, 2012; Yin, 2009). Data were collected through an interview and an examination of teacher-created lesson plans (Appendices B and C).

The interview questions focused on three areas of teacher self-efficacy: content knowledge, instructional planning, and the successes and challenges they have experienced (Appendix B). As needed, additional questions were asked to delve deeper into the teachers' thinking and to provide clarity to their responses.

The lesson plans analyzed in this case study consisted of four teacher-created STEM-centric lesson plans from teachers. Each lesson plan was examined using the EQuIP Rubric 3.0 (Appendix C). The EQuIP Rubric 3.0, developed by the educational reform organization Achieve, is designed to measure the alignment and quality of science instructional units as related to the implementation of the Next Generation Science Standards (NGSS) and performance expectations outlined in the *Framework* (NRC, 2012; NSTA, 2016). Since the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs are a state-developed iteration of the *Framework*, the EQuIP Rubric 3.0 proved to be a useful tool to analyze the teachers' lesson plans as it was aligned to the SEPs.

Procedures

The first data source for this case study was a focused interview. The second data source was the examination of four lesson plans from each teacher. A holistic analysis of the data was conducted to thoroughly examine the construct of self-efficacy (Creswell, 2013; Yin, 2009).

The interviews were recorded and transcribed verbatim with the teachers' permission, and the transcripts were shared with each respective teacher to ensure accuracy. Allowing the participants to review the transcripts of their interviews provided validity for the data collected and construct validity for the case study (Creswell, 2013; Rubin & Rubin, 2012; Yin, 2009). The interview data were analyzed for noteworthy statements and significant themes related to self-efficacy, student engagement, and the opportunities and challenges experienced in implementing the SEPs.

The lesson plan documents served as physical artifacts relevant to the case study (Yin, 2009). The lesson plans were analyzed using the EQuIP Rubric 3.0, which provided insights into how the teachers plan to implement the SEPs in their STEM-centric lessons. The EQuIP Rubric 3.0 results were analyzed to determine the degree of integration of the SEPs in the teachers' daily lessons and provided insights into the opportunities and challenges the teachers face in implementing the SEPs with fidelity. The results were analyzed for significant themes related to the research questions.

Limitations

Limitations exist in all case study research. In this case study, ten K-12 teachers agreed to participate. Having a small number of participants creates a dilemma wherein the study's conclusions may not be generalizable to a larger population of educators (Yin, 2009). Also, six of the participants were females and two were males. While having a majority of female participants in the study is indicative of the teacher workforce across the nation, having only two male participants limits the ability to generalize study findings and conclusions to male science teachers in general. However, the results that emerged from the study were analytically generalizable to larger populations of K-12 science educators. According to Yin (2009), in case study research, "the mode of generalization is *analytic* [emphasis in original] generalization, in which a previously developed theory is used as a template with which to compare the empirical results of the case study" (p. 38).

In support of using a small number of participants, Creswell (2013) suggests using "no more than four or five case studies in a single study" (p. 157). The teachers in this case study represent five different school districts in South Carolina, which aligns with Creswell's (2013) suggested limit for case study research. Yin (2009) also provides an additional rationale for using fewer participants as they are representative of the "circumstances and conditions of an everyday or commonplace situation" (p. 48). The ten teachers participating in the case study are representative of K-12 science teachers in South Carolina from eight different schools in five different school districts, and all of them teach the SEPs relevant to their specific grade level. Therefore, the ten teachers had daily experiences typical of many other K-12 science teachers in South Carolina. The data gleaned from the ten teachers in the study provided insights related to the experiences of an average K-12 science teacher in South Carolina teaching the *South Carolina Academic Standards and Performance Indicators for Science* 2014 and SEPs (Yin, 2009). The smaller sample size of ten science teachers also allowed for better identification of themes and cross-case thematic analysis of each teacher's data, which provided greater detail in the case study (Creswell, 2013).

Another limitation of the study was questionable data. Questionable data may result from the self-reported nature of the focused interview. The interview protocol was designed to allow the participants to speak about their experiences as science teachers who are charged with implementing the 2014 science standards in South Carolina. The teachers participating in this study are credentialed K-8 science teachers who were knowledgeable about the required pedagogical shifts needed to teach the SEPs, which reduced the likelihood of questionable data.

The interview questions were designed to avoid formalistic replies or the perception of blaming the teachers for imperfect implementation of the standards. Interview questions, which were designed to overlap, facilitated a comparison of answers to detect inconsistencies in responses (Rubin & Rubin, 2012). When inconsistencies surfaced, additional probing questions were used to elucidate participants' actual beliefs. The lesson plan analysis provided additional information to corroborate participants' answers.

A final limitation of the study relates to the researcher and the participants. The researcher knows the participants and is currently serving as a middle school science teacher in a public school. Being familiar with the experiences and professional demands required of a science teacher implementing the SEPs equipped the researcher to ask informed follow-up questions as necessary during the interview process; asking appropriate follow-up questions resulted in rich data. However, out of an abundance of caution, the researcher used bracketing to set aside any experiences that might have introduced bias into the data interpretation and analysis (Creswell, 2013).

Definition of Key Terms

- Content Standards: A description of learning outcomes described as knowledge and abilities for a subject area (Bybee, 2011, p. 21).
- Science and Engineering Practices (SEPs): The eight practices of science and engineering identified by the *Framework* as crucial for all students to learn in grades K-12. The SEPs are listed below:
    - Asking questions (science) and defining problems (engineering)
    - Developing and using models
    - Planning and carrying out investigations

    - Analyzing and interpreting data
    - Using mathematics and computational thinking
    - Constructing explanations (for science) and designing solutions (for engineering)
    - Engaging in argument from evidence
    - Obtaining, evaluating, and communicating information (NRC, 2013; Zais, 2014)
- Teacher Self-Efficacy: Teacher self-efficacy is the perception a teacher has about his or her instructional competence (Bandura, 1977a; Tschannen-Moran & Hoy, 2007).
- Challenges: For the purposes of this study, challenges will be defined as limitations in science education that restrict a teacher from implementing one or more of the SEPs with fidelity.
- Opportunities: For the purposes of this study, an opportunity in science education is something that increases teacher pedagogical knowledge and increases student engagement; such opportunities facilitate deeper cognitive learning.
- STEM-Centric Lessons: STEM-Centric lessons are academic lessons that incorporate science, technology, engineering, and mathematics components (Bowers & Ernst, 2018).
- Design Challenges: Design challenges are academic lessons that incorporate science, technology, engineering, and mathematics components with a specific focus on the science and engineering practices (Lesseig et al., 2016; Tomas et al., 2014).
- Problem Based Learning (PBL): Problem based learning is a student-centered, experiential learning method where students work in groups to investigate and develop solutions to real-world problems while the teacher facilitates students' learning (Hmelo-Silver, 2004).
- Transformative Learning: Transformative learning occurs when teachers change their pedagogical models of how to teach science from a traditional, teacher-centered method to

one that is inquiry-based allowing students to “recognize their roles as active members, contributors to, and possible change agents in their communities” (Lesseig et al., 2016, p. 178).

- Next Generation Science Standards (NGSS): The Next Generation Science Standards “integrate engineering design into the structure of science education by raising engineering design to the same level as scientific inquiry when teaching science disciplines at all levels, from kindergarten to grade 12” (NRC, 2013, p. 103).
- EQuIP Rubric: The Educators Evaluating the Quality of Instructional Products (EQuIP) Rubric for science provides criteria to assist educators and evaluators to objectively ascertain the degree “to which lessons and units are designed for the NGSS” (NSTA, 2016, para.1).

Summary

This qualitative case study was designed to analyze science teachers’ self-efficacy in planning and implementing STEM-centric lessons as well as to analyze the opportunities and challenges related to implementing the SEPs. Currently, no such analysis exists for the *South Carolina Academic Standards and Performance Indicators for Science 2014* or the state of South Carolina. Therefore, the case study created a body of knowledge that, though specific to South Carolina, future researchers can build upon in any states that have adopted similar iterations of the SEPs. The case study also added to the existing body of knowledge related to science instructional practices, science teachers’ perceptions of self-efficacy, STEM-centric lesson planning, and the challenges and opportunities shared by teachers implementing the SEPs.

II. REVIEW OF LITERATURE

The purpose of this case study was to examine science teachers' perceptions of self-efficacy as related to planning and executing STEM-centric lessons. The objective of Chapter II is to provide a comprehensive review of the literature related to: (a) teachers' perceptions of self-efficacy (b) the pedagogical shifts teachers must embrace to plan engaging SEP-integrated lessons, (c) the successes teachers have had integrating the SEPs into daily lessons, and (d) the challenges teachers encountered when striving to integrate the SEPS into their science lessons with fidelity. The present study explored the research topic through the lens of Alfred Bandura's (1977) social learning theory and the conceptual framework of self-efficacy.

In recent years, K-12 science standards have undergone significant revisions both nationally and at the state level (NRC, 2012, 2013; Zais, 2014). The pedagogical shifts necessitated by the revised standards have primarily been born by teacher preparation programs and in-service teachers (Wendt, Isbell, Fidan, & Pittman, 2015). The responsibility of training in-service teachers in the new pedagogical practices required to teach the revised science standards falls squarely on state departments of education, school districts, and teachers (Bybee, 2011; South Carolina Department of Education, 2019). Science teachers generally want to support their students' learning and work hard to plan learning experiences that help students reach their full potential. Studying science teachers' perceptions of self-efficacy in teaching the revised science standards in the era of standards reform is a critical step necessary to understand how well the standards are being implemented (Bowers & Ernst, 2018; Bybee, 2014; Wendt et al., 2015).

According to Bandura (1997), self-efficacy is a belief in "one's capabilities to organize and execute the courses of action required to produce given attainments" (p. 3). When confronted with challenges, such as implementing rigorous science standards, efficacious people look for opportunities to succeed despite institutional or environmental limits (Bandura, 1997). Individuals with strong beliefs about their ability to overcome challenging tasks also increase their willingness to engage in difficult tasks, to set challenging goals, to increase effort when facing failure, and to engage in strategic thinking, all of which enhance their performance and create opportunities for new skill development. However, individuals with low or diminished efficacy are discouraged by challenging tasks, lack intrinsic motivation, dwell on their deficiencies, and show limited perseverance to achieving success (Bandura, 1997; Hammack & Ivey, 2017).

This chapter examines the literature regarding science teachers' perceptions of self-efficacy in planning and executing STEM-centric lessons using the lens of Alfred Bandura's (1977b) social learning theory and the conceptual framework of self-efficacy. The development of *A Framework for K-12 Science Education* (the *Framework*; NRC, 2012) and adoption of the *South Carolina Academic Standards and Performance Indicators for Science 2014* (Zais, 2014) by the South Carolina Department of Education compelled K-12 public school teachers to make major pedagogical shifts in how they teach science (Bowers & Ernst, 2018; Bybee, 2014; Zais, 2014). An evaluation of science teachers' self-efficacy in planning and teaching the *South Carolina Academic Standards and Performance Indicators for Science 2014* (Zais, 2014) provided insight into how well teachers implement all aspects of the standards.

Self-efficacy

Bandura (1997) believed perceptions of self-efficacy are derived from several factors: (a) enactive mastery experiences, (b) vicarious experiences, (c) verbal persuasion, (d) physiological and affective states, and (e) the integration of efficacy information, which impact teachers' perceptions of self-efficacy. Mastery experiences provide evidence that individuals can succeed in the face of a variety of tasks and challenging situations (Bandura, 1997). These experiences can enhance or undermine perceptions of self-efficacy depending on how well teachers perform in various situations (Bandura, 1997; Hammack & Ivey, 2017). In the era of science standards reform along with the requirement to integrate the SEPs in daily science lessons, science teachers' perceptions of self-efficacy and the impact their self-efficacy beliefs may have on their instructional competence should be studied (Bandura, 1997; Hammack & Ivey, 2017; Hodges, Gale, & Meng, 2016; Rich, Jones, Belikov, Yoshikawa, & Perkins, 2017).

Bandura (1997) highlighted the importance of teachers' perceptions of self-efficacy when he stated, "Teacher efficacy in science education is of particular concern, given the increasing importance of scientific literacy and competency in the technological transformations occurring in society" (p. 242). Bandura also suggested that studying teacher self-efficacy provides a better understanding of the complex nature of self-efficacy because "teachers' perceived efficacy rests on much more than the ability to transmit subject matter" (Bandura, 1997, p. 243).

Hammack and Ivey (2017) investigated teachers' perceptions of self-efficacy for teaching engineering and engineering design to their students in a mixed-methods study that explored correlations between teachers' self-efficacy and their understanding of the design, engineering, and technology aspects of the science and engineering practices. The sample population included 542 kindergarten through fifth-grade public school teachers representative of teachers in

Oklahoma. Data were collected using the Engineering Design Self-Efficacy Instrument, the Teaching Engineering Self-Efficacy Scale, and the Design, Engineering, and Technology Survey. The Engineering Design Self-Efficacy Instrument consisted of nine questions on an 11-point Likert scale, and the Teaching Engineering Self-Efficacy Scale included 23 items on a 6-point Likert scale. Cronbach's alpha values for the Engineering Design Self-Efficacy Instrument engineering design subscale ($\alpha = .97$) and the Teaching Engineering Self-Efficacy Scale pedagogical content knowledge subscale ($\alpha = .96$) indicated internal consistency for the subscales (Hammack & Ivey, 2017).

Teachers' responses to the Engineering Design Self-Efficacy Instrument engineering design subscale revealed that 75% of the respondents felt low self-efficacy for engineering design ($M = 31.97$; $SD = 28.49$) and the engineering design process ($M = 39.80$; $SD = 27.43$; Hammack & Ivey, 2017). Responses to the Teaching Engineering Self-Efficacy Scale pedagogical content knowledge subscale indicated that less than 5% felt a strong sense of self-efficacy in teaching engineering (Hammack & Ivey, 2017). The study results suggested that teachers felt a negative sense of self-efficacy related to being able to teach engineering and engineering design successfully. Based on an analysis of the results, the researchers recommended that teachers and preservice teachers need professional development and collegiate courses designed to provide mastery experiences. Providing teachers with mastery experiences should help them increase their perceptions of self-efficacy in teaching engineering and engineering design to their students (Hammack & Ivey, 2017). Providing teachers and preservice teachers with adequate training may increase their self-efficacy and improve their instructional competence simultaneously.

A critical feminist study of preservice teachers conducted by Wendt, Isbell, Fidan, and Pitman (2015) highlighted the essential relationship between providing professional development training and an increase in teachers' self-efficacy and instructional competence. In their study, Wendt et al. created vicarious experiences for elementary teacher candidates by having a researcher model how to teach lessons from the engineering design challenge unit. The teacher candidates engaged in mastery experiences when they used the model lessons to plan and execute an engineering unit to their students. Wendt et al. collected data through interviews before and after the teacher candidates participated in professional development training. Data were also collected during classroom observations when the teacher candidates taught the engineering design challenge unit to their students. After the study concluded, Wendt et al. (2015) found that the teacher candidates reported an increase in their perceptions of self-efficacy when they engaged in "modeling, practice, and first-hand experience" (p. 9), which also led to an increase in their perceptions of instructional competence.

In a similar study, Rich, Jones, Belikov, Yoshikawa, and Perkins (2017) confirmed the need for providing training not only for preservice teachers but also for in-service teachers. In their mixed-methods, grounded theory study on elementary teacher self-efficacy and teachers' beliefs about teaching computing and engineering, Rich et al. conducted a year-long training on the engineering and technology components of STEM-centric lessons. The study involved two elementary schools with similar characteristics and demographics. Rich et al. conducted the study in one school (n = 27) and used the other school (n = 25) for comparison. In the study school, the researchers explored teacher development, including elements that provided mastery experiences and looked at the teachers' self-efficacy for computing and engineering. The training included mastery experiences and consisted of weekly professional development sessions related to engineering, computing, and several short-term workshops (Rich et al., 2017).

Rich et al. (2017) collected quantitative data using the Teacher Efficacy and Attitudes Toward STEM Survey using a Likert scale. Follow up interviews with 13 of the study school's teachers provided the qualitative data for the study. After coding and analyzing the quantitative and qualitative data, Rich et al. discovered that the participants' computing teaching beliefs (U = 220.5; $p < .050$), and perceptions of computing self-efficacy ($t = -3.66$; $p < .001$) were statistically different from the control school participants who did not receive any professional development. The researchers also noted that the engineering and computing professional development sessions positively influenced the study school teachers' instructional competence for engineering teaching beliefs ($U = 90$; $p < .001$) and engineering self-efficacy ($t = 5.88$; $p < .001$). The researchers posited that the key to successfully increasing teachers' instructional competence and perceptions of self-efficacy is to allow teachers to engage with the science and engineering practices directly. When they engage with the practices, they will experience them first-hand and can transfer their knowledge to the learning experiences of their students (Rich et al., 2017).

When perceptions of self-efficacy increase, teachers may become more willing to implement the science and engineering practices in their daily lessons. Hodges, Gale, and Meng (2016) conducted a qualitative case study that analyzed six eighth-grade science teachers' perceptions of self-efficacy during the application of the Science Learning Integrating Design, Engineering, and Robotics project. During the eight-week study, the teachers implemented a problem-based learning (PBL) curriculum using LEGO bricks with their students to address the engineering aspects of the science and engineering practices (Hodges et al., 2017).

Before implementing the LEGO-based PBL curriculum (LEGO PBL) for the study, the teachers had engaged in two years of curriculum development and had test piloted a variety of PBL curricula designed to provide them with numerous mastery experiences as they worked with each curriculum (Hodges et al., 2017). According to Bandura (1977b), vicarious and mastery experiences may produce positive outcomes that could increase the motivational processes that govern learning. When teachers experience success, they also begin to self-reinforce their behaviors and learning due to the positive results, which leads to the development of positive self-efficacy beliefs (Bandura, 1997). The teachers in the study engaged in mastery experiences as they worked with the curriculum, had vicarious experiences when they observed the successes and failures of their peers, and experienced the positive effects of verbal persuasion based on the feedback they received from the authors of the curriculum and the researchers (Bandura, 1997; Hodges et al., 2016).

Hodges et al. (2016) collected self-efficacy survey and journaling data from the study participants as the teachers implemented LEGO PBL. The teachers' journal responses reflected what the teachers thought about their self-efficacy while learning and applying the LEGO PBL. Based on the guided reflective journal entries from each participant, Hodges et al. discovered the teachers had personal confidence ratings of 8.1 on a ten-point scale, which indicated high levels of self-efficacy related to implementing the LEOG PBL. Outside factors such as teachers' large class sizes and the emphasis on high-stakes test preparation imposed on the teachers by their school district were the only concerns expressed by the teachers regarding the implementation of the LEGO PBL (Hodges et al., 2016). Despite the challenges that teachers faced at the school and district level, their instructional competence and self-efficacy remained high after participating in the professional development sessions as teachers' confidence ratings went up or down by .05 points on the 10 point scale (Hodges et al., 2016).

The second data source for Hodges et al.'s (2016) study was a survey that measured teachers' perceptions of self-efficacy related to the six different elements of the LEGO PBL and the teachers' use of inquiry methods of learning. According to Hodges et al., the teachers' responses to the survey indicated that they collectively had high perceptions of self-efficacy for each element overall, as indicated by survey question averages ranging from 8.83 to 9.67 on a ten-point scale. The explain element of the LEGO PBL received the lowest average (8.83) and was considered an area in which teachers needed to improve their skills. The element required teachers to have students engage in scientific reasoning and then develop a sound argument that students could support with evidence. Hodges et al. suggested that this area of weakness felt by the otherwise highly efficacious teachers highlighted the need for ongoing training. The researchers also suggest that teachers need support to ensure continuous instructional competence improvement, to increase their positive perceptions of self-efficacy, and to improve their pedagogical skills. Hodges et al.'s (2016) study supports findings from previous research (AAAS, 1993; Bandura, 1997; Bybee, 2011; Guzey, Tank, Wang, Roehrig, & Moore, 2014; NRC, 1996; Rich et al., 2017).

Pedagogical Shifts

To engage students effectively in the SEPs, teachers must learn new pedagogical skills, which are often different from those they learned in teacher preparation programs or those they have used for years (Bybee, 2011; Southerland et al., 2016). For example, traditional methods of teaching science over the past two decades did not emphasize integrating the SEPs but allowed teachers to teach scientific inquiry as a stand-alone unit (Bybee, 2011, NRC, 2012, 2013; Zais, 2014). Thus, the pedagogical skills teachers need to teach science content have changed because of the need to integrate the SEPs in the daily instruction of science content (Pruitt, 2014). The needed pedagogical change is evident in that teachers who are tasked with teaching a disciplinary core idea are now expected to integrate the appropriate SEPs in their instruction so that students learn science content through the use of the SEPs (Bowers & Ernst, 2018; Guzey et al., 2014; NRC, 2012, 2013; Zais, 2014). Making pedagogical shifts to integrate the SEPs not only changes the way teachers teach but also changes the classroom learning environment (Guzey et al., 2014; Southerland et al., 2016).

When teachers embrace the necessary pedagogical shifts to integrate the SEPs in their lessons, the classroom learning environment encourages student engagement in investigations or design solutions to problems (Guzey et al., 2014). As students regularly engage in the SEPs, they also take ownership of their learning, increase their depth of understanding, and improve their levels of achievement (Guzey et al., 2014; Lesseig et al., 2016). To make the pedagogical shifts necessary to produce such positive outcomes, teachers must first learn how to engage in the SEPs effectively through professional development opportunities that provide them with mastery and vicarious experiences (Bandura, 1997; Hodges et al., 2016).

Professional development. To refine instructional practices and to learn the pedagogical changes needed to teach the science and engineering practices with fidelity, teachers must engage in professional development training (Guskey, 2002; Hodges et al., 2016, Wendt et al., 2015). Many professional development sessions consist of an hour-long after school training, a one-day to three-day workshop, or a week-long summer learning session. Professional development sessions and workshops of such short durations have limited success in changing teachers’ pedagogical practices (Lakshmanan et al., 2011). In contrast, professional development opportunities that extend across multiple years may support better learning outcomes.

Lakshmanan et al. (2011) conducted a three-year case study that examined changes in teachers' self-efficacy and changes in their classroom instructional practices as they participated in multiple professional development sessions. A total of 107 teachers participated in the study. During the semester-long trainings, teachers participated in "Educator Inquiry Groups… that provided hands-on learning experiences and resource sharing opportunities" (Lakshmanan et al., 2011, p. 538) designed to improve classroom practices. The teachers also took one science content course each year that incorporated inquiry-based teaching methods. Data were collected using (a) pre- and post-test assessments for the content courses, (b) classroom observations based on the Reformed Teaching Observation Protocol, (c) the Science Teaching Self-Efficacy Belief Survey instrument, (d) document reviews, and (e) interviews (Lakshmanan et al., 2011).

Lakshmanan et al. (2011) found that teachers' instructional competence and perceptions of self-efficacy significantly increased ($p < 0.05$) and had a lasting effect on classroom practices and self-efficacy throughout the three-year study ($r = 0.35$). However, Lakshmanan et al. noted a negative correlation ($r = -0.45$) between the changes in teachers' perceptions of self-efficacy and increases in their long-term observation protocol scores. The negative correlation indicated an initial rapid increase in the teachers' perceptions of self-efficacy and instructional competence after participating in professional development, followed by a slower increase in self-efficacy and classroom performance. Lakshmanan et al. also found that teachers who expected to initially perform at high levels before the professional development did show higher levels of instructional competence after participating in the training ($r = 0.64$). Thus, extended professional development opportunities may be more effective than those of a shorter duration in improving teachers' perceptions of self-efficacy and their instructional competence (Lakshmanan et al., 2011).

In another study about professional development, Guzey, Tank, Wang, Roehrig, and Moore (2014) conducted a qualitative research study that involved 198 teachers in grades three through six representing 17 different school districts in the Minneapolis-St. Paul area. The researchers investigated the teachers' experiences as they participated in professional development workshops related to implementing engineering into their daily lessons. The goal of the professional development was to give teachers vicarious and mastery experiences that would provide them with the new learning they needed to feel comfortable with changing their pedagogical practices (Guzey et al., 2014). The professional development also provided teachers with the necessary skills to integrate engineering in their science lessons. To facilitate the study goal, Guzey et al. (2014) provided 30 hours of face-to-face professional development delivered through school-based professional learning communities and 16 hours of workshops that allowed the teachers to experience various design challenges as if they were the students (Guzey et al., 2014).

After participating in the workshops, the teachers wrote a lesson plan for one of the engineering design challenges and implemented the lesson plan in their classrooms. First, the teachers assessed their students' knowledge of engineering before teaching the engineering lesson by having students circle items that were related to engineering or technology from a 16-item assessment (Guzey et al., 2014). Next, the teachers taught the engineering lesson based upon the lesson plan they created in the professional development workshops. After teaching the lesson, the teachers collected 5-10 student artifacts, such as verbal statements, drawings, and pictures that related to the engineering design process, which students engaged in during the lesson (Guzey et al., 2014). Teachers were then asked to share the student artifacts from the engineering design challenge lesson with members of their professional development group and to reflect on how the student artifacts might help teachers understand their students' understanding of the engineering design process. The discussions allowed the teachers to make valuable instructional decisions for their students' learning needs (Guzey et al., 2014). The teachers also participated in a professional development session that allowed them to process their learning from the workshops and classroom implementation of their lesson plans. In the final professional learning community meeting, the teachers created team posters that reflected their new understanding of how to implement the engineering design process in their daily lessons (Guzey et al., 2014).

Guzey et al. (2014) analyzed 25 professional learning community reports that included 108 lesson plans with student artifacts and 66 professional development team posters. Seventy-seven individual lessons, which included student artifacts and team posters, were acceptable for the case study and were subsequently coded and categorized. Guzey et al. found that 47% of the 77 lessons were complete engineering lessons that included a realistic context. The lessons also provided students with opportunities to engage in the design, build, test, and redesign aspects of the engineering design cycle. While ten-percent of the lessons lacked a realistic context, 12% lacked a redesign component, and 17% only allowed students to build and test their designs (Guzey et al., 2014). In 14% of the lessons, the teachers misunderstood the engineering design cycle. They misapplied it to their lesson plans, which resulted in their students not engaging in the engineering design cycle process (Guzey et al., 2014).

The data from Guzey et al.'s (2014) study indicated that most of the teachers (69%) made the necessary pedagogical shifts that enabled them to teach complete or nearly complete engineering lessons to their students after participating in the year-long professional development. Providing students with engineering design challenges provides them with opportunities to learn from their failures as they redesign their designs or problem solutions, allows them to engage in interdisciplinary learning, and promotes student motivation and achievement (Guzey et al., 2014; NASEM, 2019; NRC 2012, 2013). High quality, long-term professional development opportunities play an integral role in helping teachers make the essential pedagogical shifts in teaching the science and engineering practices (Guzey et al., 2014; Lesseig et al., 2016).

The effectiveness of professional development may also increase when providers of professional development opportunities consider the social context of the professional development sessions. In a five-year quantitative case study by Southerland et al. (2016), 106 study participants from 11 Southeastern states engaged in two long-term research experiences for teachers (RET) that focused on teacher self-efficacy, pedagogic dissatisfaction, and instructional competence. The researchers were specifically interested in the way the teachers' thinking might change after participating in the research experiences (Southerland et al., 2016).

The study included two research experience models for the science teachers to participate in during their RET professional development program. The two research experience models were science pedagogy (*n* = 52) and scientific research (*n* = 54; Sutherland et al., 2016). The science pedagogy model allowed the researchers to gather information related to the teachers' classroom practices, and the scientific research model aimed to revitalize teachers' passion for science (Southerland et al., 2016).

To address the self-efficacy aspects of the study, Southerland et al. (2016) used four data collection instruments. The first was the Science Teaching Efficacy Belief Instrument (Riggs &

Enochs, 1990), which included a 23-question Likert-scale. The second instrument was the Teaching Science as Inquiry Instrument (Smolleck et al., 2006) comprised of 69 multiple-choice items. A seven-item, semi-structured interview protocol, the Teacher Belief Inventory (Luft & Roehrig, 2007), provided the third data source that allowed the researchers to discover the teachers' underlying beliefs about science teaching. The final instrument measured the teachers' degree of discontentment with their pedagogic skills using the Science Teachers' Pedagogical Discontentment Scale. The instrument included a 30-item Likert-scale (Southerland et al., 2016).

Data were also collected using classroom observations before and after participating in the science pedagogy model to address the pedagogical aspects of the study. The final data collected in the study were observations of the teachers as they engaged in the scientific research model (Southerland et al., 2016). All classroom observations were scored using the Reformed Teacher Observation Protocol rubric, which utilized a 5-point Likert-type scale that included descriptors ranging from *never occurred* to *very descriptive*. The rubric also included 25-items categorized into three subgroups covering lesson design, lesson content, and classroom culture (Southerland et al., 2016).

From the six data sources, Southerland et al. (2016) identified structural variables for the two research experiences. Relationships among the data were explored using structural equation modeling and confirmatory factor analysis to examine the relationships between the constructs, which allowed the researchers to examine the validity and reliability of the models (Southerland et al., 2016). Based on the data, there was a negative correlation between teachers' pre-program pedagogic discontent and their perceptions of instructional competence and self-efficacy. The pre-program data indicated that for every point increase on the instruments that measured science inquiry teaching self-efficacy, there was a decrease in the teachers' need for social interactions during the RET program. The science teaching self-efficacy and teachers' self-efficacy for inquiry accounted for an 8% variance in social interaction (Southerland et al., 2016). After teachers participated in the RET program, post-program data indicated a positive correlation between continuous social interactions during the professional development program and the teachers' perceptions of self-efficacy and instructional competence (Southerland et al., 2016).

Southerland et al. (2016) suggested that professional development opportunities are most effective when they are "conducted in a social context" (p. 12) so that participants can make sense of their vicarious and mastery experiences within a community of learners. Providing teachers with opportunities to collaborate in a social setting while attempting to master new learning allowed the teachers to take on a more student-center perspective, which indirectly improved their pedagogical practices (Southerland et al., 2016).

In a mixed-methods case study related to teachers' ability to make pedagogical shifts, Kang, Donovan, and McCarthy (2018) focused on 17 second-grade teachers' self-reported responses to the NGSS Science and Engineering Practices Survey using a five-point Likert scale. The survey also included an open-response portion containing open-ended questions based on a four-point *novice* to *expert* scale. Kang et al. (2018) used the results from the survey and the open-ended questions as a baseline to create a professional development workshop designed to enhance the teachers' weak areas of professional content knowledge.

After the teachers participated in the professional development, Kang et al. (2018) analyzed the teachers' effectiveness in engaging students in the SEPs based on the open-ended response portion of the survey. The open-response portion of the survey used a modified novice to expert continuum that indicated progressive levels of performance based on the teachers' mastery experiences about their pedagogical content knowledge of the NGSS SEPs. The researchers' analysis revealed that teachers' professional content knowledge increased (M = 2.19; α = .70) after receiving the professional development training, and that the teachers were better able to integrate the SEPs where appropriate. The survey data also showed that the teachers had favorite instructional strategies that they used to incorporate the SEPs and to engage students in the SEPs. Open-responses from the survey indicated that the strategies the teachers preferred were "group/pair work, experiments, investigation, starting lessons with observations, samples/realia, collecting data, teacher modeling of practice, teacher-guided inquiry, and allowing students to explore independently" (Kang et al., 2018, p. 22).

Kang et al. (2018) noted that each instructional strategy utilized by the teachers was relevant to one or more of the eight SEPs and enabled the teachers to teach various disciplinary core ideas through the SEPs as suggested by the *Framework* and the NGSS (NRC, 2012, 2013). Kang et al.'s (2018) results align with previous research (Sias et al., 2017; Tomas et al., 2014) that found teachers who demonstrated instructional competence and positive self-efficacy reported higher student engagement.

Lesson planning. When teachers embrace the pedagogical shifts necessary to implement the SEPs effectively, a definite difference in their daily classroom lessons becomes evident. The most crucial difference is that teachers' daily lessons prominently feature problem-based learning or design challenges. According to Lesseig, Nelsen, Slavit, and Seidel (2016), when teachers implement problem-based learning and design challenges, they create a learning environment based on "student-centered instruction and … student learning goals that encompass interdisciplinary knowledge and application" (p. 178). Creating a learning environment that provides students with opportunities to engage in the SEPs through problem-based learning or design challenges requires carefully crafted STEM-centric lessons.

By definition, a STEM-centric lesson includes a learning objective based on a performance expectation that incorporates science, technology, engineering, and mathematics components (Bowers & Ernst, 2018). STEM-centric lessons should also address appropriate literacy components that allow students to access the text of the performance expectation and subsequent laboratory investigation or design challenge components (Krajcik, Codere, Dahsah, Bayer & Mun, 2014). Wendt et al. (2015) posited that effective STEM-centric lessons help students engage in critical thinking, problem-solving, and teamwork as they solve problem-based learning units or design challenges.

To make lesson planning more manageable, the NGSS provides grade-level specific performance expectations for each disciplinary core idea and suggests appropriate crosscutting concepts and science and engineering practices that allow students to make sense of the science content (NRC, 2013). Helping teachers gain the necessary skills to create and execute STEM-centric lessons requires additional teacher training.

Capobianco and Rupp (2014) conducted a study of 23 fifth and sixth grade STEM teachers who used professional development to help the teacher create better STEM-centric lesson plans. The teachers participated in two weeks of intensive professional development aimed at helping them create STEM-centric lessons during their summer break. After the summer professional development, the teachers also participated during the school year in two to four half-day follow up sessions. The follow-up sessions were geared toward creating standards and engineering design-based lesson plans (Capobianco & Rupp, 2014). Based on their learning from the professional development sessions, the teachers created two STEM-centric instructional units and implemented them with their students. Data were collected from the teachers' implementation plans (*n* = 29) and from classroom observations (*n* = 6; Capobianco & Rupp, 2014). The researchers evaluated the implementation plans on a three-point scale ranging from *exemplary* to *needs improvement* using the Science Lesson Plan Analysis Instrument. The implementation plan data (*M* = 66.4) indicated teachers showed strengths in how they designed learning opportunities for their students to engage in real-world problems using the SEPs and engineering design cycle (Capobianco & Rupp, 2014).

Capobianco and Rupp (2014) collected classroom observation data from six study participants using a modified version of the Inquiring into Science Instruction Observation Protocol. The researchers coded the data from the observations. Then they used the coded data to create their own engineering design-based classroom observational rubric, which included five performance levels ranging from *high fidelity* for implementing the SEPs to *no evidence*. Teachers with a mean score of three or higher had a high degree of fidelity related to integrating the SEPs in their lesson plans. The data indicated that the overall mean observation score (*M* = 3.40) for the teachers as they facilitated the engineering design lessons increased after participating in professional development (Capobianco & Rupp, 2014).

Data from a quantitative study by Bowers and Ernst (2018) indicated the importance of providing teachers with professional development designed to increase their STEM-centric lesson planning skills. In the study, Bowers and Ernst's participants consisted of a cohort of 16 educators comprised of first through fifth-grade teachers, resource teachers, an administrator, and literacy and mathematics coaches. The cohort participated in the McDaniel College Elementary STEM Leadership program, which allowed the participants to earn a pre-K through sixth grade STEM endorsement (Bowers & Ernst, 2018).

As the cohort worked through the program, the teachers completed the competency in planning assessment. Bowers and Ernst (2018) scored the assessment with a four-point rubric ranging from *unsatisfactory* to *exemplary*. The rubric measured the teachers' proficiency in planning STEM-centric lessons. The researchers used a Wilcoxon signed-rank test to assess the values on the rubric to determine if teachers' demonstrated proficiency in planning STEM-centric lessons ($n = 16$, $p = 0.9932$). Data analysis indicated the teachers demonstrated proficiency in planning STEM-centric lessons. Bowers and Ernst's (2018) study results support previous research (Capobianco & Rupp, 2014; Guzey et al., 2014; Lesseig et al., 2016) that found teachers who participated in professional development sessions were able to increase their ability to design SEPs-integrated lesson plans.

A variety of STEM-centric lesson plan rubrics exist to evaluate science lesson plans since the adoption of the NGSS or similar iterations of the standards. One rubric developed to evaluate science lesson plans objectively is the Engineering-Infused Lesson rubric developed by Peterman, Daugherty, Custer, and Ross (2017) for use in their research study of engineering science lessons. Peterman et al. searched online lesson plan repositories and found 80 suitable STEM-centric lesson plans for the study. The Engineering-Infused Lesson rubric allowed the researchers to evaluate each lesson plan's curricular materials, teacher pedagogical practices, and the extent to which students engaged with engineering content and real-world applications of engineering (Peterman et al., 2017).

After reviewing the lesson plans, Peterman et al. (2017) used the Engineering-Infused Lesson rubric to code each lesson plan. Scores for each lesson plan were derived from the rubric and indicated that teachers had incompletely aligned their lessons with the NGSS ($p < .01$) and had not adequately incorporated engineering curriculum materials ($p < .05$) for their students

(Peterman et al., 2017). Data from the rubric, however, revealed a satisfactory amount of pedagogical best practices for the engineering curriculum ($p < .001$) embedded in the lesson plans. Overall, Peterman et al. discovered that the Engineering-Infused Lesson rubric was successful in identifying strengths and weaknesses in the engineering lesson plans.

Another, more comprehensive rubric used to evaluate STEM-centric lesson plans is the Educators Evaluating the Quality of Instructional Products Rubric-Version 3.0 (EQuIP Rubric 3.0) developed by the National Science Teachers Association (NSTA, 2016). Shernoff, Sinha, Bressler, and Schultz (2017) used applicable elements of the EQuIP Rubric 3.0 in combination with crucial elements of the Buck Institute for Education's Project Design rubric in their qualitative study. The study focused on the impact an NGSS aligned professional development had on four secondary teachers' ability to write NGSS-aligned curricula and instructional lesson plans.

Shernoff et al. (2017) employed a "qualitative, ground-up approach" (p. 7) to analyze the teachers' interview data, which allowed the researchers to discover emerging patterns and themes. The lesson plans were analyzed using the pertinent aspects of the two rubrics. The interview data were combined with an analysis of the lesson plans created by the teachers after participating in the professional development sessions. Combining the two data sets allowed the researchers to obtain a deeper level of understanding of what the teachers learned by participating in professional development. The data indicated that two of the teachers were inconsistent in their planning for STEM-centric lessons. However, the other two teachers in the study, who routinely collaborated, were able to write learning objectives and inquiry-driven questions aligned with the standards and SEPs (Shernoff et al., 2017).

Using lesson plan rubrics can help school administrators provide impartial feedback about teachers' instructional plans and can also help teachers self-evaluate their STEM-centric lesson plans. Lesson plan rubrics may also help alleviate the problem of missed opportunities for students to engage in authentic STEM learning experiences because the rubrics allow teachers to self-assess their lesson plans and determine areas of improvement (Bowers & Ernst, 2018; Capobianco & Rupp, 2014; Peterman et al., 2017; Shernoff et al., 2017; Southerland et al., 2016). Creating lesson plans that integrate the SEPs and engage students in the inquiry process or a design challenge is critical to creating a student-centered classroom where learning is student driven (Lesseig et al., 2016; Shernoff et al., 2017).

Opportunities and Challenges

Teachers experience many opportunities and challenges as they engage students in STEM-centric lessons. The educational infrastructure of a school may impact the quality of instruction for some students. Educational infrastructure comprises the facilities, systems, and services that allow a school district to serve the professional needs of teachers and to provide instruction for students (Shirrell, Hopkins, & Spillane, 2019). The ideal educational infrastructure supports teachers' professional learning through ongoing professional development courses as well as provides teachers with adequate facilities, appropriate funding, and enough instructional time to help students realize positive academic outcomes through engaging lessons (Shirrell et al., 2019).

Student engagement. According to the National Academies of Sciences, Engineering, and Medicine (2019), student engagement reflects "the interaction of students with the classrooms and school contexts in which they're functioning" (p. 59). Therefore, the structure of students' schools and their teachers' classroom practices can influence their engagement in daily lessons (NASEM, 2019).

In a meta-analysis study, Kim and Seo (2018) explored the relationship between teacher self-efficacy, student achievement, and student engagement as a subfactor of teacher efficacy. Data from the study showed that veteran teachers with positive self-efficacy beliefs ($p < .001$) were more likely to use instructional practices that supported student engagement ($p < .001$; Kim & Seo, 2018). The findings of Kim and Seo (2018) support the data from Lesseig et al.'s (2016) study of teachers' implementation of STEM design challenges. Lesseig et al. (2016) found that teachers who provided learning experiences that incorporated the SEPs for their students reported increased student motivation and engagement.

To ensure students have authentic experiences while using the SEPs to investigate a disciplinary core idea, Alonzo and Ke (2016) suggested teachers should design STEM-centric lessons that engage students in the full gamut of SEPs whenever possible. The researchers cautioned that focusing on one or two SEPs in a STEM-centric lesson creates a situation where students may not be engaged in a complete engineering design cycle or the entire inquiry process, which may decrease student engagement (Alonzo & Ke, 2016). However, when students investigate disciplinary core ideas using a complete engineering design cycle or multiple SEPs, student engagement and academic achievement are expected to increase (English, 2017; Filippi & Agrawal, 2017; Guzey et al., 2014; Kim & Seo, 2018; Lesseig et al., 2016).

In another study concerning student engagement in the engineering design process and academic achievement, Alemdar et al. (2018) investigated middle school students' academic achievement and three types of student engagement—behavioral, emotional, and cognitive—after completing engineering courses. Alemdar et al. surveyed and interviewed students who had participated in middle-level engineering coursework for three years or less. Results of a one-way ANOVA indicated that students who completed two or more years of engineering coursework in middle school had significantly higher achievement levels on the science milestone assessment ($p < .0001$) compared to students who had completed one year or less of the engineering courses (Alemdar et al., 2018). To ensure the data were not skewed by the overrepresentation of high-level students or the underrepresentation of lower-level students, Alemdar et al. conducted multiple one-way ANOVA analyses of the data with the responses of members of these groups removed. The analyses revealed that regardless of whether high-level student data were removed ($p < .0001$), lower level student data were removed ($p < .0001$), or both categories of students were removed ($p < .002$), the achievement levels remained significantly different. Likewise, student engagement increased after completing one or more of the engineering courses. Data from Alemdar et al.'s (2018) study revealed that the engineering courses were significantly positively related to students' cognitive engagement ($p < .03$) and behavioral engagement ($p < .005$). However, the influence of the engineering courses on students' emotional engagement was not significant ($p < .07$), which emphasized the importance of providing students with positive student-school, student-student, and student-teacher experiences (Alemdar et al., 2018).

Collaboration. As teachers participate in professional development sessions designed to increase their self-efficacy and instructional competence, they do so through collaboration (Guskey, 2002; Guzey et al., 2014; Hodges et al., 2016, Southerland et al., 2016; Wendt et al., 2015). In a quantitative study, Al-Salami, Makela, and de Miranda (2017) examined the changes in 29 middle and high school teachers' attitudes toward STEM teaching after completing a 12 to 15-week professional development course that involved collaboration. Al-Salami et al.'s (2017) study data revealed correlations among variables in the study related to interdisciplinary teaching, teamwork, and teachers' attitudes.

Al-Salami et al. (2017) found a strong, positive correlation between the teachers' change in attitudes toward interdisciplinary teaching as compared to their attitudes toward teamwork ($p < .03$) and teaching satisfaction ($p < .049$). The data also indicated a significant, negative correlation between teachers' attitudes toward interdisciplinary teaching and their resistance to change ($p < .03$). A fourth positive correlation was revealed in the data between teachers' change in attitude toward teamwork and their change in teaching satisfaction ($p < .01$; Al-Salami et al., 2017). When teachers have opportunities to collaborate, they increase their pedagogical skills, which increases their instructional competence and perceptions of self-efficacy (Al-Salami et al., 2017; Guskey, 2002; Guzey et al., 2014; Hodges et al., 2016, Southerland et al., 2016; Wendt et al., 2015).

However, many teachers do not have the opportunity to collaborate regularly. Avramides, Hunter, Oliver, and Luckin (2015) conducted a qualitative case study of 57 teachers that focused on a new cross-curricular model of teacher inquiry: the NEXT-TELL project. The project was designed to support teachers as they used data from cross-curricular inquiries to improve their pedagogical practices, used instructional technology, and used of formative assessments with their students (Avramides et al., 2015).

Teachers in the study participated in semi-structured interviews ($n = 13$) and completed a survey ($n = 15$) about their experiences with the project (Avramides et al., 2015). Avramides et al. found that teachers who did not have relationships with their cross-curricular colleagues ($n = 5$) indicated that collaboration was difficult. The survey results indicated that the teachers noted a need for improved collaboration among colleagues. In the interviews, the teachers shared the struggles they experienced when trying to collaborate with a colleague who did not teach the same subject (Avramides et al., 2015).

Isolation. Although Shernoff et al. (2017) reported that two teachers who planned NGSS-aligned lessons with their content area or grade-level peers were able to create quality STEM-centric lesson plans, other researchers have found that many teachers feel isolated as they navigate the NGSS (Al-Salami et al., 2017; Lesseig et al., 2016). Al-Salami et al.'s (2017) qualitative study using interview data revealed that the middle school teachers' negative attitudes toward creating interdisciplinary STEM units could be a result of a lack of communication and collaborative planning with colleagues.

In their interpretive longitudinal phenomenological study, Nehmeh and Kelly (2018) had similar results to Al-Salami et al. (2017). Nehmeh and Kelly (2018) examined the perceptions of two high school physics teachers who were the only physics teacher in their respective high schools. Data were collected through semi-structured interviews over four years (Nehmeh & Kelly, 2018). Nehmeh & Kelly's (2018) study indicated that the teachers' struggles intensified with teaching courses outside of their certification areas and limited equipment, textbooks, supplies, and curricula because they taught in isolation. The teachers also reported negative perceptions of self-efficacy due to their students not making positive academic gains and to a lack of opportunities to expand their pedagogical skills through collaborative planning with other physics teachers (Nehmeh & Kelly, 2018). Since they struggled to increase their pedagogical skills in isolation, both teachers in the study actively developed a network of physics teachers outside their schools after the study. (Nehmeh & Kelly, 2018). Nehmeh and Kelly (2018) concluded that teachers who work in isolation might doubt their self-efficacy and instructional competence without the support from and collegial planning with other science teachers.

Professional development. A critical factor in helping teachers improve their craft is professional development. Zaccarelli et al. (2018) conducted a descriptive case study about the changes in classroom practice of an elementary teacher after participating in a long-term science professional development program. The professional development program was designed to increase teachers' ability to engage students in scientific discussions and to increase their ability to engage in argumentation from evidence, which is one of the SEPs. Data for the study were collected through pre- and post-interviews and through pre- and post-observations. The Science Discourse Instrument measures classroom discourse practices on a four-point scale ranging from *consistently* to *never* and was used to rate the teacher's classroom observations. Zaccarelli et al. rated the teacher and students as they engaged in arguing from evidence and critiquing ideas during the observations. Even though the study only had one participant, data indicated that the teacher's ability to engage students in argumentation based on evidence improved after the professional development, which allowed for more student-centered learning (Zaccarelli et al., 2018).

However, not all professional development training is implemented with fidelity once teachers return to the classroom (Capobianco & Rupp, 2014). Cook and Weaver's (2015) qualitative study results indicated that seven high school teachers trained in problem-based learning methods implemented the lessons they created in a professional development workshop in a "less than optimal manner where elements of best practice were present but not consistently implemented" (p. 31). After the teachers completed the professional development workshops, Cook and Weaver (2015) conducted classroom observations and semi-structured interviews designed to elucidate the teachers' experiences with implementing a problem-based learning unit.

The study data indicated that the teachers enjoyed collaboratively planning the problem-based learning unit and found value in having a student-centered classroom (Cook & Weaver, 2015). However, limitations existed with the teachers' ability to implement the units with fidelity. Cook and Weaver (2015) noted that teachers had concerns about the length of time to implement the unit. The concerns about time ranged from not being able to cover state-mandated content to not having enough time in class to allow students to complete investigations. The teachers also indicated that they did not feel confident in teaching the problem-based unit despite having attended the professional development workshops. In similar findings, Shernoff et al. (2017) suggested that although teachers in their study improved in their abilities to create STEM-centric curricula and lesson plans, the teachers reported that they lacked sufficient knowledge of the SEPs to accurately teach the more complex practices such as supporting claims with evidence.

Skaza, Crippen, and Carroll (2013) had similar findings in their mixed-method study of 81 high school science teachers. The researchers surveyed teachers to examine their use of computer-based system dynamics simulations and stock and flow models as part of a STEM curriculum that used STELLA software. Data indicated that only 2.8% of the teachers used the simulations in their lessons. In comparison, 11.7% of the teachers chose to use alternative simulations from online sources such as The JASON Project, and another 11.7% conducted physical simulations using board game pieces or students instead of the STELLA software simulations (Skaza et al., 2013). Some teachers in the study reported negative perceptions of self-efficacy (29.9%) and a decrease in instructional competence when they attempted to teach the technology-enabled activities from the STEM curriculum (Skaza et al., 2013).

Skaza et al. (2013) examined survey responses from participants who did not use the simulations or models. The researchers attempted to identify why teachers did not fully implement the STEM curricula. Limited or no access to the STELLA software that was necessary to run the simulations was the main reason cited in the study (68.8%) by the teachers who did not use the software to conduct the simulations and models with their students. Over 62% of teachers in the study indicated they needed additional training to use the software to help them overcome limitations in their understanding of how to use the simulations and models in their teaching (Skaza et al., 2013). To examine more closely the experiences and understandings of the teachers, Skaza et al. convened a focus group of four teachers who represented diverse schools, communities, and student populations.

The focus group interview data indicated that time constraints were the main reasons the teachers did not use the STEM curriculum simulations. The teachers also considered computer-mediated instruction to be a distraction that decreased students' attention to daily learning targets and increased classroom management concerns (Skaza et al., 2013). Skaza et al. recommended that the school district provide professional development sessions for the STEM curriculum and STELLA software to increase teachers' self-efficacy in teaching the simulations and models.

Time. Teaching science requires enough time for planning STEM-centric lessons and adequate amounts of class time for students to engage in authentic learning experiences (NRC, 2012). However, research indicates that teachers repeatedly report not having enough time to plan engaging lessons and report not having enough class time in the daily school schedule (Cook & Weaver, 2015; Filippi & Agarwal, 2017; Lesseig et al., 2016; Shernoff et al., 2017 Skaza et al., 2013).

Teig, Scherer, and Nilsen (2019) conducted a study that focused on teachers' perceptions of self-efficacy and the time constraints of their daily school schedule. Eight hundred-four elementary and middle school science teachers participated in the study. Data were collected using a four-point Likert self-efficacy scale with categories ranging from *low* to *very high*. Teig et al. used structured equation modeling to examine the relationships between the constructs. Based on the data, teachers who rated time constraints as a limiting factor in their ability to engage students in STEM-centric lessons also used fewer cognitive activation strategies with their students. Using fewer cognitive action strategies indicated lower perceptions of teachers' self-efficacy (Teig et al., 2019). Teig et al.'s study results reflected other researchers' findings (Al-Salami et al., 2017; Kubat, 2018; Shernoff et al., 2017).

Kubat (2018) conducted a phenomenological study that focused on 12 science teachers' efforts to integrate STEM into their science lessons. Data were collected through semi-structured interviews. An analysis of the data indicated that the teachers in Kubat's (2018) study believed time constraints (42%) limited how much content they could teach to their students. Kubat's (2018) study results were similar to research conducted by Al-Salami et al. (2017) and Cook and Weaver (2015), where teachers reported that student buy-in, state-mandated content requirements, teacher evaluation methods, and time constraints were challenges to implementing STEM units.

The research of Shernoff et al. (2017) indicated that teachers in the traditional school setting did not have enough time to plan effective STEM-centric lessons or they did not have enough time to implement the lesson plans with fidelity. To address teachers' concerns related to limited time during the school day or semester, Shernoff et al. (2017) suggested a reduction in the amount of required content and providing teachers with additional planning and instructional time. Increasing teachers' instructional and planning time may require a reconceptualization of the school day. According to Shernoff et al. (2017), making significant changes to how the organization of the school day could give teachers the time they need to increase their self-efficacy and would allow the teachers to teach STEM-centric lessons with fidelity.

Facilities. Adequate physical space within school facilities is necessary to give students enough room to carry out the investigations and engineering design challenges developed by their teachers. However, many classrooms do not have adequate physical space or equipment for investigations and experiments (Bybee, 2011; Kubat, 2018; Nehmeh & Kelly, 2018). In Kubat's (2018) phenomenological study, 12 teachers participated in semi-structured interviews about how they integrate STEM into their daily lessons and described the advantages and disadvantages of teaching STEM lessons. Three of the teachers (25%) reported the physical conditions of their schools were not conducive to providing rigorous STEM lessons, and six teachers (50%) reported overcrowded classes that created challenging environments in which to conduct scientific inquiry and engineering design challenges (Kubat, 2018). Kubat (2018) recommended improvements in the physical conditions of the teachers' classrooms or laboratories and suggested that more time be devoted to STEM education through extracurricular venues.

In similar research results, Cook and Weaver (2015) noted limited equipment as a problem for teachers implementing a problem-based learning unit. Teachers reported a lack of access to equipment and limited funds to purchase new equipment in Al-Salami et al.'s (2017) mixed-method study of middle and high school teachers. The teachers also identified the lack of appropriate funding levels for science equipment as one of the biggest challenges to creating and implementing STEM-centric lessons (Al-Salami et al., 2017).

Summary

The review of the literature explored the concepts of teacher self-efficacy as related to teachers' instructional competence, student engagement in the SEPs, and the opportunities and challenges teachers experience as they attempt to integrate the SEPs into their daily lessons. Additional concepts emerged from the literature related to the pedagogical shifts teachers need to embrace as they teach the SEPs (Bybee, 2014; Kang et al., 2018; Wendt et al., 2015). A major concept that also emerged relates to the effectiveness of professional development and the importance of integrating it into classroom lessons with fidelity (Guskey, 2002; Hodges et al., 2016; Wendt et al., 2015). Another important concept that surfaced from the literature is the critical role lesson plans play in preparing teachers to integrate the SEPs daily (Peterman et al., 2017; Shernoff et al., 2017).

The goal of this review of the literature was to examine the literature regarding science teachers' perceptions of self-efficacy in planning and executing STEM-centric lessons. The reviewed literature suggests that science teachers struggle with their perceptions of self-efficacy and instructional competence when tasked with integrating the SEPs into their science lessons. Previous research supports the use of professional development to increase teachers' perceptions of self-efficacy and to improve pedagogical skills such as integrating the SEPs in lesson plans and allowing students to take ownership of their learning. However, professional development is only one of many options. Despite the frequent use of professional development to help teachers learn the pedagogical shifts needed to integrate the SEPs in their daily lessons, there appears to be few examinations in the literature of alternative ways to develop science teachers' pedagogical skills. A continuation of the research using the qualitative case study methodology related to teachers' perceptions of self-efficacy in planning and executing STEM-centric lessons may provide other options for teachers.

III. METHODOLOGY

Introduction

The purpose of this study was to examine science teachers' perceptions of self-efficacy as related to planning and executing STEM-centric lessons. The multifaceted dimensions of science teaching include not only helping students learn content, but also lesson planning, student engagement, and working with school- and district-based infrastructure that impact teachers' instructional competence and self-efficacy (Bandura, 1997). This study provided insight into K-12 science teachers' perceptions of self-efficacy related to their pedagogic skills to plan engaging, SEP-integrated science lessons in public schools.

Research Design

A qualitative, instrumental case study was used for this study (Creswell, 2018; Yin, 2018). The case study explored science teachers' perceptions of self-efficacy, student engagement, and the opportunities and challenges associated with implementing the SEPs across South Carolina. Case study research was suited for the investigation because it allowed the researcher to investigate a "contemporary phenomenon in depth and within its real-world context" (Yin, 2018, p. 15). The case study also used interviews that allowed the researcher to "explore in detail the experiences, motives, and opinions" (Rubin & Rubin, 2012, p. 3) of the science teachers. Case study research also allows for in-depth data collection from multiple sources such as documents, archival records, and observations (Yin, 2018). Examining numerous data sources provides multiple ways to measure the same phenomena, which strengthens case study findings (Creswell, 2018; Yin, 2018). Using the case study approach also provided robust data from a cross-section of science teachers within the state that allowed the researcher to conduct literal and theoretical replications (Yin, 2018).

The case study focused on public school K-12 science teachers in South Carolina. The case was bounded by place and time (Creswell, 2018) because the teachers worked in the same state during the 2019-2020 school year and were required to teach the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs. The issues explored in the case study were science teachers' perceptions of self-efficacy as related to planning and executing STEM-centric lessons and the pedagogical shifts science teachers must undergo to engage students in more profound levels of learning using the SEPs.

Context of the Study

The research study took place in South Carolina during the 2019-2020 school year and involved public school K-12 teachers from five school districts in four counties. According to The Nation's Report Card (2018), the state school system consists of 101 districts with 1,255 traditional public schools and 70 charter schools. The school districts employ over 52,000 full-time teachers with more than 777,000 enrolled students. The overall student population consists of 51% Caucasian students, 34% African American students, 9% Hispanic students, and 6% students of other ethnicities. The state's student population also includes 5.8% English language learners and 65% of the students are on free or reduced meal plans (The Nation's Report Card, 2018).

The teachers' interviews took place in person or over the phone and were recorded with permission. The teachers in the study represented school districts that were rural, suburban, and urban. Of the nine schools represented by the teachers, four were Title I schools and one was a charter school.

Lesson plans were analyzed using the EQuIP Rubric 3.0 (NSTA, 2016) to determine the presence or absence of SEP-integration in the teachers' lesson plans. Four of the teachers submitted documents such as PowerPoint presentations, annotated pictures of student work, and student lab investigation worksheets in place of formal lesson plans. The documents indicated how the teachers integrated the SEPs into their daily lessons. The lesson plan data corroborated the teachers' interview data, which strengthened the validity of the study (Yin, 2018).

Research Questions

The following research questions, as stated in chapter one, guided the case study:

1. How does science teachers' self-efficacy influence their teaching of the 2014 science standards and SEPs?
2. How do teachers engage students in the SEPs?
3. What are the opportunities and challenges teachers experience when implementing the SEPs?

Research Participants

The participants were selected using purposive sampling to ensure a wide range of grade levels and diverse school and district demographics for the study. When research participant selections began, only three teachers agreed to participate in the study. To find more teachers for the study, the researcher utilized the snowball sampling technique (Gay et al., 2012). The snowball sampling technique produced 13 viable study participants who expressed an interest in participating in the study. However, only ten science teachers agreed to participate in the study.

Of the ten teachers who agreed to participate in the case study, six worked in the same school district, three of the teachers worked in three separate districts, and one teacher worked for the state charter school district. Eight teachers were female, and two teachers were male. The elementary teachers had 25 to 34 years of experience, the middle school teachers had two to 17 years of experience, and the high school teachers had five and 14 years of experience as science teachers. Nine of the ten teachers in the study had completed advanced coursework toward a post-graduate degree. Four teachers worked in elementary schools, four teachers worked in middle schools, and two teachers worked in high schools. The teachers were recruited from across the state to represent the general population of science teachers, schools, and school districts throughout the state. Table 1 presents the professional information of the teachers.

Table 1

Participants' Professional Information

Participant (pseudonym)	Teaching Experience	Instructional Position	Education Level	Area of Certification
Molly	26	Elementary – Engineering	Masters	Education
Charlotte	27	Elementary – Advanced Science and Mathematics	Masters	Education
Julie	25	Elementary	Bachelors +18	Education
Barbara	34	Elementary	Doctorate	Education
Joy	2	Middle – Science and Social Studies	Bachelors	Education
Frank	12	Middle – Science and Mathematics	Masters	Education & Environmental Science
Teresa	15	Middle	Masters	Education
Susan	17	Middle	Masters	Education, Biology, and Chemistry
James	5	High – Earth Science	Masters	Education & Geology
Elaine	14	High – Biology	Masters	Education & Biology

Role of the Researcher

The researcher for the study was a middle school science teacher with 24 years of experience in two states that included five public schools and one Christian school. In the state selected for the study, the researcher spent 23 years of her career working in three public school districts, one parochial school district, and five schools. During her career, she taught sixth, seventh, and eighth grade general and advanced science, and ninth grade earth science and physical science. The investigator was not employed at any of the study's school locations but did work in one of the school districts.

During the researcher's career, she experienced the adoption of new science content standards designed to better prepare K-12 students for college and careers. The new standards required integration of the SEPs into her daily lesson plans. Thus, the researcher understood the experience of making pedagogic shifts in teaching the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs (Zais, 2014). To ensure her experiences did not introduce bias into the study's data interpretation and analysis, the researcher implemented bracketing.

Bracketing occurs when a researcher sets aside previous experiences in order to approach a research study with an unbiased perspective (Creswell, 2018). The researcher has served as a teacher-mentor and peer-evaluator for two school districts for ten years. The training received to become certified as a mentor and as an evaluator proved to be instrumental in ensuring the researcher interpreted the interview data and rubric data objectively. The researcher was able to suspend judgment and limit assumptions, which minimized researcher bias.

Ethical Considerations

In all research endeavors, ethical concerns may arise. The potential for ethical issues is inherent in this qualitative case study methodology because the researcher knew seven of the participants personally and collected interview data, lesson plans, and other documents directly from the participants. To ensure "the highest possible standards of conduct in [educational] research" (AERA, 2011, p. 146), the American Educational Research Association's Code of Ethics (Code) guided portions of the study.

Principle D of the Code protects research participants' rights and confidentiality (AERA, 2011). The study used pseudonyms and general descriptions of school and district demographics to ensure the confidentiality and anonymity of the teachers. The pseudonyms and general demographic descriptions also prevented others from misusing study data to inflict harm on the participants' career (AERA, 2011).

Southeastern University and the researcher implemented additional ethical safeguards. The Southeastern University Institutional Review Board approved the research study assigning it the exempt status. The researcher also obtained permission to modify the Science Teacher Efficacy Beliefs Instrument-Version A (Riggs & Enochs, 1990), which is a quantitative survey instrument for in-service teachers, for the study (See Appendix A). The researcher modified the survey questions to write interview questions for the qualitative case study.

Furthermore, the teachers received full disclosure of the nature of the case study before they participated in the study. The teachers who agreed to participate signed informed consent agreements acknowledging the low level of risk associated with the study and the option to withdraw from the study at any time. The teachers' interviews were recorded and transcribed verbatim and were verified by the teachers before undergoing data analysis (Creswell, 2018; Rubin & Rubin, 2012; Yin, 2018). The study data and all identifying information were kept in a password-protected, encrypted file accessible only to the primary investigator and the researcher. Finally, the results of the study contained no identifiable information about the study participants or the schools and districts in which they worked.

Methods to Address Validity and Reliability

Validity

Yin (2018) posits two case study test designs to establish the validity of a qualitative instrumental case study. The first test design increases construct validity. Yin (2018) recommends using multiple sources of data to establish "converging lines of inquiry" (p. 44), emphasizes the need to establish a strong chain of evidence, and recommends participants and the researcher's peers review the case study. The study collected data from interviews and lesson plans provided by the teachers to ensure construct validity. The teachers who participated in the study reviewed the interview transcripts and suggested revisions for clarification. Participants Julie and Molly added clarifying statements to the transcripts, and the other eight teachers agreed that the transcript was accurate as recorded. The researcher's dissertation committee implemented a peer-review process, which provided feedback and probing questions, which provided an external check of the data collection and analysis procedures.

The other test design involves the external validity of the case study (Yin, 2018). The ability to generalize the case study's findings to the larger population of teachers increases the study's validity (Yin, 2018). The research questions included "how" and "what" question types, which increased the external validity of the study (Gay et al., 2012; Yin, 2018). Questions involving "how" allowed the teachers in the study to describe their perceptions of self-efficacy and explain how they engaged students in the SEPs through STEM-centric lessons. The data collected from the teachers were qualitative, which allowed the researcher to use analytic generalization, which allowed the researcher to develop claims based on the data along with supportive argumentation (Yin, 2018).

Reliability

Reliability in a case study is essential to "minimize errors and biases" (Yin, 2018, p. 46) so that future researchers who replicate the study obtain similar results. To ensure reliability for the study, the researcher developed a research design that ensured the interview protocol aligned with the research questions, thereby ensuring the data analysis was relevant (Yin, 2018). The researcher also recorded the teachers' interviews and transcribed them verbatim (Creswell, 2018; Rubin & Rubin, 2012; Yin, 2018). A case study database held all the study's data (Yin, 2018). The database was shared with the dissertation committee to allow the committee to conduct a critical review of the data independent of the case study's findings. As the researcher conducted the case study, the dissertation committee reviewed the case study's research design and processes to ensure alignment with the research questions.

Data Collection Procedures

According to Yin (2018), case study data collection includes gaining access to participants, using appropriate instruments to collect data, and planning for unforeseen events. To examine teachers' perceptions of self-efficacy as related to planning and executing STEM-centric lessons, the researcher chose to conduct interviews and collect STEM lesson plans from the teachers.

Instruments Used in Data Collection

Semi-structured interviews with open-ended questions were used to collect the data (Creswell, 2018; Rubin & Rubin, 2012; Yin, 2018). To create the interview questions, the researcher modified the Science Teacher Efficacy Beliefs Instrument-Version A (Riggs & Enochs, 1990). The modified interview questions included nine open-ended questions with eight follow-up questions (Appendix B). The follow-up questions probed deeper into the teachers' real-world experiences and activities (Rubin & Rubin, 2012; Yin, 2018). All teachers were offered a copy of the interview questions before the interview session. However, only one teacher requested a copy of the questions. Three interviews were conducted face-to-face, and seven interviews were conducted over the phone. The interview meetings ranged from 15-60 minutes.

Accurate data collection practices are essential to obtain useful data for case study research. To ensure accurate data collection during the interviews, the researcher audio-recorded the interviews and gave each participant a pseudonym. Teachers verified the accuracy of the interview transcripts. Two teachers made corrections to the transcript to clarify the intent of their responses. The other eight teachers verified the original transcripts.

Another instrument used in data collection for the study was the EQuIP Rubric 3.0. The EQuIP Rubric 3.0 measures a science lesson or unit's alignment with the NGSS and performance expectations outlined in the *Framework* (NRC, 2012; NSTA, 2016). The *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs are an iteration of the NGSS. Therefore, the EQuIP Rubric 3.0 was a practical instrument to determine if the teachers' STEM-centric lessons integrate the SEPs. To avoid introducing the quantitative aspects of a four-point rubric into the qualitative case study, the researcher used the rubric to determine the presence or absence of planning for SEP-integrated science lessons. The specific areas examined in each lesson or unit were (a) three-dimensional design, (b) instructional supports, and (c) monitoring student progress (NSTA, 2016).

Data Analysis

The researcher applied the data analysis spiral suggested by Creswell (2018) to analyze the study data. Qualitative case study data analysis involves the process of "moving in analytical circles rather than using a fixed linear approach" (Creswell, 2018, p. 185) often found in quantitative studies. The goal of the data analysis spiral is to use analytic strategies to produce specific analytic outcomes from the data (Creswell, 2018).

Managing and Organizing the Data

The first analytical spiral involved managing and organizing the data into a secure, sortable database. The researcher gave each interview transcript a unique identification code and stored the files in folders within the database. The teachers' lesson plans and other lesson documents were also stored in the database within each teachers' unique file folder.

Reading and Memoing Emergent Ideas

The second spiral required the researcher to listen to the interview audio files three times. The researcher also reviewed the transcripts as the audio files were playing to understand the nuances of what the teachers said in the interviews. The goal was to ensure the researcher understood the full meaning of the text. During the playback of the audio files, the researcher made margin notes on the transcripts to identify key ideas and concepts related to the research questions. Segment memos consisted of partial phrases from the transcripts or summary statements that reflected important ideas from the text (Creswell, 2018). The initial lesson plan review employed document memoing (Creswell, 2018), which allowed the researcher to capture concepts and key ideas from the lesson plans that supported the memos noted in the interview transcripts.

The memoing process led to the development of detailed descriptions of the teachers' real-world experiences. Inductive coding allowed the researcher to discern ideas from the data themselves. The codes permitted the researcher to make sense of the memoing descriptions

(Creswell, 2018). The initial code list included 27 codes and was recorded in a codebook. A sample initial coding table is displayed in Table 2.

Table 2

Sample Initial Codes (shortened names) from Each Participant

Julie	Charlotte	Teresa	Joy	Frank
District support in place to enhance instructional competence (Support)	Confident with teaching disciplinary core ideas (Instructional Competence)	Limited budget to purchase equipment and materials (Funding)	Dealing with a learning curve for new standards (Instructional Competence)	Student-driven learning engages students (Student Engagement)
Overcrowded classes make instruction challenging (Facilities)	Seeks additional learning and new teaching strategies to ensure the ability to teach content (Self-Taught)	District professional development is lacking (Professional Development)	One-on-One support needed (Support)	Professional development on how to analyze and interpret data (Professional Development)
Vertical collaboration to identify and address students' skill gaps (Teacher Collaboration)	State support documents are useful (Support Documents)	Relevant, real-world learning for students (Real-World Connections)	Frustrated with instructional delivery (Instructional Competence)	Students can re-do assessments to increase learning (Assessment)
Elaine	Barbara	Susan	Molly	James
Student engagement is essential (Student Engagement)	Integrates other content areas into science lessons when applicable (Cross-Curricular Integration)	Getting students to think critically is important (SEP Integration)	Confident with teaching Science and Engineering Practices (Instructional Competence)	Collegial collaboration allows teachers to share materials and resources (Teacher Collaboration)
Students' ability to reason in science supersedes content standards (SEP Integration)	Uses visual models to increase student understanding (SEP Integration)	Vocabulary is necessary for students to understand the content (Instructional Competence)	Professional development is useful but needs to be ongoing (Professional Development)	Spends personal funds on materials for laboratory investigations (Funding)
State support documents need revision to include sample activities and sample test questions (Support Documents)	Teaching science is time-intensive (Time)	Flexibility in scope and sequence is required (District Pacing Guides)	The science and engineering practices build students' confidence (Student Engagement)	Needs to review the science content standards (Instructional Competence)

Describing and Classifying Codes into Themes

The third phase of the data analysis spiral involves reducing the codes into a manageable set of themes related to the research questions (Creswell, 2018). The 27 codes were thematically grouped based on common ideas or having similar characteristics. The grouped codes were condensed into themes. A second codebook contained six themes: self-efficacy, pedagogic shifts, collaboration, lesson planning, student-centered teaching, and educational infrastructure.

Developing and Assessing Interpretations

The fourth spiral required the researcher to make sense of the data (Creswell, 2018). The researcher analyzed the data by identifying related codes and connecting concepts within the codes to create themes (Creswell, 2018). Each theme included a detailed description and noteworthy statements from the interview transcripts. The lesson plan data were incorporated into the theme development where applicable. For example, if a lesson plan evidenced that a teacher planned a SEP-integrated lesson, then it was coded as "SEP-integration" within the theme of lesson planning. Table 3 displays a sample of the data exhibited by themes used for interpretation.

Table 3

Sample Codebook for Theme: Self-efficacy

Theme	Theme Description	Significant Statements
Self-efficacy	A teacher’s perception of their instructional competence in a specific area.	“For this change in the standards in 2014, they weren't difficult for me in science, like I said, I’ve taught for 25 years.” “I read the standard and I read the engineering practices, and sometimes I feel like I don't exactly know how to blend them together.” “So, I think I am more effective as a teacher when I'm teaching students to use those [the SEPs]. I really think that that really drives how I do instruction.” “Well, the standards itself, I know by heart, and so I feel very confident in teaching those. Um, the engineering practices, not so much.”

Representing and Visualizing the Data

The final spiral involves representing and visualizing the data. Yin (2018) recommends a cross-case synthesis of case study data. The researcher conducted a within-case analysis of each teacher, followed by a cross-case analysis comparing the teachers to each other. First, the data for each teacher were analyzed, conclusions were developed, and results were reported independently. Because case studies offer comprehensive descriptions of the cases based on their real-world settings (Creswell, 2018), the researcher chose to use a narrative approach for each cross-case analysis of the interviews. The data from the teachers' lesson plans were compared through a cross-case analysis using a table format and were described using a narrative approach. Yin (2018) posits that cross-case analysis allows researchers to identify cross-case patterns and marked differences among the multiple cases. The diversity of participants from various schools in South Carolina provided insights into science teachers' perceptions of self-efficacy, student engagement, and the opportunities and challenges associated with implementing the SEPs across South Carolina.

Summary

Chapter III presented the methodological approach for this qualitative, instrumental, case study. The research study examined science teachers' perceptions of self-efficacy as related to planning and executing STEM-centric lessons. The procedures used for data collection included a semi-structured interview protocol to interview the teachers and the EQuIP Rubric 3.0 to examine the teachers' lesson plans. Ethical concerns and protections for the participants were explained to ensure the trustworthiness of the study. The steps taken to ensure the validity and reliability of the data were disclosed. The chapter concluded with an explanation of the data collection, coding, and thematic development processes that explored the research questions of this study. The data analysis was conducted through the lens of Bandura's (1977) social learning theory and the conceptual framework of self-efficacy. An in-depth analysis of the findings from this case study is provided in Chapter IV.

IV. RESULTS

The purpose of this case study was to examine science teachers' perceptions of self-efficacy as related to planning and executing STEM-centric lessons. The study examined the teachers' perceptions of self-efficacy, their SEP-integrated lessons, and the opportunities and challenges the teachers experienced when implementing the SEPs in their daily lessons. The goal of the study was to gain insight into the teachers' perceptions of self-efficacy as they taught the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs. The data were examined through the theoretical lens of Bandura's (1977b) social learning theory and the conceptual framework of self-efficacy. Using a qualitative approach for the study allowed for an examination of the teachers' experiences as they endeavored to teach the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs, and the impact the standards had on the teachers' perceptions of self-efficacy. This case study is the first to examine science teachers' perceptions of self-efficacy in the context of South Carolina public schools. The case study methodology provided an in-depth view of the teachers' perceptions of self-efficacy as related to the teachers' real-world struggles and successes as they engaged students through SEP-integrated lessons (Creswell, 2018). Chapter IV provides a within-case analysis of each teacher, a cross-case analysis comparing the teachers' experiences, and the results of the qualitative study.

Methods of Data Collection

Data were collected from ten teachers in five South Carolina school districts. Initially, the researcher contacted five teachers face-to-face to invite them to participate in the study. Three of the teachers gave consent to participate. The researcher employed the snowball sampling technique (Gay et al., 2012) to recruit more study participants. The snowball sampling technique produced 13 more viable study participants, many of whom worked in the same school district. After the potential participants received a detailed explanation of the study, seven science teachers signed written consent forms to participate, bringing the number of study participants to ten.

Ten teachers volunteered to participate in the study. The teachers were given pseudonyms to protect their identity and to ensure easy identification throughout the study. Four of the teachers in the study were veteran teachers with over 20 years of experience. Another four teachers had 12–17 years of experience, and two of the teachers had five years of experience or less. The participants' ages spanned over 40 years. Two of the teachers were 20–30 years of age, one was 30–40 years old, two teachers were 40–50 years old, four teachers were 50–60 years old, and one teacher was 60–70 years old. The public school instructional positions held by the ten science teachers spanned third grade through tenth grade. Nine of the teachers worked in traditional public schools, and one teacher worked in a public charter school in South Carolina. Participants included eight female teachers and two male teachers.

All the teachers participated in traditional teacher preparation programs to receive their teaching degree and license. However, three of the teachers did not begin their careers in education, and three of the teachers obtained advanced science degrees after becoming a teacher. Before becoming teachers, James received a bachelor's degree in geology and worked in the oil industry. Susan received bachelor's degrees in chemistry and biology and worked for an environmental corporation and in the medical field. Teresa worked in the retail industry. Two of the teachers hold master's degrees in a science field. Frank has a master's degree in environmental science management, and Elaine has a master's degree in biology. Barbara has bachelor's and master's degrees in elementary education and earned an EdD degree in teacher leadership. Demographic information is shown in Table 4.

Table 4

Demographic Data for Case Study Participants

Participant	Age	Years of Experience	Instructional Position	Grade Level
Molly	40-50	26	Elementary	3rd-5th
Charlotte	50-60	27	Elementary	5th
Julie	50-60	25	Elementary	4th
Barbara	50-60	34	Elementary	5th
Joy	20-30	2	Middle	6th
Frank	30-40	12	Middle	7th
Teresa	50-60	15	Middle	7th-8th
Susan	60-70	17	Middle	7th-8th
James	20-30	5	High	9th
Elaine	40-50	14	High	10th

The primary data were collected from three face-to-face interviews and seven phone interviews. The instrument used was an interview protocol consisting of nine open-ended questions with eight follow-up questions about teachers' perceptions of self-efficacy, STEM-centric lesson planning, engaging students in the SEPs, and the opportunities and challenges the teachers dealt with on a day-to-day basis (Appendix B). Individual interviews were conducted from January 2020 to March 2020 and were scheduled at the convenience of the teachers. The interviewees included two high school science teachers, four middle school science teachers, and four elementary teachers.

Seven of the teachers chose to interview over the phone, one teacher chose a restaurant venue, and two teachers chose to interview at home. Nine interview sessions were audio-taped using a hand-held recorder, and one used a laptop app to record the interview. Each interview session followed the interview protocol. The interview protocol addressed the three research questions of this study:

1. How does science teachers' self-efficacy influence their teaching of the 2014 science standards and SEPs?
2. How do teachers engage students in the SEPs?
3. What are the opportunities and challenges teachers experience when implementing the SEPs?

The interview protocol guided the interview sessions and ensured continuity in the data collected from each teacher to address the research questions. Each interview recording was initially transcribed using the Temi API software program. The researcher conducted a thorough review of the transcriptions using the audio files to ensure each transcript was accurately transcribed verbatim. The teachers reviewed the final transcripts and verified that they accurately represented their answers to the interview questions. Two teachers chose to make corrections to the transcripts. The validated transcripts were coded and categorized based on the questions in the interview protocol.

The second data source for the case study came from the four STEM-centric lesson plans each teacher submitted. The lesson plans were analyzed using the EQuIP Rubric 3.0 (Rubric).

The researcher examined each lesson plan for the presence or absence of (a) three-dimensional design, (b) instructional supports, and (c) monitoring student progress (NSTA, 2016). The three-dimensional learning portion of the Rubric provided insights into the teachers' integration of the science and engineering practices, crosscutting concepts, and disciplinary core ideas. Three-dimensional learning allows students to make sense of natural phenomena or design solutions to real-world problems. The Rubrics' instructional supports section provided an examination of how the teachers planned to incorporate students' prior knowledge as they investigate new phenomena or problems. The student progress elements of the Rubric examined the teachers' incorporation of summative and formative assessments (NRC, 2012). Although the EQuIP Rubric 3.0 uses a four-point scale, the researcher did not assess the degree to which each area of the rubric was present in the lesson plans to avoid introducing quantitative aspects into this qualitative research study. Lesson plan data were collected to corroborate participants' interview answers to strengthen the validity of the study (Yin, 2018).

Findings

Ten teachers from five different school districts in South Carolina participated in the case study. The within-case analysis for the study was conducted through an examination of the teachers' data. One teacher each from four different school districts consented to participate in the study. As a result of the snowball sampling technique, an additional six teachers from a fifth school district participated in the study.

Study Population

The research data came from schools in the Upstate, Midlands, and Lowcounty regions of South Carolina. The case study involved teachers from across South Carolina who worked in public K-12 school districts and the state charter school district. South Carolina has four general regions: the Upstate, the Midlands, the Pee Dee, and the Lowcountry. Geographical location information for each teacher is provided in Table 5.

Table 5

Regional Location for Case Study Participants

Participant	Level of Teaching Assignment	Subjects Taught	Type of School District	Region of South Carolina
Molly	3rd-5th	Elementary – Engineering	Public	Lowcountry
Charlotte	5th	Elementary – Advanced Science and Mathematics	Public	Lowcountry
Julie	4th	Elementary	Public	Upstate
Barbara	5th	Elementary	Public	Lowcountry
Joy	6th	Middle – Science and Social Studies	Public	Midlands
Frank	7th	Middle – Science and Mathematics	Public	Lowcountry
Teresa	7th-8th	Middle – General, Advanced Science and Earth Science	Public	Lowcountry
Susan	7th-8th	Middle – Science	Public	Upstate
James	9th	High – Earth Science	Public	Lowcountry
Elaine	10th	High – Biology	Charter	Midlands

Analytic Focus

The within-case analysis of each teacher's interview and lesson plan data allowed the researcher to identify significant statements that related to the teachers' perceptions of self-efficacy as related to planning and executing STEM-centric lessons. Writing memos and using an inductive coding process guided the development of the codes (Creswell, 2018). The within-case analysis led to the development of 27 codes. Next, the researcher conducted a comparison of each significant statement among all the teachers' data, which led to the identification of common statements across the cases. The cross-case analysis of the teachers' significant statements revealed six themes. Table 6 shows the 27 codes grouped into six themes.

Table 6

Codes grouped by Theme

Self-efficacy	Pedagogic Shifts	Collaboration	Lesson Planning	Student-centered Teaching	Educational Infrastructure
Instructional competence	Professional development	Teacher-teacher collaboration	SEP-integration	Student-student collaboration	Facilities
Stress	Self-taught	Mentoring	Models	Student engagement	Overcrowding
		Support	State mandates	Real-world connections	Funding
			SC support documents	Claim-Evidence-Reasoning	Materials
			SC instructional units	Critical thinking & problem solving	Equipment
			Developmentally inappropriate	Assessment	Time
			District pacing guides		
			Cross-curricular integration		

The six themes and findings were examined in-depth in the context of the study's research questions and individually.

Research Questions

After the teachers validated the interview transcripts and submitted four STEM-centric lesson plans, the data were analyzed. The interview audio files and transcripts were reviewed three times to ensure a full understanding of the transcripts. The teachers' lesson plans were examined using the EQuIP 3.0 Rubric to identify important concepts and key ideas that supported or refuted the interview data. An initial codebook of the interview transcripts and lesson plans data were analyzed using color-coded memos. The color-coded memos led to the development of 27 codes, which guided the identification of themes for the case study. A second codebook organized the significant data that emerged from an examination of and was used to develop six themes. The second codebook addressed the research questions.

Research Question 1

How does science teachers' self-efficacy influence their teaching of the 2014 science standards and SEPs?

All teachers in the study shared experiences about their instructional competence that impacted their perceptions of self-efficacy. Four of the teachers indicated high levels of instructional competence for teaching the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs. Molly, who supported general education teachers' work with students through an engineering specials class, mentioned how the SEPs help students investigate the disciplinary core ideas. She stated, "I mainly operate within that SEP of being given a problem, designing a solution, doing research and experiments in order to drive [students' design] solutions." Elaine summarized the concept of how integrating the SEPs into science lessons resulted in a strong sense of instructional competence. She said, "I think I am more effective as a teacher when I'm teaching students to use those [the SEPs]. I really think that that really drives how I do instruction."

Six teachers in the study disclosed low levels of instructional competence for teaching the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs. Charlotte shared her lack of confidence. She said, "Well, the standards itself, I know by heart… I feel very confident in teaching those. Um, the engineering practices, not so much." Joy shared her frustration with trying to integrate the SEPs into daily science lessons. She stated, "I read the standard, and I read the engineering practices, and sometimes I feel like I don't exactly know how to blend them together." Teachers who reported low levels of instructional competence also mentioned feeling stressed about integrating the SEPs in their daily lessons.

Frank revealed a problem with the layout of his district's instructional pacing guide that impacted his instructional competence:

> Our district [pacing guide] helps us follow the standards, but I don't really feel like that helps [us] follow the science and engineering portion as well. I very rarely look at the engineering practices because that's not [at] the forefront of [the district pacing guide].

Teresa lamented the difficulties she has faced when other teachers have misunderstood science content and taught students misconceptions. She stated, "The teachers in elementary [teach them] something wrong and… that's a pain. Sometimes I want to pull my hair out and scream." Teresa's frustration stemmed from K-6th grade teachers not learning the new content of the standards. Joy provided an example where her instructional competence impacted a science lab. She shared how she couldn't explain why a lemon wouldn't light up a light bulb. She said, " It was really frustrating for them because they could not get it to light up, and they were asking me why. I really couldn't tell them why." Charlotte expressed frustration with the South Carolina instructional units and support documents. She shared, “I don't deal with engineering. So, you expect me to teach it, and all you do is put words on a page. Why don't you give an example or give a sample?”

When the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs were adopted, traditional science teaching methods changed, and teachers’ pedagogical skills had to change as well. All teachers in the study indicated a need for professional development related to how to integrate the SEPs into their lessons. Joy shared, “I feel like I definitely need more time to have somebody sit down with me and really go over the standards with the support document [to] see how they relate.” All the teachers indicated that they sought out formal professional development as well as informal learning opportunities and collaboration with other teachers. Three of the elementary school teachers and one high school teacher stated that they attended national and state-based professional development sessions. The other six teachers indicated that they only received school-based professional development and that it was delivered sporadically. Julie indicated that she had to

> … do more research on my own to be able to understand the topic well enough so that when I presented it to the students, I was able to present it in a way that they could understand. It required me depending on other teachers who were more experts in the field.

All teachers mentioned learning the content and SEPs on their own at home. Charlotte shared:

> I had to teach electricity, and I didn't know what any of that stuff was. We had a FOSS [Full Option Science System] kit. I took the FOSS kit home, and I watched the video, and I read the [teacher guide], and I played with all the stuff and taught myself how to do it.

Susan had a similar response as Charlotte, when speaking of equipping herself to teach. She said, “Research! That's it. You have to prepare; you have to take the time ... so I can find more information for myself.” All the teachers revealed that they collaborated with colleagues to learn new ways of delivering instructional content to their students. Two of the teachers, a middle school teacher and an elementary school teacher, indicated that they looked for teacher-mentors during the school year to help them integrate the SEPs into their lessons. James stated:

> I just moved rooms... two doors down from the engineering teacher at our school. I think having him next door is a really good opportunity in terms of just being able to bounce ideas off him because his background is in biology. I think that's a good opportunity… to pick his brain... like how he teaches, how he takes that science component and then hooks into engineering.

Joy shared, “I feel like with this being my first time in a sixth-grade classroom, I really haven't had the time to [explore the standards and SEPs]. Getting the time and really appreciating that time is something that I would like.”

Research Question 2:

How do teachers engage students in the SEPs?

The primary way the teachers in the study engaged students in the SEPs was by having students use the SEPs to investigate the grade level disciplinary core ideas. James described how he integrated the SEPs more easily into one unit compared to another unit. He said, “If we're doing a geosphere unit, I'll do a little more hands-on with what I'm planning as opposed to something with astronomy, which is a little more theoretical.” Molly shared how she planned engaging engineering lessons. She stated, “I usually start with the build idea: What is the problem that they're going to have? What kind of solution they need? Then I go [backward] from that thinking, 'Okay, well, what's the science they need to know?'" All the teachers in the study reported using the developing and using models SEP often. Charlotte emphasized the importance of using models in science lessons when she said, "Talking doesn't work, so you have to bring in examples, and you've got to do the model."

Every teacher in the study indicated that they used the *South Carolina Academic Standards and Performance Indicators for Science 2014* to engage students in the SEPs. The teachers also stated that they used the South Carolina science support documents, the South Carolina science instructional units, and the district pacing guides in varying degrees to plan engaging science lessons. Joy, a novice teacher, revealed that she depended on the South Carolina support documents to help her with instructional plans. She shared, "I really use the support documents to kind of see exactly what the kids really need to know." She feels that the standards are not always explained, and the support documents help. She said, "I always reference it, especially with planning. That way, I know exactly what to tell the kids that they need to know,"

Elaine, a veteran teacher with a degree in biology favored a more flexible method of planning engaging science instruction. She stated:

> It's kind of taking all the little bits and pieces that I have in the world around me and then using those to plan at the gross level and then at the unit level. Then, in that unit level, to plan for the day-by-day because I have a sequence of activities that I like to do. But, sometimes, a student might have a question [and I'm] going, "Okay, perfect!" Tomorrow is going to be this activity where we are looking at eye color, and that means we're doing polygenic traits before we get to do something else. But, [my] students are interested in this; it is where they're engaged. I'm just kind of trying to be flexible, I guess.

Six of the teachers reported that they did not use the South Carolina instructional units to help them plan science instruction. Three of the teachers indicated that they found useful resources in the instructional units. Elaine shared that she uses the Collaborate, Plan, Align, Learn, Motivate and Share (CPALMS) websites found in the instructional units. She added that she liked how the instructional units identified each science unit's key vocabulary terms. One teacher indicated that the units were useful for creating sub plans.

Julie and Barbara described how their students enjoyed investigating the disciplinary core ideas through collaborative groups. Julie shared, "But just to tell them that they're going to be able to work together with their peers and construct [something] or do an investigation to prove [something]. Just that right there [gets] them excited." Barbara stated, "Well, [I] have them team up, have them brainstorm… and half the time they realize they knew a lot more than they thought they did."

All teachers in the study mentioned using real-world connections to engage students in the SEPs. Julie said, "I also try to tie science into everyday life. A lot of times I let students share what they know, and when students hear things from other students, that gets them more excited." Charlotte has used creative means to engage her students in the SEPs. She shared:

> While we were doing heterogeneous mixtures… [students decided] that Santa could no longer eat cookies. They had to come up with another healthy recipe that was a heterogeneous mixture. But when I showed them [a] fake Facebook post where Santa says, "Heads are gonna roll!" [because] the reindeer were talking trash about him on Facebook [since] he was so fat… the kids just died! They loved it, and it engaged them.

Molly shared how she uses real-world connections to help students of different ability levels engage in the SEPs. She said:

> For [my] classes that may not be as high or may not have that rich background, I try to relate it to their everyday life. I was told a few years ago that science is 50% common sense and experience and the other 50% is vocabulary, so I try to find something in their life that ties to it.

Teresa used the claim-evidence-reasoning technique to engage her students in the SEPs through critical thinking and problem-solving. She shared that after her middle school students do a build or an investigation, she asks them, "Where's your evidence? It's not [the] fuzzy, feel-good [stuff]. Where's your evidence? They get tired of me saying, where's your evidence?" Elaine described how she uses critical thinking and problem solving to move her high school students to higher levels of learning. She said:

> I generally don't ask them basic Bloom's level one [questions]. I want to know why [they] think, and what [they] think. I'll say, "Well, what do you think about that?" One of my biggest things that I've done is when I ask students to answer a question, I asked them to give me a claim, like, what's the claim? What evidence did they use to come up with their claim and [what was their] reasoning? I use… claim, evidence, reasoning [but] with my students, I call it claim, evidence, justification. "How does that evidence support your claim?" [I am] trying to get them engaged in those reasoning skills.

Susan also allows her students to engage in the SEPs through critical thinking and problem-solving processes. She described a typical laboratory investigation scenario. She said:

> I've given them the question. I've given them the lab utensil. They now have to think of the steps and the procedures [needed to find the answer to the question]. Then they have to try [their solution], and they might have to try [it] four and five, six, [or] seven times

> before it works. That's teaching them about how scientists [investigate things]. They try things over and over again before it can even become a theory.

Four teachers shared how they use assessment to engage students in the SEPs. Frank shared, “After the summative assessment, I'll go back and say, ‘You're missing this part or these parts of the summative assessment. Here's an assignment that you can do to help you and then you can retake the test.’” Elaine stated the importance of allowing students to redo assessments, which reflected the reiterative process of scientific inquiry and the engineering design cycle. She said, “One of the things I really think of is it's the process with science. It's not the absolute answer. I give kids the opportunity to come back. They can come back and correct quizzes. We go over them.” Molly uses the same reiterative design process with her students. She said, “The assessment is always the build and the improve [portions of the engineering design cycle]. That's pretty much a given thing, and I also try to include feedback for them at that point.”

Research Question 3:

What are the opportunities and challenges teachers experience when implementing the SEPs?

Opportunities. Each teacher in the study readily identified opportunities they experienced while implementing the SEPs. The teachers associated the concept of students experiencing successful learning outcomes as synonymous with the concept of opportunities. Joy and Frank described successful science investigations as an opportunity. Frank said:

> We do a lot of investigations in class… a lot of modeling. I think a lot of the success has been from those two. Just because, it's student engagement and they like to build things. Anytime you model something or have them build models of something; it really makes the lesson go well.

Charlotte shared the success of how a model helped her students with scientific vocabulary. She shared, “The bathymetry boxes [have] been a great success. It helps the kids visualize that obscure vocabulary… and that's been very successful.” Barbara held similar thoughts about vocabulary and went on to describe how she used the SEPs for cross-curricular connections. She said:

> It's so much easier to develop vocabulary because you start with the questioning and then let them plan and conduct their own experiments. Then, overlap it with mathematical computation, overlap it with math and ELA, and… end it with writing. Always end it with writing.

Seven teachers in the study reported that they routinely engaged students in the SEPs through cross-curricular connections with other subjects. The teachers stated that they incorporated writing and math in their lessons. Barbara shared that she was working on integrating social studies in her science lessons as well. Molly described how she worked with teachers in her school to help them incorporate more cross-curricular connections in their social studies lessons. She shared, “I'm finally, after years, seeing [social studies teachers] come up with projects… that they [discussed with their] science [teammate.] It's been a long way coming. But just getting the buy-in from everyone sometimes is difficult.”

Teresa and Joy related the opportunities they experienced when implementing the SEPs to student engagement. Joy said, “One success would be just the student engagement and the student thinking and really seeing them problem solve instead of me doing the problem-solving.” Both teachers also mentioned how on-campus and off-campus field trips engaged their students with the SEPs by giving them real-world experiences.

Julie indicated that the opportunities she experienced when implementing the SEPs related to the success of her students. She said, "A success for me implementing those [the SEPs] is to see my students really own the learning." Elaine shared similar thoughts when her students learned from their failures during laboratory investigations. She shared, "[I tell them to] 'do the lab again. See what happens; that way we learn as much from our failures as we learn from being successful.' I have seen some incredible growth with students." Molly described how rewarding it was when her students persevered with a design challenge that originally failed. She shared that when her students say, "'If it doesn't work, I'll just do this instead' it is a very big success." Molly also shared an example of why students of every ability level deserve the opportunity to engage with the SEPs. She described one of her student's successes saying, "That kid's grades, nothing to write home about, but he had a knack for the engineering. Those are the children who may not be successful on paper." Exploring the disciplinary core ideas with the SEPs gives students "an opportunity where they can be successful," which builds their confidence.

James described being able to collaborate with a colleague as an opportunity. He said, "It's kind of like an opportunity to pick his brain and add it [his knowledge] into my classroom in terms of ideas." Molly shared a different form of collaboration. She identified mentoring teachers and sharing her expertise as an opportunity she had experienced while implementing the SEPs. She shared:

> I've had opportunities to work with them [teachers] when they were not comfortable with the SEPs to [help them] as they needed it and give support if they needed it. I've also presented at a couple of Title 1 conferences on the importance of giving the STEM opportunities not just to your high ability children but to all children.

Challenges. All teachers in the study quickly identified the challenges they experienced while implementing the SEPs. The challenges were related to school facilities or district-wide systems that negatively impacted the teachers' ability to provide instruction for students.

One challenge was physical classroom space for five of the teachers. James taught earth science in a non-laboratory classroom during the 2019-2020 school year. He said, "I don't have a lab class now. You know, I don't have access to water or anything like that in my class. I have to bring it in before the class actually starts and… prep our labs beforehand." Charlotte and Julie identified the lack of classroom space as a challenge in implementing the SEPs. Charlotte shared, "There's so much stuff that if you're going to do hands-on science… there's just not enough space to put it." Julie explained how she made space for her students to complete their science lessons. She said:

> Space is always an issue. Like I mentioned before, [I have] 29 students in a classroom. We [have] whiteboard tables, which helps a little bit. Sometimes, I just have to push the tables out of the way. Sometimes, we end up going in the hallway if we're testing something… you kind of just make it work.

Challenges related to equipment were noted by six of the teachers. Teresa, who worked in a new school, said, "Oh equipment, we don't have equipment because, you know, we're new." Frank worked in a school that has accumulated and misplaced a lot of equipment over the years. He shared that the school used "these things called FOSS kits that I've tried to use… It's just a lot of work just trying to find this stuff around our school."

The teachers also reported challenges associated with not having enough materials to allow their students to authentically engage with the SEPs. Elaine described a situation where she did not have enough materials. She said, "A lot of my frustrations with delivering content is that I don't have the materials that I need for that. Like, when [my last school] opened, we legitimately had two hot plates for the entire science department." In contrast, Charlotte, Julie, and Molly reported having enough materials for their classroom needs. Molly stated, "I'm very lucky now that I have materials, but there have been years where materials are scarce."

Challenges related to school or district-systems were also problematic for seven of the teachers. Julie and Teresa reported that they had overcrowded classrooms, which impacted their ability to implement the SEPs. Teresa shared:

> I've got a class of 39… I can't move in there. I use a lot of technology, which kind of stinks because if I do something… I got to take it all to the hallway. The school is overcrowded and that limits a lot. I would say the class sizes cause a huge issue!

Funding was also a challenge for seven of the teachers. Susan was not at the school for the prior year and did not participate in budget planning. She finds that she does not have the things she needs for class. She said, "I'm constantly…borrowing things this year, and I don't know [whom] to turn to." Elaine shared that the school budget has been problematic for her in the past. She stated that her previous school gave her $500 to spend on materials for six different science courses. Molly acknowledged the challenges teachers face with limited budgets and inadequate funding. She shared:

> They [materials] cost and I'm always laughing when you skim projects, and I'm going, "I need 7,000 more straws," and they're [administrators] like, "What do you need 7,000 straws for?" But if you give ten straws [to] each group for the whole school, you use a bunch of straws. Even though I'm at a place where... there's a pretty big budget for STEM. If I did not have that, I couldn't… it would be almost impossible.

Two of the teachers did not report funding as a challenge for them because their students' parents or they themselves purchased the necessary materials to implement the SEPs. Julie stated:

> I don't really think that supplies are a challenge for my school. We have very supportive parents that we contact when we're going to be doing some type of investigation or something with an engineering practice. We also have district money that is given to us once a year, and we use that to do a purchasing order.

Charlotte indicated that she used personal funds to buy what she needed to implement the SEPs in her lessons. She said, "Funding has never been a challenge, not really. You know, I can go to the store and pick up what I need." One teacher reported having enough funding to purchase what he needed to implement the SEPs each year. Frank said, "I feel like there's pretty good support as far as financial support from our school."

Six other teachers reported funding as a challenge and also reported that they used personal funds to be able to implement the SEPs in their lessons. James stated, "The biggest challenge I have now is just a lack of supply in terms of proper materials for a lab. I'll pay for a lot of labs out of my own pocket." Teresa shared that sometimes she employed extreme measures to ensure she had adequate materials to implement the SEPs without having to spend her own money. She said, "We [administration] always close up our purse in the front office when I say, 'Can I,' and they say, 'Well, you can have this piece but not this piece.' There's not equipment either. I dig through trash a lot."

Nine of the teachers in the study indicated that they did not have enough time to implement the SEPs with fidelity in their science lessons. Frank described how his daily schedule created a challenging situation for him. He said:

My biggest limitation is [that] I teach math… too, so I have to share my planning time. I can't always plan great lessons because I'm also planning for math and grading things for another subject. I think the lack of time to build those really great lessons... or to set up a lab, that takes a lot of time. I think time is the biggest [challenge], and there's always more that you can do.

Barbara also described her challenges in finding time to set up design challenges and investigations. She shared:

> Just finding the time to get out all the materials. You know, science is a lot harder to prepare for than any of the other subjects. It's more layered and more time-intensive than the other subject areas, but well worth it.

Elaine recalled her challenges related to time and implementing the SEPs. She said:

> I was teaching four different lab classes at the same time. I'm having to do a ton of work for that. There's just not time. The same thing applies for… prepping material. I have to give it up at some point. I have to say, "Okay, it's this, it's enough." When I know that if I actually had another two hours, it could be amazing.

Only one teacher did not cite time as a challenge to implementing the SEPs.

District pacing guides were identified as a challenge. Teachers from three different school districts shared their challenges with the pacing guides. Julie said, "I guess for me, I've always struggled with this. The pace that they expect those standards to be taught at is difficult for me. I think, sometimes, that the standards are way over the head of a fourth-grader." Joy held a similar view of the district pacing guide for her sixth graders. She shared:

> With the science and engineering practices, I know that like with our pacing guide... the science instructional coach for the district [wants] us to teach one unit within the first

> nine weeks. But it's so much content and, especially with sixth graders, the first three weeks you're just getting them used to middle school.

Frank mentioned that the district pacing guide limited how much remediation he could do with his students. He wished for more time for his students to be able to "go back though" to master the content. He shared, "Usually, that time isn't there for all students." Elaine recounted a time when her district's pacing guide limited her ability to implement the SEPs with fidelity. She shared, "When a school district says, 'Well, you got to treat them [students] all the same way, or you've got to do it [teach] this particular way,' I lose my ability to help that one kid sometimes."

In contrast, three teachers stated that their district pacing guides were flexible. Susan said, "We didn't go in the order that South Carolina has. We felt it was better to teach waves and force and motion more towards the end of the year. We're going to do that, which is a new dynamic at the school." Barbara's district allows teachers to adjust pacing guides. She shared, "When I didn't think we were allowed to, that was hard… But now… being allowed to run it around like that makes it easier."

Themes

To identify themes from the data, the researcher implemented Creswell's (2018) data analysis spiral. The data spiral involves memoing and developing codes, which were categorized into themes. The data were organized according to the themes that emerged from the analysis, and codebooks were formed. Table 7 presents the themes that emerged from the data analysis.

Table 7

Theme Descriptions

Theme	Description
Self-efficacy	A teacher's perception of their instructional competence in a specific area.
Pedagogic Shifts	Changes in how teachers plan for and teach STEM-centric lessons.
Collaboration	Teacher-to-teacher collaboration that supports teachers' ability to plan STEM-centric lessons.
Lesson Planning	The act of planning a developmentally appropriate STEM-Centric lesson or unit that integrates the SC 2014 science standards and science and engineering practices.
Student-Centered Teaching	Teaching that places the student at the center of instructional choices.
Educational Infrastructure	The hard of the soft infrastructure of a school that directly or indirectly impacts instruction.

Theme 1: Self-efficacy

Self-efficacy, according to Bandura (1977b), is an individual's perception of competence in a specific area. Teachers' self-efficacy is based on their instructional competence. All the teachers in the study indicated that they struggled with their perceptions of self-efficacy for teaching the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs. James, who is new to his district, said, "I think any teacher realistically can go… self-doubt your first year. I feel like you always have those moments in those fields where you're not as strong." Molly, a veteran teacher, indicated that she knows many teachers who are not comfortable integrating the SEPs. She shared, "Science tends to be something that they are afraid of. So, when the SEPs came in, even [for] teachers who had been teaching a long time, it was new." Julie stated, "Sometimes I struggle with some of the [curriculum] when… it's a brand-new unit, and I've never taught it before."

However, the data analysis indicated that most of the veteran teachers in the study had higher perceptions of self-efficacy compared to novice teachers, teachers who were new to their district, or teachers who had changed grade levels. Elaine, a veteran teacher with an advanced degree in science, stated, "I think I am most effective when I'm teaching the practices or using the practices to drive instruction because that's also something they're going to be able to use later." In contrast, Joy, a novice teacher, said, "I don't feel like I am teaching them [the SEPs] well. I guess with this being my first year in sixth-grade science, I'm really just trying to get the content down to help them [students] know."

The teachers' perceptions of self-efficacy were related to how prepared they were to design and teach STEM-centric lessons. To create SEP-integrated lesson plans and to teach them with fidelity, the teachers noted that pedagogical shifts were necessary.

Theme 2: Pedagogic Shifts

Pedagogic shifts refer to changes in how teachers plan for and teach STEM-centric lessons based on their learning from professional development and self-preparation. Appropriate changes in pedagogical strategies result in design challenges and inquiry-based investigations that create transformative learning opportunities for students.

All teachers in the study indicated varying degrees of instructional support as they attempted to integrate the SEPs into their daily science lessons. One teacher who worked in one of the Upstate school districts indicated the availability of ongoing school and district-level support after the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs were adopted. Teachers from the Midlands and Lowcountry regions and one teacher from the Upstate region indicated that the only support available to them was at the building level. All teachers said it was necessary to teach themselves most of the time how to do an investigation or design challenge.

Nine of the teachers stated that they struggled with integrating the engineering design process, which is a component of the SEPs. Charlotte admitted, “I'm not comfortable with the engineering practices. I mean, I'll reach out and try some things, but I basically teach the scientific method, you know, [but] I try to implement the engineering design method.” In reference to supporting students with science projects and engineering design projects, Frank indicated that he had more experience with the scientific method. He shared, , “I haven't had a lot of experience with the design method, and that's been challenging.” The only teacher comfortable with the engineering design process was Molly.

Teachers’ perceptions of self-efficacy were also positive when the teacher used a variety of instructional resources. Charlotte stated that she used several resources to teach her science lessons. She said, “We use hyper slides… videos, articles… GIM kit, Quizlet… hands-on experiments… and outside resources like Newsela, generation genius, [and] discovery education.” Susan shared that she incorporated physical movement in her lessons. She stated, “We also sometimes [act] out vocabulary words. They have to act them out to each other. We do GIM Kit games. They love that…and build crossword puzzles for each other.”

Teachers who reported working on a team or who reported cross-curricular collaboration had positive perceptions of self-efficacy compared to those who did not have such supports in place. James expressed appreciation for his fellow science colleagues. He said, “We help each other out a lot with material and content. We’re a pretty good support group for each other.”

Theme 3: Collaboration

Teacher collaboration can occur during formal planning periods or at other times during the school day when teachers have brief periods to talk about instructional strategies and content. Collaboration supports teachers' ability to plan STEM-centric lessons through shared resources and may include one-on-one mentoring.

Regardless of whether the teachers reported positive or negative perceptions of self-efficacy, all the teachers in the study found value in collaborating with colleagues. Susan shared, “Support is wonderful! Collaboration... I can't say enough about it; people help me left and right.” All but two of the teachers in the study regularly collaborated with at least one colleague. Frank, one of the teachers who did not collaborate with other teachers, stated, “We don't have enough time because our planning periods are all different… no, I do not collaborate very often. I mean, like maybe once a month we meet, but we really don't plan together.” Teresa, the other teacher who did not collaborate and a veteran teacher who worked in a newly opened school with novice teachers, also recounted, “I feel stale. There's nobody to bounce thoughts off from.” She said novice teachers “don't even know where the standards are... I had to introduce them to the 2014 standards.”

The need to help other science teachers with the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs led to two teachers reporting how they mentored other teachers. Elaine recounted her experience at a National Science Teachers Association conference. She shared, “I took my whole department, and I encouraged them to look at the science and engineering practices because again, for me, that's the important part of the science knowledge." Molly shared, "There's a lot of teachers who are not as comfortable, especially in elementary… I've had opportunities to work with them… with the SEPs to… help pull them along as they needed it and give support if they needed it."

Data analysis indicated a need for veteran teachers and novice teachers to increase their perceptions of self-efficacy related to integrating the SEPs in their daily science lessons. A clear need for ongoing, high-quality professional development was apparent in all cases. However, formal professional development was not the preferred method desired by the teachers. The data indicated that seven of the teachers sought out expert-teachers within their school building to help them create SEP-integrated science lessons and to help them learn new pedagogical practices for teaching science. Only one teacher in the study did not mention the need for support from an expert-teacher. Two of the teachers in the study reported being expert-teachers who worked one-on-one with teachers as needed. The most desired form of professional development that emerged from the data was providing teachers with a personal, one-on-one mentor-type relationship with an expert teacher.

Theme 4: Lesson Planning

According to Jorgenson, Vanosdall, Massey, and Cleveland (2014), STEM-centric lessons include "at least two of the [Science, Technology, Engineering, or Mathematics] disciplines" (p. 41). STEM-centric lessons also have literacy components interwoven with "problem-solving, discovery, and other higher-order thinking skills" (Jorgenson et al., 2014, p. 39). For the teachers in the study, lesson planning involved the creation of developmentally appropriate STEM-centric lessons or units based on the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs, the South Carolina support documents, the South Carolina instructional units, and district pacing guides.

The teachers in the study reported planning STEM-centric lessons for their students based on one or more of the documents during their interviews. All teachers stated that they used the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs, support documents, and district pacing guides to plan their lessons. However, six teachers reported not using the South Carolina instructional units because they did not find them useful.

Each teacher submitted four lesson plans for examination in the study. The lesson plans were examined using the EQuIP Rubric 3.0. The EQuIP Rubric 3.0 allowed the researcher to objectively examine each lesson plan's alignment with the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs. Molly, who reported being a member of the state committee that created the South Carolina instructional units, was the only teacher who integrated all the SEPs in her engineering design lessons. The lesson plans of all the teachers included a component related to developing and using models SEP. Six of the teachers' lesson plans were STEM-centric according to the criteria suggested by Jorgenson et al. (2014). In contrast, four of the teachers' lesson plans only included developing and using models SEP and did not contain any additional SEPs, technology, engineering, or mathematics components. Consequently, the four teachers' lessons did not meet the criteria for being STEM-centric lesson plans. Table 8 shows the presence or absence of one or more of the SEPs in the teachers' lesson plans.

Table 8

Lesson Plan Examination with the EQuIP Rubric 3.0 – Science and Engineering Practices

	SEP Integration							
Participant	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
Molly	✓	✓	✓	✓	✓	✓	✓	✓
Charlotte		✓						
Julie		✓						
Barbara		✓	✓	✓				
Joy		✓						
Frank		✓						
Teresa		✓				✓		
Susan		✓		✓		✓		
James		✓		✓				
Elaine		✓		✓		✓		

An unexpected outcome of examining the teachers' lesson plans with the EQuIP Rubric 3.0 was the presence of crosscutting concepts (See Table 9). Crosscutting concepts are part of three-dimensional learning experiences. Three-dimensional learning incorporates the disciplinary core ideas, the science and engineering practices, and the crosscutting concepts (NRC, 2012). Creating lessons that include crosscutting concepts allow students to make intellectual connections between disciplinary core ideas and to discover relationships across the disciplines of science. The *South Carolina Academic Standards and Performance Indicators 2014* includes the three-dimensional learning design recommended by the *Framework* (NRC, 2012; Zais, 2014).

Although four of the teachers' lesson plans contained only the developing and using models SEP, all the lesson plans included three-dimensional learning, as evidenced by the inclusion of at least one crosscutting concept. The single crosscutting concept found in all lesson plans was the systems and system models concept. Six additional crosscutting concepts were included in seven of the teachers' lesson plans (See Table 9). Teachers who plan three-dimensional learning experiences create rigorous science lessons that help students "acquire and apply scientific knowledge to unique situations and to think and reason scientifically" (NRC, 2013, p. xvi). Teachers who incorporate three-dimensional learning naturally integrate the SEPs and provide students with opportunities to engage in the SEPs at age-appropriate levels (NRC, 2013).

All the lesson plans of the teachers included real-world connections and formative assessment components. The lesson plans of two teachers included summative assessments as well. Table 9 shows the presence or absence of one or more of the crosscutting concepts, real-world connections, and assessment in the teachers' lesson plans.

Table 9

Lesson Plan Examination with EQuIP Rubric 3.0 – Crosscutting Concepts and Other Components

	Crosscutting Concepts								
Participant	Patterns	Cause and Effect: Mechanism and Prediction	Scale. Proportion, and Quantity	Systems and System Models	Energy and matter: Flows, Cycles, and Conservation	Structure and Function	Stability and Change	Real-World Connections	Assessment
Molly		✓	✓	✓		✓		✓	✓
Charlotte	✓			✓	✓			✓	✓
Julie				✓				✓	✓
Barbara			✓	✓				✓	✓
Joy				✓				✓	✓
Frank				✓				✓	✓
Teresa		✓	✓	✓	✓	✓		✓	✓
Susan	✓		✓					✓	✓
James	✓	✓	✓				✓	✓	✓
Elaine	✓			✓				✓	✓

Creating STEM-centric lesson plans that engaged students in the SEPs as they investigate real-world problems revealed a positive sense of self-efficacy among the teachers in the study. Planning lessons that give students freedom of choice in how they solve a real-world problem or investigate real-world phenomena allow students to develop the ability to think and work like a scientist or engineer. Such lessons are student-centered.

Theme 5: Student-Centered Teaching

Every teacher in the study integrated at least one SEP in their lesson plans to engage students in investigating disciplinary core ideas. All teachers indicated that they used real-world connections to make learning relevant to their students' lives. One of the main ways the teachers engaged students in the SEPs was through collaborative group work. Whether students were working on an engineering design problem or using scientific inquiry to investigate phenomena from the natural world, the teachers reported that all students participated and engaged in the lesson. Julies shared that the goal is for her students was "to work together, to make a plan, and [to] execute that plan to get an end result." Frank indicated that his instructional competence increased when he had students work together. He shared that project-based teaching allowed him to meet the diverse needs of his students. No teacher mentioned having classroom management or disciplinary problems at any time during the interview.

When asked about putting students at the center of instructional decisions teachers described how they differentiated instructional content for their students. Joy shared, "I have a lower group and a higher group… I'm able to… talk with them… one-on-one to see what they know. Then [I] build on that with where I want them to go." Frank described the effectiveness of using the SEPs when teaching disciplinary core ideas. He said, "The… most frequent way I engage students [in] the science and engineering practices [is] through labs. Realistically, I think that's the best way of delivering those [SEPs] to students too."

The study data indicated that all the teachers included student-centered instructional practices in their lesson plans and interactions with their students. The teachers' perceptions of self-efficacy, whether positive or negative, did not deter them from planning SEP-integrated science lessons designed to engage students in three-dimensional learning experiences.

Theme 6: Educational Infrastructure

Educational infrastructure consists of the facilities, systems, and services that allow a school district to serve the professional needs of teachers and to provide instruction for students (Shirrell, Hopkins, & Spillane, 2019). Two types of educational infrastructure pertain to this case study: hard educational infrastructure and soft educational infrastructure. Hard educational infrastructure refers to the physical facilities in which learning occurs as well as the necessary materials and equipment to conduct science instruction. Soft educational infrastructure comprises fiscal budgets, master schedules, time, district pacing guides, and student populations. The teachers in the study regularly dealt with the opportunities and challenges of the hard and soft educational infrastructures.

All teachers in the study associated student growth and success as opportunities they encountered while integrating the SEPs. Molly shared, "I'm always fascinated in builds… but every once in a while, you get a child who comes up with something totally different, totally unexpected, and that for me is the biggest success." Elaine spoke of her students' transformation as learners. She said, "Watching those kids transform from 'I can't do it. I don't know anything about that' to, 'Okay, I'm willing to give this a go. I'm getting most of these correct now!' That's amazing." None of the teachers related opportunities to themselves but instead focused on their students as they answered the interview questions.

Every teacher in the study experienced challenges related to integrating the SEPs. Three teachers mentioned small or overcrowded classrooms but were able to find ways to overcome the size limitations of their rooms. A lack of sufficient materials and equipment also created challenging situations for implementing the SEPs with fidelity. However, the teachers overcame the challenges by sharing materials and equipment or by purchasing the needed supplies with their own money.

Limited funds forced one teacher to choose something adequate over something that would be the best for her students' instruction. Elaine shared, "Oftentimes, we'll choose something different because we don't have what would be best." Another teacher sought out a grant to ensure every seventh-grade student could attend a grade-level field trip. Teresa said, "I take the entire seventh-grade class kayaking. When we go out, [the field trip covers the] entire ecology unit… the Outdoor Foundation gives me a $2,000 grant." In both cases, the teachers overcame the challenges of integrating the SEPs into their lessons and engaging students in the SEPs to provide high-quality learning experiences for their students.

Time constraints based on school schedules or balancing work life with home life were challenging for all the teachers. Frank shared that he arrives early at school to prepare lessons for his students. By doing so, he is able to spend his time outside of school work hours with his four children. Theresa shared a time when she embraced her students' desire to go deeper in their learning. The experience led to her giving them the freedom to continue their lab, which resulted in the investigation taking longer than the time she had allotted for the lesson. . By allowing her students to take longer with the investigation, Teresa's perceptions of her self-efficacy increased. Referring to her self-efficacy, she thought the lab took her to “another height.” District pacing guides were also noted as challenges related to time. Three of the teachers mentioned the difficulties they faced as they attempted to meet the needs of their students while keeping up with the district pacing guide.

Overall, the data showed that the teachers associated student success to the opportunities they experienced with engaging students in the SEPs. The teachers also found ways to overcome the challenges they encountered. The teachers’ perceptions of self-efficacy were influence by an inadequate understanding of the SEPs. The teachers' self-efficacy was also shaped by their inability to implement STEM-centric lesson with fidelity because of a lack of appropriate materials, equipment, and time. However, the data indicated that the teachers always put students at the center of their instructional decisions, focused on students’ academic growth, and found ways to overcome the challenges they met.

Evidence of Quality

To validate the qualitative research in the study, the researcher used the teachers’ lesson plans to corroborate their interview answers. The two data sources established “converging lines of inquiry” (Yin, 2018, p. 44), that allowed the researcher and the dissertation committee to review the case study data objectively. The teachers reviewed, corrected, and verified their interview transcripts. The lesson plans were examined using the EQuIP Rubric 3.0. The data were collected and analyzed according to Creswell’s (2018) data analysis spiral. To establish trustworthiness, the researcher bracketed her experiences as a middle school science teacher to ensure an understanding of the teachers’ experiences and insights while suspending judgment. The transferability of the study findings to other settings was achieved by comparing the data among the teachers. All teachers interviewed were South Carolina public school science teachers, which allowed the data to be transferrable to teachers who work in public K-12 school districts in South Carolina. Detailed descriptions of the teachers' real-world experiences were included in the findings section to ensure transferability to other settings.

Summary

This qualitative, instrumental case study was designed to gain insight into South Carolina science teachers' perceptions of their self-efficacy as they teach with the science and engineering practices. Chapter IV provided a window into the teachers' daily experiences as science teachers. The teachers' interview and lesson plan data indicated how the teachers perceived their self-efficacy and instructional competence, how they planned lessons to engage students in the SEPs, and how they dealt with the opportunities and challenges that impacted their implementation of the SEPs. The data were color-coded, which revealed 27 codes. An examination of the codes led to the development of six themes. The themes that emerged from the study were self-efficacy, pedagogic shifts, collaboration, lesson planning, student-centered teaching, and educational infrastructure.

V. DISCUSSION

The present study examined South Carolina science teachers' perceptions of self-efficacy in planning and executing STEM-centric lessons based on the *South Carolina Academic Standards and Performance Indicators for Science 2014* and Science and Engineering Practices (SEPs). The final chapter of this dissertation restates the research problem and reviews the methodology used in the study. The first section of this chapter summarizes the study results and identifies the limitations of the study. The final sections discuss the implications of the results on future educational practices and provide recommendations for future research.

Statement of the Problem

The purpose of this case study was to examine science teachers' perceptions of self-efficacy as related to planning and executing STEM-centric lessons.

Method of Data Collection

As presented in Chapter 3, the research was a qualitative, instrumental case study of ten South Carolina K-12 public school science teachers' perceptions of self-efficacy as related to planning and executing STEM-centric lessons. As a case study, this research used a qualitative perspective to examine the teachers' perceptions of self-efficacy, their SEP-integrated lessons, and the opportunities and challenges the teachers experienced when implementing the SEPs in their lessons.

The case study relied on interview data and teacher-created STEM-centric lesson plans. The interviews were conducted from January 2020 through March 2020. An interview protocol addressed the three research questions and guided the interview sessions. Each teacher submitted four STEM-centric lesson plans of their choice. The lesson plans were analyzed using the EQuIP Rubric 3.0.

Summary and Discussion of the Results

The theoretical foundation of this study was related to Dewey's social constructivist theory that posits that learners construct meaning rather than passively obtain new learning (Dewey, 1916). Bandura (1977b) built upon Dewey's work and developed the social learning theory. Social learning theory consists of three essential constructs: observational learning, self-regulation, and self-efficacy. The present study focused on the self-efficacy aspect of Bandura's (1977b) theory and applied this aspect to the teachers' perceptions of self-efficacy.

Self-efficacy is an individual's perception of competence in a specific area (Bandura (1977b). Teacher self-efficacy, therefore, is teachers' perceptions of their instructional competence. Study data indicated that the participating teachers' beliefs about their self-efficacy had a strong influence on their instructional competence for teaching the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs.

The importance of this study lies in the fact that it was the first of its kind for South Carolina K-12 public school science teachers. As such, the study provided insight into the teachers' perceptions of self-efficacy and the state of the SEPs implementation in South Carolina. The study also added to the existing body of knowledge related to integrating the SEPs.

Research Question 1

How does science teachers' self-efficacy influence their teaching of the 2014 science standards and SEPs?

The teachers in this study reported that teaching the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs had an impact on their self-efficacy. Four teachers, who were veteran teachers with 14-34 years of teaching experience, had high perceptions of self-efficacy. Six of the teachers revealed that they had negative perceptions of self-efficacy because they perceived they had not integrated the SEPs well into their daily lessons. Two of the teachers who reported low perceptions of self-efficacy were novice teachers with five years or less of teaching experience. The two novice teachers indicated their negative self-efficacy beliefs stemmed from a lack of adequate training in their teacher preparation programs. The other four teachers with negative perceptions of self-efficacy were veteran teachers, with 12-27 years of teaching experience. The negative perceptions of self-efficacy revealed by the four veteran teachers seemed to come from their difficulty in making the necessary pedagogical shifts to integrate the SEPs.

Prior research studies (Bowers & Ernst, 2018; Bybee, 2014) indicated a need for teachers to make pedagogic shifts in teaching authentic STEM-centric lessons. Making pedagogical shifts from lower levels of cognition to the higher levels of critical thinking and problem-solving help to ensure that the SEPs are implemented with fidelity in STEM-centric lessons. When the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs were adopted, the South Carolina Department of Education realized that novice and veteran teachers had to make substantial pedagogical shifts. The pedagogic shifts that were required of

South Carolina science teachers were different from traditional teacher preparation program training and the way science has been taught for many years.

Previous researchers (Kim & Seo, 2018; Tschannen-Moran & Hoy, 2007) of teachers' perceptions of self-efficacy concluded that veteran teachers were able to make the pedagogical shifts necessary to authentically engage students in the SEPs more easily than novice teachers. However, veteran teachers do not always make the pedagogical shifts effortlessly according to the present study's data. Teachers who were unable to make substantial pedagogical shifts reported frustration and low perceptions of self-efficacy (Filippi & Agarwal, 2017). The teachers in this study also reported low perceptions of self-efficacy and frustration.

When the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs were adopted, the SCDOE anticipated an increase in teachers' stress levels as the expectations for instructional delivery techniques drastically changed. The *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs required teachers to integrate the SEPs into science content rather than teaching inquiry in isolation as required by the previous state science standards (Wragg, 2014). Using the inquiry process and the engineering design cycle in science lessons was a major pedagogical change in how South Carolina science teachers delivered instructional content. However, only four teachers in the study reported that they were confident with this pedagogic shift. Anticipating that veteran and novice teachers would experience negative perceptions of self-efficacy, the SCDOE created support documents and instructional units for the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs. The goal of the SCDOE was to provide resources to counteract the potential frustration and negative self-efficacy that many teachers would experience during the adoption of the standards. School districts across South Carolina used the standards, support documents, and instructional units to develop district pacing guides.

All teachers in the study shared that they used district pacing guides or used the South Carolina support documents to guide their implementation of the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs. The teachers who reported low perceptions of self-efficacy stated that they relied heavily on the support documents or district pacing guides to know what to teach each year. Teachers with positive self-efficacy used the support documents as one of many resources to guide their instructional decisions. Only two teachers indicated that they used the South Carolina instructional units that the SCDOE provided to support the implementation of the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs. However, these two teachers only used a small portion of the instructional units. The teachers in this study underutilized the South Carolina instructional units. All teachers in the study indicated that they sought ongoing help with understanding the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs. However, the teachers did not rely on the in-depth instructional units for guidance. Instead, the teachers sought guidance through professional development sessions and collaboration with colleagues.

Upon the adoption of the *South Carolina Academic Standards and Performance Indicators for Science 2014*, the SCDOE created professional development opportunities for K-12 science teachers. Each year the Office of Standards and Learning offered statewide professional development for science teachers at all levels. The professional development topics included explicit instruction in the SEPs, scientific inquiry, and transdisciplinary lessons with a literacy focus (Pressley, 2019a; Pressley, 2019b). The hybrid professional development sessions consisted of online and face-to-face meetings that began in the summer and lasted for one school year. The Office of Standards and Learning also offered two cohorts in various regions of the state to accommodate the learning needs of as many teachers as possible (Pressley, 2019a; Pressley, 2019b). School district science coordinators were charged with sharing the professional development sessions with teacher in their districts. The professional development sessions were also publicized on the SCDOE website.

The SCDOE professional development opportunities provided teachers with training in how to implement problem-based learning and how to provide students with choices that allow students to drive their learning. The professional development sessions focused on methods to create learning experiences with lesson designs centered on critical thinking and problem-solving (Pressley, 2019a; Pressley, 2019b). South Carolina teachers who participated in the year-long professional development sessions received books, materials, and supplies to use with their students. To foster collegiality, teachers who participated in the state-level professional developments were encouraged to share their learning with teachers in their home districts. All South Carolina science teachers had the opportunity to attend the professional development sessions but no teachers in the study participated in the sessions.

The teachers in the present study indicated that they did not attended the free professional development sessions because they either did not know the sessions existed, or they chose not to attend for personal reasons. The teachers reported that they wanted to increase their ability to teach SEP-integrated science lessons. However, they did not take advantage of the free professional development provided by the SCDOE. As an alternative, the teachers sought out one-on-one help from expert-teachers to gain a better understanding of how to integrate the SEPs into their daily science lessons.

The six teachers with negative self-efficacy indicated that they routinely sought help from colleagues to help plan STEM-centric lessons. Two of the teachers with high perceptions of self-efficacy shared that they helped veteran and novice teachers prepare SEP-integrated lessons regularly. Seven of the teachers in the study indicated minimal opportunities for the professional development available to them at the district and school level. Six of the seven teachers who did not receive adequate support related to understanding the SEPs experienced negative perceptions of self-efficacy. One teacher who reported limited opportunities for professional development stated that she could make the pedagogic shifts needed for her to create STEM-centric lessons without additional training. The teacher also indicated that she had worked at the university level and presented a professional development session for science teachers related to the SEPs. Three teachers in the study reported having access to adequate professional development opportunities at the district, and school levels. Two teachers who had access to abundant district and school level professional development opportunities shared that they were also able to attend a national science conference in the past year. The third teacher, with adequate access to professional development, stated that ongoing professional development at the district level and school level was the norm in her district.

Veteran teachers and novice teachers alike expressed a desire to increase their perceptions of self-efficacy by gaining a better understanding of how to integrate the SEPs in their science lessons. A need for ongoing, high-quality professional development was evident in all cases. However, the teachers in this study reported that the method they preferred to help them make the necessary pedagogical shifts to integrate the SEPs and to increase their perceptions of self-efficacy was through teacher-to-teacher collaboration and self-preparation techniques.

Previous studies (Guskey, 2002; Guzey et al., 2014; Hodges et al., 2016; Lakshmanan et al., 2011; Lesseig et al., 2016; Wendt et al., 2015) indicated that ongoing, high-quality professional development increased teachers' perceptions of self-efficacy. Participating in formal professional development offered participants mastery experiences and vicarious experiences. Vicarious experiences allow teachers to determine their mastery levels by comparing their performance to the performance of others (Bandura, 1997; Hammack & Ivey, 2017). Vicarious experiences may also increase an individual's perception of self-efficacy if the observed action demonstrates success. Bandura (1977a) suggested that the act of observing other individuals successfully perform challenging tasks raises the self-efficacy of less productive people. The individual's self-efficacy increases because the individual comes to believe that they can achieve similar levels of success despite having no prior experience with the task or having experienced previous failures (Bandura, 1977a).

The teachers in the study acknowledged the importance of attending formal professional development sessions. Nevertheless, the teachers' preferred method of receiving ongoing, high-quality professional development was collaborating with an expert-teacher in a mentoring capacity. Seven of the teachers sought out expert-teachers in their school building or on their grade-level team to help them create SEP-integrated science lessons and to help them learn new pedagogical practices for teaching science. The teachers in the study with low self-efficacy indicated that their perceptions of self-efficacy increased after collaborating one-on-one with an expert-teacher.

All the teachers in the study indicated that they had to learn how to teach SEP-integrated lessons by going through the inquiry and engineering design processes by themselves as if they were students. The teachers were able to understand better how to integrate the SEPs after experiencing the lesson as if they were students themselves, which increased their perceptions of self-efficacy. When teachers prepare for a lesson by teaching themselves the skills needed to successfully complete the lesson, they are engaged in mastery experiences. Bandura (1997) believed that mastery experiences foster positive perceptions of self-efficacy because they require the synergistic use of cognitive, behavioral, and self-regulating tools that enable teachers to develop successful solutions to challenging circumstances.

Based on the data collected in this study, the teachers' perceptions of self-efficacy influenced their teaching of the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs. The teachers with low self-efficacy reported low levels of instructional competence. The teachers with high self-efficacy reported high levels of instructional competence. All teachers sought out mastery experiences and vicarious experiences, which in turn increased their perceptions of self-efficacy. Self-preparation, collaboration with teammates, and mentorships with expert-teachers helped the teachers learn and implement new pedagogical practices, which increased the teachers' perceptions of self-efficacy.

Research Question 2:

How do teachers engage students in the SEPs?

The teachers in this study used a variety of methods to engage students in the SEPs. The most common method used to engage students in the SEPs involved the developing and using models SEP. Every teacher in the study indicated that they used models to help students understand and investigate the disciplinary core ideas. Previous research by Kang et al. (2018) indicated that teachers have favorite instructional strategies that they used to engage students in the SEPs. The present study's data indicated that the teachers had a favorite SEP that they integrated as often as possible. Eight teachers mentioned using collaborative grouping to engage students in the SEPs as they worked with models, engaged in the inquiry process, or participated in a design challenge. Four teachers specifically mentioned using hands-on techniques during their STEM-centric lessons.

The second most common method employed by the teachers to engage students in the SEPs involved critical thinking and problem-solving activities. Wendt et al. (2015) indicated that STEM-centric lessons foster critical thinking, problem-solving, and collaborative teamwork among students. Five teachers reported that they required their students to use critical thinking and problem-solving skills to derive solutions to problems or design challenges. One teacher explained that she would have her students work toward a solution using an iterative process where they had to continuously return to the problem until a viable solution was found. Two teachers indicated they used the claim-evidence-reasoning process to help their students provide justifiable solutions to real-world problems. Using real-world connections to engage students through creative scenarios and problems provided a meaningful context for the teachers' students to learn the disciplinary core ideas. One teacher highlighted the importance of using real-world connections to engage all levels of learners during a lesson, as well as the importance of giving students feedback on both formative and summative assessments.

Four teachers specifically mentioned how giving students feedback on summative assessments resulted in their students learning more content. Two of the four teachers reported that their students were allowed to retake summative assessments after receiving feedback and participating in tutoring or reteaching sessions. All teachers in the study indicated that their lessons and assessments aligned with the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs.

Every teacher used the *South Carolina Academic Standards and Performance Indicators for Science 2014*, the South Carolina science support documents, the South Carolina instructional units, or district pacing guides to plan STEM-centric lessons. The novice teachers in the study relied more on the support documents, while the veteran teachers use the support documents as a lesson planning resource. The South Carolina instructional units were underutilized by the teachers. In general, the teachers did not seem to find any merit in the instructional units, aside from using a few websites as instructional resources. Two teachers indicated that they used the academic vocabulary from the units but nothing else. One teacher shared that she only found the instructional units useful for making emergency substitute lesson plans. The instructional units contain information designed to assist teachers with planning STEM-centric lessons and for creating three-dimensional learning experiences for students. However, the teachers in the study did not use the instructional units effectively when planning their science lessons.

Teachers who implement lesson plans that engage students in the SEPs and that allow students to use the SEPs to investigate the disciplinary core ideas create a student-centered classroom where students drive their learning (Lesseig et al., 2016; Shernoff et al., 2017). The practice of examining teachers' lesson plans can provide insight into how teachers purposefully plan to engage students in the SEPs. Capobianco and Rupp (2014) posited that analyzing lesson plans with a rubric allows researchers to determine if teachers purposefully planned to engage students in the SEPs. Examining STEM-centric lesson plans using rubrics also reveals the extent of SEP-integration present in teachers' lesson plans. Shernoff et al. (2017) stated that using the EQuIP Rubric to examine lesson plans provides researchers with insight into the fidelity of STEM-centric lesson plans.

Each teacher in the study submitted four lesson plans that were examined using the EQuIP Rubric. Rubric data indicated that all teachers planned lessons that included at least one of the SEPs. The developing and using models SEP was present in every lesson plan. Other SEPs were present in the teachers' lesson plans. Five teachers included two to three SEPS in addition to the developing and using models SEP. The second most common SEP included in the lesson plans was the analyzing and interpreting data SEP, which was in four lesson plans. The third most common SEP, which was found in three lesson plans, was the constructing explanations and designing solutions SEP. The teacher who taught an elementary engineering class included all the SEPs in her lesson plans.

The data also indicated that all the teachers planned three-dimensional learning experiences for their students. Three-dimensional learning is an integration of the disciplinary core ideas, the science and engineering practices, and the crosscutting concepts (NRC, 2012). The data indicated that all the teachers in the study planned STEM-centric science lessons that allowed students to investigate disciplinary core ideas through the SEPs and provided opportunities for students to use the crosscutting concepts to explore the relationships among the fields of science.

Every teacher in the study included at least one crosscutting concept in their lesson plans. The crosscutting concept systems and system models was present in eight of the teachers' lesson plans. The second most common crosscutting concept found in the lesson plans was scale, proportion, and quantity, which was present in five of the teachers' lesson plans. The third most common crosscutting concept found in the lesson plans was patterns, which was present in four of the teachers' lesson plans. The inclusion of the crosscutting concepts indicated that the teachers, regardless of their level of experience or their perceptions of self-efficacy, attempted to plan authentic STEM-centric lessons for their students.

Previous research (Bowers & Ernst, 2018; Capobianco & Rupp, 2014; Guzey et al., 2014; Lesseig et al., 2016) indicated that teachers who participated in formal professional development programs increased their ability to plan SEP-integrated lessons collaboratively. However, the present study's results did not support the previous research as it relates to formal professional development. The study data indicated that the teachers preferred to plan STEM-centric lessons collaboratively through one-on-one mentoring from expert-teachers or with content area colleagues. Nine of the teachers in the study indicated that they planned their STEM-centric lesson collaboratively during their planning periods or informal meetings. None of the teachers reported an increase in their ability to plan STEM-centric lessons as the result of attending formal professional development sessions.

All teachers in the study showed strengths in planning for the developing and using models SEP and the crosscutting concept systems and system models. The teachers also showed strengths in aligning their lesson plans with the *South Carolina Academic Standards and Performance Indicators for Science 2014.* The teachers reported that lesson plans that allowed students to investigate disciplinary core ideas through one SEP and that included at least one crosscutting concept engaged students in the SEPs.

Prior research (Peterman et al., 2017; Shernoff et al., 2017) supported the use of rubrics to examine teachers' lesson plans to determine teachers' pedagogical practices and the extent to which teachers planned to engage students with the SEPs. The present study used the EQuIP Rubric 3.0 to examine the teachers' lesson plans. The data indicated that nine of the teachers included the scientific inquiry aspects of the SEPs in their lesson plans but did not include the engineering design cycle. However, the tenth teacher included the engineering design cycle along with the scientific inquiry process when appropriate. The study data supported Peterman et al.'s (2017) research in that the teachers in this study did not adequately incorporate the engineering aspects of the SEPs.

Overall, the data also indicated the teachers were able to plan for the pedagogic shifts required by the *South Carolina Academic Standards and Performance Indicators for Science 2014*. The study findings align with Guzey et al.'s (2014) conclusion that most science teachers can make the necessary pedagogical shifts to teach STEM-centric lessons to their students when given appropriate support.

An interesting finding that emerged from the examination of the lesson plans was that the rubric data indicated little difference among the teachers who reported low self-efficacy as compared to the teachers who reported high self-efficacy. The teachers who shared low perceptions of self-efficacy included nearly the same number of SEPs and crosscutting concepts in their lesson plans as the teachers with high perceptions of self-efficacy. However, two teachers were outliers. Of the teachers with high self-efficacy, Molly integrated eight SEPs in her lesson plans. Of the teachers with low self-efficacy, Teresa included five crosscutting concepts in her lesson plans. All other teachers in the study included one to four SEPs and one to four crosscutting concepts in their lesson plans. The teachers' self-efficacy does not seem to influence the teachers' ability to plan STEM-centric science lessons that engage their students in the SEPs. All teachers in the study skillfully planned STEM-centric lessons. However, according to the teachers' interview responses, the execution of the lesson plans seemed to be lacking, which resulted in the teachers with low self-efficacy doubting their instructional competence.

Research Question 3:

What are the opportunities and challenges teachers experience when implementing the SEPs?

Opportunities. The teachers in the study reported an increase in student engagement and achievement as the two most common opportunities they experienced when implementing the SEPs. The hands-on nature of SEP-integrated lessons easily engaged the students. Two teachers shared that student engagement increased when they made the pedagogical shifts required of the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs. One teacher pointed out that her students became more independent in their ability to think critically and problem-solving during her STEM-centric lessons. Two teachers indicated that the inclusion of off-campus, on-campus, or virtual field trips engaged their students in the SEPs through real-world connections. The teachers reported that the developing and using models SEP played a central role in their lesson plans and provided students with opportunities to engage in depth with the disciplinary core ideas.

An increase in student achievement when they implemented the SEPs into their daily science lessons was noted by six of the teachers. Two teachers shared that after implementing the SEPs, they noticed their students retained what they learned and had a measurable increase in their content knowledge. One teacher indicated that her students learned how to persevere during difficult design challenges, which resulted in more substantial academic gains. The finding related to student achievement supports pervious research by Tomas et al. (2014) in that providing student-centered STEM design challenges and opportunities for collaboration encourages in-depth cognitive learning and creates engaging learning experiences for students of all ability levels.

The present study aligns with previous research (Guzey et al., 2014; Lesseig et al., 2016; NASEM, 2019; NRC 2012, 2013) on student engagement, perseverance, and motivation. The open-ended nature of design challenges and the students' desire to solve real-world problem cause the students to naturally want to engage with the SEPs to investigate disciplinary core ideas. Teachers who provide students of all ability levels with STEM-centric lessons that encourage creativity and collaboration increase students' engagement with the content and encourage higher-order thinking skills. Students also demonstrate more perseverance when given opportunities to solve real-world problems or design challenges. Opportunities to practice the iterative design of scientific inquiry or the engineering design cycle allow students to learn from their failures as they work toward design or problem solutions. Cross-curricular connections also allow students to engage in interdisciplinary learning experiences, which promotes student motivation and achievement.

Seven of the teachers reported that they experienced being able to connect their STEM-centric lessons with cross-curricular content when implementing the SEPs. Jorgenson et al., (2014) posited that STEM-centric lessons include at least two of the science, technology, engineering, or mathematics disciplines. STEM-centric lessons also should include literacy components combined with opportunities for students to engage in problem-solving and critical thinking (Jorgenson et al., 2014). The most common cross-curricular connections in the present study were literacy, writing, and mathematics. Nine of the teachers in the study indicated that they regularly collaborated with grade-level colleagues or expert-teachers to create cross-curricular connections and to increase the teachers' pedagogical skills in implementing the SEPs. The opportunity to plan with colleagues or to be mentored by expert-teachers was crucial to increasing the teachers' perceptions of self-efficacy. Two veteran teachers in the study reported being expert-teachers who routinely provided support to novice and veteran teachers in their schools.

Lakshmanan et al. (2011) found that teachers' instructional competence and perceptions of self-efficacy increased after participating in professional development, which influenced their classroom practices. However, the initial positive influence on classroom practices waned over time, which highlight the need for extended professional development opportunities. Southerland et al. (2016) posited that professional development opportunities are most effective when conducted in a social context. Other research studies (Al-Salami et al., 2017; Guskey, 2002; Guzey et al., 2014; Hodges et al., 2016, Southerland et al., 2016; Wendt et al., 2015) concurred that teachers need to have opportunities to collaborate in a social context. When teachers collaborate, they increase their pedagogical skills, which increases their instructional competence and their perceptions of self-efficacy. The present study supports the previous research because the teachers indicated a need for ongoing professional learning opportunities even though they preferred collaborating with colleagues and expert-teachers on a one-on-one basis.

One teacher in the study reported being unable to collaborate with her colleagues in a meaningful way. The veteran teacher shared that she was not able to adequately collaborate with other teachers in her school because they were novice teachers. She lamented the lack of expert-teachers with whom she could plan STEM-centric lessons. The teacher described negative perceptions of self-efficacy in her interview responses. However, an examination of her lesson plans with the EQuIP Rubric 3.0 indicated that she possessed great skill in planning three-dimensional learning opportunities for her students. The ability of the teacher to plan ideal STEM-centric lessons suggests that she should have positive perceptions of self-efficacy. The apparent contradiction between her level of ability and her sense of self-efficacy has been found in other studies. Previous studies (Al-Salami et al., 2017; Lesseig et al., 2016; Nehmeh & Kelly, 2018) indicated that teachers who work in isolation frequently doubt their instructional competence and have negative perceptions of self-efficacy. The negative beliefs appear to stem from a lack of support and a lack of collegial planning with other science teachers. Teaching in isolation has created challenging circumstances for the teacher in the present study and caused her to perceive a lack of opportunities to increase her pedagogical skills through collaborative planning, thus impacting her self-efficacy beliefs.

Challenges. Every teacher in the study indicated challenges in implementing the SEPs. Five teachers in the study indicated that their classroom space was not conducive to implementing the SEPs with fidelity. Two teachers in the study shared their challenges with overcrowded classes. A middle school teacher reported having classes of approximately 39 students in her classes, and an elementary teacher stated that she often had 27 students in her class. When class sizes were large, the teachers had difficulty implementing STEM-centric lessons. The two teachers also indicated that, to provide enough room for their students, they often took their classes into the hallway to complete investigations or design challenges. One teacher lamented that she had to rely on technology simulations for many laboratory investigations because there was not enough room for her students to do the labs in the classroom. She regretted not being able to allow her students to explore phenomena through hands-on learning experiences. The teacher also indicated that she did not like taking her classes into the hallway because it disrupted instruction in nearby classes.

Previous research studies (Bybee, 2011; Kubat, 2018; Nehmeh & Kelly, 2018) found that many science classrooms do not have adequate physical space or adequate equipment to allow teachers to plan high-quality STEM-centric lessons. Kubat's (2018) research study found that the physical conditions of schools were unfavorable for providing rigorous STEM-centric lessons. Hodges et al. (2016) also found that overcrowded classrooms created challenging learning environments where it was difficult for teachers and students to engage in authentic scientific inquiry and engineering design challenges. The present study had a similar finding and supported previous research (Bybee, 2011; Hodges et al., 2016; Kubat, 2018; Nehmeh & Kelly, 2018).

One teacher shared the challenges he experienced because he did not teach in a traditional science classroom and needed a lab with running water. When students engage in the SEP-integrated lessons, they need adequate classroom infrastructure to conduct their investigations. The teacher reported that he had to bring equipment and materials, including water, into his classroom in order for his students to complete laboratory investigations. Two other teachers reported that there was not enough storage space in their classrooms for the number of materials and equipment they needed to store.

Six teachers reported that a lack of or shortage of equipment and materials made implementing the SEPs challenging. Two teachers in the study either did not have enough equipment for investigations and design challenges or had a difficult time finding existing equipment that was not in a centralized location. Three teachers often used personal funds to obtain enough materials and equipment to provide their students with authentic STEM-centric lessons.

Prior research studies (Bybee, 2011; Kubat, 2018; Nehmeh & Kelly, 2018) indicated that science teachers who do not have adequate materials and equipment struggle to teach STEM-centric lessons with fidelity. The challenges of implementing the SEPs with insufficient materials and equipment are even more problematic when teachers plan problem-based learning units for their students (Cook & Weaver, 2015). Engineering design challenges and problem-based learning units require enough materials and equipment for students to engage in authentic learning experiences. The powerful learning experiences of design challenges and problem-based units are lost without proper materials and equipment available. The present study found that nine of the teachers did not submit lesson plans that contained engineering design challenges. The lack of engineering design lessons in the teachers' lesson plans may be explained by the insufficient levels of materials and equipment available to the teachers. Teachers who do not have sufficient materials and equipment cannot implement authentic, high-quality STEM-centric lessons and may not be able to make the pedagogic shifts required to integrate the SEPs with fidelity. Teachers who experience continuous challenges with implementing the SEPs may develop negative self-efficacy.

Seven teachers indicated that funding was a serious challenge to implementing the SEPs. The elementary teachers in the study shared that they used monetary resources that were not part of their school's budget to overcome the challenges of their limited school budgets. Two additional ways the teachers obtained funds to purchase materials and equipment for their classes came from parent support and personal funds. One teacher explained that purchasing materials and equipment for elementary students is not as costly as the expenses incurred for middle and high school students. Therefore, she felt it was practical for her to use personal money to buy what she needed for her science lessons.

One of the middle school teachers explained that her school's science budget was also limited, which created a situation where she only had partial supplies for her STEM-centric lessons. As a result, the teacher resorted to rummaging through waste bins and recycling bins to find materials to repurpose for her students' investigations and design challenges. Two high school teachers shared that their schools had limited science budgets that made implementing the SEPs challenging. The teachers taught courses for more than one scientific discipline and needed different materials and equipment for each content area.

Previous research studies (Al-Salami et al., 2017; Bybee, 2011; Filippi & Agarwal, 2017) found that science teachers often lack appropriate levels of funding to equip their science classrooms with proper equipment and materials. When teachers lack adequate funding, many abandon innovative pedagogical practices that support the integration of the SEPs and return to their previous pedagogical practices. Teachers who cannot teach high-quality STEM-centric lessons reported frustration and a lack of motivation to continue innovative practices. The teachers in the present study reported the lack of adequate funding for their STEM-centric lessons to be challenging and stressful.

Nine teachers in the study reported that having insufficient time to plan or prepare science lessons made implementing the SEPs challenging. Two of the teachers indicated that they did not have enough time to plan for STEM-centric lessons due to teaching different courses. Six teachers stated that there was an insufficient amount of time during their planning periods to set up authentic learning experiences for their students and to complete all the other things required of them. Two other teachers shared their frustrations with not having enough time to prepare great lessons for their students. The teachers had to be satisfied with creating suitable lessons when they knew that their lessons could be fantastic if they had more time to prepare.

Teaching STEM-centric lessons that integrate the SEPs requires ample time for planning STEM-centric lessons and enough class time for students to engage in authentic learning experiences (NRC, 2012). Prior research studies (Cook & Weaver, 2015; Filippi & Agarwal, 2017; Lesseig et al., 2016; Shernoff et al., 2017 Skaza et al., 2013; Teig et al., 2019) indicated that teachers do not have enough time to plan STEM-centric lessons and do not have enough class time to allow students to thoroughly investigate the disciplinary core ideas. Kubat's (2018) research study found that time constraints limited the amount of content teachers could present to their students. Skaza et al.'s (2013) study indicated that that time constraints were the main reason teachers did not use STEM curricula. The challenge of time constraints may provide another explanation as to why the teachers in the present study did not plan engineering design challenges for their students. The teachers indicated that a lack of time to plan STEM-centric lessons and to allow students to investigate disciplinary core ideas with the SEPs was a major challenge. However, the teachers' self-efficacy did not seem to be influenced by time constraints.

Seven teachers indicated that they encountered challenges when attempting to follow their school districts' pacing guides. An elementary teacher reported that the pacing guide moved students through the content at a brisk pace, which was not ideal for her diverse learners. A middle school teacher shared that the school district leadership's expectation that sixth-graders complete one science unit in the first nine weeks was challenging. The teacher noted that sixth-graders needed time to acclimate to middle school, which makes completing the unit in the first nine weeks unrealistic. Two teachers indicated that following district pacing guides made it hard for them to offer remediation to students who did not initially master the course content. The seven teachers who found the pacing guides challenging also reported that they followed the guides with little deviation. However, the other three teachers in the study did not base their instructional pacing solely on district pacing guides. Three of the veteran teachers adopted a student-centered approach to their instruction and rearranged the district pacing guide content. Rearranging the content allowed the teachers to create authentic cross-curricular connections based on their diverse learners' academic needs.

Previous research studies (Al-Salami et al., 2017; Cook & Weaver, 2015; Lesseig et al., 2016; Shernoff et al., 2017) indicated that teachers believed state science standards, on which many district curriculum guides are based, contained more content than could be covered in a single school year. The present study found similar results. Three teachers indicated the *South Carolina Academic Standards and Performance Indicators for Science 2014* contained too much information for students to master in a school year. A possible solution offered by Shernoff et al. (2017) was to reduce the amount of required content and to provide teachers with additional planning and instruction time during the school day. The teachers in the present study did not advocate for changes to their instructional schedule. However, they did indicate a desire for dedicated, protected planning time to meet with colleagues and expert-teachers to plan high-quality STEM-centric lessons.

Study Limitations

This case study provided valuable data related to K-12 science teachers' perceptions of self-efficacy. However, the study had several limitations. A limitation of the study is that the study population was limited to South Carolina K-12 teachers who worked in public schools. Limiting the population to a single Southeastern state may limit the generalizability of the results to public school science teachers in other states. It may limit the generalizability of the results to science teachers who do not work in public schools (Yin, 2018).

The research was also limited by the number of high school teachers who participated in the study. Four elementary teachers and four middle school science teachers agreed to participate. However, only two high school science teachers participated in the study. The high school teachers' perspectives were crucial to obtaining a broad range of grade levels for the study. However, having only two high school teachers in the study limited the amount of data that could be collected. Thus, the strength of the study's findings related to high school science teachers' perceptions of self-efficacy may be diminished.

Another limitation involves the gender of the teachers. The study involved ten K-12 science teachers. Eight were females and two were males. Although the study population reflects the typical gender ratio of female to male teachers in a public school, the male perspective on self-efficacy was less prominent in the study.

Collecting data through interviews was the primary way data were collected for this study. The teachers participated in only one interview due to time and schedule constraints. Although the teachers reviewed, corrected, and verified their interview transcripts, there is still a possibility of bias in their answers to the interview questions. Bias in the interview responses could have come from the teachers desire to downplay their struggles with the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs. The teachers may also have used the interview questions to reflect on and to critique their instructional competence and their ability to plan STEM-centric lessons. Teachers who hold themselves to extremely high standards may have been critical of themselves as they developed their responses.

To address the limitation of bias and to corroborate the teachers' answers, a lesson plan examination was conducted. The teachers submitted four lesson plans, which were examined with the EQuIP Rubric 3.0. Triangulating the interview data, the teachers' verification of the interview transcripts, and the lesson plan data provided converging lines of evidence that strengthened the study's findings and generalizability (Yin, 2018). Classroom observations of the teachers implementing a STEM-centric lesson with their students would add strength to the study finding but was beyond the scope of the present study.

An additional study limitation involved the researcher, who was a middle school science teacher. In order to approach the study with an unbiased perspective, the researcher used bracketing to set aside previous experiences (Creswell, 2018). The researcher also implemented previous training as a mentor and peer evaluator to objectively interpret the interview data and the rubric data.

A final limitation of the study is that it only included the teachers' perceptions of self-efficacy as they attempted to implement the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs and an examination of their STEM-centric lesson plans. The study did not include input from the teachers' administrators, instructional coaches, colleagues, or students. Although the input from other stakeholders may be different from what the teachers perceive, valuable information on the teachers' self-efficacy and instructional competence could have been gleaned from these sources. However, the researcher chose to focus on the teachers' perceptions of self-efficacy for South Carolina K-12 public school science teachers.

Implications for Practice

The objective of this study was to examine science teachers' perceptions of self-efficacy as related to planning and executing STEM-centric lessons. Although a single case study cannot fully reveal everything that influences teachers' self-efficacy, this study would suggest that their self-efficacy can be influenced in positive ways. The findings of this study have implications for researchers, school administrators, instructional coaches, district-level science leadership, and state-level science leadership.

Five recommendations for future practice resulted from this study of science teachers' perceptions of self-efficacy as related to planning and executing STEM-centric lessons.

Recommendation 1

South Carolina science teachers are expected to teach the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs (Zais, 2014). The South Carolina Office of Standards and Learning created professional development courses, support documents, and instructional units, which provide teachers with a variety of experiences and resources designed to support them as they integrate the SEPs. Teachers who participate in the professional development courses engage in mastery experiences designed to positively influence their perceptions of self-efficacy (Bandura, 1977a, 1997). However, the professional development courses and the South Carolina instructional units were underutilized by the teachers in the study. The findings of this study support the need for the SCDOE to review the accessibility of the professional development sessions and the usability of the South Carolina instructional units. The study findings suggest a format revision of the South Carolina instructional units. Making the instructional units reflect the format of the South Carolina support documents might make the units more user friendly. The teachers in the study indicated that the support documents were useful for planning STEM-centric lessons. The study findings also suggest that the SCDOE should increase the number of professional development courses offered to science teachers in different regions of South Carolina. Currently, there are only two courses offered each summer. Increasing the number of professional development sessions to at least one in each region of South Carolina would accommodate more teachers who could benefit from the ongoing professional development courses. Regional professional development cohorts would allow the teachers to continue the preferred practice of planning collaboratively in small groups.

Recommendation 2

Teachers who attend professional development sessions often return to their students with innovative pedagogical practices and enthusiasm that wanes over time (Lakshmanan et al., 2011). To combat the loss of interest in innovative practices, Southerland et al. (2016), suggested that teachers receive high-quality, ongoing professional development sessions. The feasibility of offering ongoing formal professional development sessions is limited due to factors such as cost and time constraints. The study findings suggest a cost-effective solution to this problem may be found inside the school building using current personnel. The teachers reported seeking out expert-teachers or content area colleagues to help them learn and sustain the innovative pedagogical practices needed to plan and teach STEM-centric lessons. Teachers within the school who have expertise in integrating the SEPs could be utilized as informal instructional coaches. The expert-teachers could lead professional learning community sessions or could mentor teachers of all experience levels one-on-one. The learning teachers obtained in the professional learning communities or through mentoring would provide the teachers with mastery experiences that would positively influence their self-efficacy (Bandura, 1977a, 1997; Hammack & Ivey, 2017). The findings also suggest that teachers who work in isolation also need a professional learning community for support. The professional learning community could be provided through an online format. The online format would offer isolated teachers a common place to collaborate and could provide mentoring from expert-teachers. The online format would also provide a place to house a repository of shared STEM-centric lesson plans and instructional videos of teachers displaying best pedagogical practices. Sharing lesson plans and best pedagogical practices would provide vicarious experiences for the teachers and could increase their perceptions of self-efficacy (Bandura, 1977a, 1997; Hammack & Ivey, 2017).

Recommendation 3

Every teacher in the study indicated that they integrated the developing and using models SEP. The teachers seemed to favor that SEP over the other (Kang et al., 2018). The other seven SEPs were included sporadically in the teachers' lesson plans, and the engineering design process was notably lacking in nine teachers' lesson plans. The failure to integrate engineering design curricula into teachers' lesson plans is a common occurrence (Peterman et al., 2017). The study findings support the need for the teachers to receive training on how to integrate all the SEPs and the engineering design cycle into their lessons when appropriate. Some SEPs are more cognitively demanding for students and teachers. SEPs such as engaging in argument from evidence or obtaining and evaluating, and communicating information, as well as the engineering design cycle, require more critical thinking and problem-solving skills (Alemdar et al., 2018; Wendt et al.,2015). The study finding supports the need for science teachers to receive training on how to integrate and implement all the SEPs and the engineering design cycle.

Recommendation 4

Teachers often engage in self-reflection after they teach their lessons. Capobianco and Rupp (2014) and Shernoff et al. (2017) posited that teachers should take self-reflection a step further and examine not only their teaching practices but also their lesson planning skill. A lesson planning rubric, such as the EQuIP 3.0 among others, is ideal for teachers to reflect on their lesson plans (NRC, 2012; Peterman et al., 2017; Shernoff et al., 2017). A high-quality lesson plan rubric allows teachers to identify to what extent their lesson plans are aligned with the disciplinary core ideas, to what extent they have appropriately integrated the SEPs, and to determine which crosscutting concepts best support the lesson. Examining lesson plans for these three factors allows the teachers to ensure they are planning lessons that support three-dimensional learning as required by the *South Carolina Academic Standards and Performance Indicators for Science 2014*. The study findings support having teachers self-examine their lesson plans to identify areas of strengths and areas of weakness. Identifying areas of weakness would allow the teachers to identify areas where they could enhance the learning experiences for their students. Identifying areas of strength would provide positive reinforcement and encouragement to the teachers' perceptions of self-efficacy.

Recommendation 5

Most teachers are resilient and resourceful individuals who can teach lessons anywhere and can overcome challenging situations. Public schools are often overcrowded, and classroom space is limited (Hodges et al., 2016; Kubat, 2018). The study findings reflect the situations of many science teachers across the nation. Teachers have too many students in their classrooms, and their classrooms are too small to accommodate inquiry and design challenges (Bybee, 2011; Kubat, 2018; Nehmeh & Kelly, 2018). The study findings support the need to reduce science class sizes. Some science teachers are assigned to general education classrooms rather than science classrooms. Science classrooms are unique spaces that are designed to ensure the safety of the occupants and are designed to simulate real-world science experiences. Science classrooms are generally equipped with laboratory-grade tables and countertops, safety showers, eyewash stations, fire blankets, and sinks. The study findings also support the need to ensure that science teachers are assigned to science classrooms. When it is not possible to assign a science teacher to a science classroom, the classroom should be retrofitted to bring the necessary furniture and plumbing fixtures into the classroom. Science teachers need to have and need to be able to store equipment and materials for their students to carry out investigations and engineering builds. Many teachers lack adequate equipment and materials due to inadequate budgets (Bybee, 2011). Storing equipment and materials for four or more classes can also be problematic if the teacher does not have access to adequate storage space. The study findings support the need for teachers to have access to funding to purchase materials and equipment as well as adequate storage space to store the items.

Recommendations for Future Research

The findings of this study contribute to the growing knowledge base of the factors that influence teachers' perceptions of self-efficacy. The study results suggest that collaborating one-on-one with expert-teachers influences teachers' perceptions of self-efficacy more than formal professional development sessions. When teachers engage in mastery experiences and observe best pedagogic practices through vicarious experiences, their self-efficacy improve (Bandura, 1977a;1997, Hammack & Ivey, 2017). Allowing teachers to participate in new learning experiences through continuous social interactions such as mentoring and professional learning communities positively influences their perceptions of self-efficacy and instructional competence (Dewey, 1916; Southerland et al., 2016). Based on the conclusions generated from this study, additional research is needed on the influence mentor teachers have on the self-efficacy of science teachers and the benefits of learning new pedagogical practices in social contexts. Replicating this qualitative study using a mixed-methods approach and additional data collection instruments would provide robust data sources for analysis. Additional data sources could include a survey with open-ended questions, focus group interviews, and classroom observations. A mixed-methods research methodology might also provide more participants through the use of a survey instrument. South Carolina teachers with limited time may be more inclined to respond to survey questions, which would increase the study population and would increase the range teaching levels represented in the study. Increasing the study population and including more teachers from K-12 levels would increase the generalizability of the findings to K-12 science teachers across South Carolina and the nation.

Conclusion

Teachers serve a vital role in preparing the next generation of local, state, national, and global leaders. The ability to help students learn the necessary content and essential skills to become productive citizens require teachers to have positive perceptions of self-efficacy. Teacher self-efficacy involves teachers' perceptions of their instructional competence (Bandura, 1977b). The present study examined science teachers' perceptions of self-efficacy as related to planning and executing STEM-centric lessons aligned with the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs.

Bandura (1977a, 1997) posited that professional development courses provide teachers with mastery and vicarious experiences that increase their self-efficacy. The teachers in the study indicated a desire for professional development, but they preferred a less formal format. The teachers revealed that they chose to collaborate one-on-one with colleagues and expert-teachers on a routine basis as they prepared STEM-centric lessons. The teachers reported increased perceptions of their self-efficacy and improved instructional competence after collaborating with their colleagues, which supports prior research (Bandura, 1977a,1997; Hammack & Ivey, 2017). The collaborative meetings among the teachers also helped the teachers learn new pedagogic strategies to integrate the SEPs into their lessons.

The study findings also highlighted areas where the teachers would benefit from examining their lesson plans. Many of the teachers' lesson plans lacked the engineering design cycle or only integrated one SEP. Integrating more cognitively demanding SEPs and the engineering design cycle into lesson plans requires teachers to fully understanding all the SEPs, the inquiry design process, and the engineering design cycle (Alemdar et al., 2018; Wendt et al.,2015). Using a lesson plan rubric explicitly designed for STEM-centric lessons and units would allow the teachers to identify areas of strengths and weaknesses in their lesson plans. The rubrics would also ensure the teachers were providing three-dimensional learning experiences for their students (NRC, 2012; Peterman et al., 2017; Shernoff et al., 2017). As the teachers examined their lesson plans, they would also be able to identify the material and equipment they needed to teach the lesson with fidelity (Bybee, 2011). Identifying the materials and equipment needed for STEM-centric lessons provides an opportunity to prioritize funding for essential items.

The study findings contribute to the existing base of knowledge related to factors that influence teachers' perceptions of self-efficacy. Overall, the findings from this study identified areas where teachers could be better supported as they plan and execute STEM-centric lessons aligned with the *South Carolina Academic Standards and Performance Indicators for Science 2014* and SEPs. The study findings also identified areas where district and school infrastructure could be modified or enhanced to provide learning environments conducive to STEM-centric lessons. Providing appropriate levels of support through mentoring and lesson plan analysis, as well as enhancing classroom learning environments, will create situations where science teachers' perceptions of self-efficacy are positively influenced.

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APPENDICES

Appendix A

Request for Authorization to Use and Modify a Survey Instrument

January 13, 2019

Greetings Dr. Riggs,

I am a doctoral student at Southeastern University in Lakeland, Florida. I am researching the implementation of the Science and Engineering Practices (SEPs) in K-12 science classes in the Southeastern United States. The purpose of my qualitative case study is to examine an in-service teachers' perceptions of self-efficacy as related to planning and executing STEM-centric lessons involving the integration of the SEPs. To my knowledge, no formal review of science teachers perceived self-efficacy related to implementing the SEPs exists for my state. As such, this study will provide insight into the state of SEPs implementation in my state and will add to the existing body of knowledge related to teaching the SEPs in an era of standards reform.

As I seek to conduct the case study, I request your permission to use and modify the STEBI-A survey published in your article *Towards the Development of an Elementary Teacher's Science Teaching Efficacy Belief Instrument*. I intend to transform the survey items into interview questions where applicable. If you grant your permission, please respond to me by email indicating your permission to modify your survey for my case study. My email is bjdennewitz@seu.edu. Thank you so much for your time.

Gratefully,

Ms. Bryanna J. Dennewitz, M.Ed.

Doctoral Candidate - Curriculum & Instruction

Southeastern University - College of Education
https://www.seu.edu/

Response from Dr. Riggs

January 13, 2019

Hello Bryanna,

You are welcome to use the STEBI and modify it for your context. It is not under copyright. Best wishes for your study!

Iris Riggs

Department of Teacher Education and Foundations
CSU San Bernardino
(909) 537-5614

Appendix B

Interview Instrument

<u>Questions</u>:

How does science teachers' self-efficacy influence their teaching of the 2014 science standards and SEPs?

1. Please tell me about your experiences as a science teacher.
2. Think about the 2014 science standards and the science and engineering practices. How does your self-efficacy influence your implementation of the standards and SEPs?
    a. How well do you understand the standards and SEPs?
    b. How have you implemented the SEPs?
    c. How do you teach the standards and SEPs well?
    d. How do you handle students' questions about the SEPs in one of your lessons?
3. Think of a time when you felt that you were not equipped to teach a scientific concept. What did you do to solve your dilemma so that you could teach the lesson?

How do teachers engage students in the SEPs?

4. How do you plan for science instruction?
    a. How do you engage students in the SEPs?
    b. How do you overcome the inadequacies of students' background knowledge in science?
    c. Think of a time when you had a hard time explaining why a science experiment did not work. Would you share your experience?
5. Tell me about the professional development you have participated in to help engage students in the SEPs.
6. How do you use the South Carolina science support documents and instructional units?
    a. Please describe how you use them to plan learning experiences for your students.

What are the opportunities and challenges teachers experience when implementing the SEPs?

7. Tell me about the successes and opportunities you have had as a science teacher implementing the SEPs.
8. What challenges have you experienced as a science teacher?

What else do you want to tell me about your self-efficacy regarding teaching the 2014 science standards and SEPs?

Appendix C

EQuIP Rubric for Lessons & Units: Science

Lessons *and* units designed for the NGSS include clear and compelling evidence of the following:

I. NGSS 3D Design	II. NGSS Instructional Supports	III. Monitoring NGSS Student Progress
The lesson/unit is designed so students make sense of phenomena and/or design solutions to problems by engaging in student performances that integrate the three dimensions of the NGSS.	*The lesson/unit supports three-dimensional teaching and learning for ALL students by placing the lesson in a sequence of learning for all three dimensions and providing support for teachers to engage all students.*	*The lesson/unit supports monitoring student progress in all three dimensions of the NGSS as students make sense of phenomena and/or design solutions to problems.*
A. **Explaining Phenomena/Designing Solutions**: Making sense of phenomena and/or designing solutions to a problem drive student learning. i. Student questions and prior experiences related to the phenomenon or problem motivate sense-making and/or problem solving. ii. The focus of the lesson is to support students in making sense of phenomena and/or designing solutions to problems. iii. When engineering is a learning focus, it is integrated with developing disciplinary	A. **Relevance and Authenticity**: Engages students in authentic and meaningful scenarios that reflect the practice of science and engineering as experienced in the real world. i. Students experience phenomena or design problems as directly as possible (firsthand or through media representations). ii. Includes suggestions for how to connect instruction to the students' home, neighborhood, community and/or culture as appropriate. iii. Provides opportunities for students to connect their explanation of a phenomenon and/or their design solution to a problem to questions from their own experience. B. **Student Ideas:** Provides opportunities for students to express, clarify, justify,	A. **Monitoring 3D student performances**: Elicits direct, observable evidence of three-dimensional learning; students are using practices with core ideas and crosscutting concepts to make sense of phenomena and/or to design solutions. B. **Formative:** Embeds formative assessment processes throughout that evaluate student learning to inform instruction. C. **Scoring guidance**: Includes aligned rubrics and scoring

core ideas from physical, life, and/or earth, and space sciences. B. **Three Dimensions**: Builds understanding of multiple grade-appropriate elements of the science and engineering practices (SEPs), disciplinary core ideas (DCIs), and crosscutting concepts (CCCs) that are deliberately selected to aid student sense-making of phenomena and/or designing of solutions. i. Provides opportunities to *develop and use* specific elements of the SEP(s). ii. Provides opportunities to *develop and use* specific elements of the DCI(s). iii. Provides opportunities to *develop and use* specific elements of the CCC(s). C. **Integrating the Three Dimensions:** Student sense-making of phenomena and/or designing of solutions requires student performances that integrate elements of the SEPs, CCCs, and DCIs.	interpret, and represent their ideas and to respond to peer and teacher feedback orally and/or in written form as appropriate. C. **Building Progressions**: Identifies and builds on students' prior learning in all three dimensions, including providing the following support to teachers: i. Explicitly identifying prior student learning expected for all three dimensions ii. Clearly explaining how the prior learning will be built upon D. **Scientific Accuracy**: Uses scientifically accurate and grade-appropriate scientific information, phenomena, and representations to support students' three-dimensional learning. E. **Differentiated Instruction**: Provides guidance for teachers to support differentiated instruction by including: i. Appropriate reading, writing, listening, and/or speaking alternatives (e.g., translations, picture support, graphic organizers, etc.) for students who are English language learners, have special needs, or read well below the grade level. ii. Extra support (e.g., phenomena, representations, tasks) for students who are struggling to meet the targeted expectations. iii. Extensions for students with high interest or who have already met the performance expectations to develop deeper understanding of the practices, disciplinary core ideas, and crosscutting concepts.	guidelines that provide guidance for interpreting student performance along the three dimensions to support teachers in (a) planning instruction and (b) providing ongoing feedback to students. D. **Unbiased tasks/items**: Assesses student proficiency using methods, vocabulary, representations, and examples that are accessible and unbiased for all students.

<u>Units</u> designed for the NGSS will *also include* clear and compelling evidence of the following additional criteria:

I. NGSS 3D Design	II. NGSS Instructional Supports	III. Monitoring NGSS Student Progress
D. **Unit Coherence**: Lessons fit together to target a set of performance expectations. i. Each lesson builds on prior lessons by addressing questions raised in those lessons, cultivating new questions that build on what students figured out, or cultivating new questions from related phenomena, problems, and prior student experiences. ii. The lessons help students develop toward proficiency in a targeted set of performance expectations. E. **Multiple Science Domains**: *When appropriate*, links are made across the science domains of life science, physical science and Earth and space science. i. Disciplinary core ideas from different disciplines are used together to explain phenomena. ii. The usefulness of crosscutting concepts to make sense of phenomena or design solutions to problems	F. **Teacher Support for Unit Coherence:** Supports teachers in facilitating coherent student learning experiences over time by: i. Providing strategies for linking student engagement across lessons (e.g. cultivating new student questions at the end of a lesson in a way that leads to future lessons, helping students connect related problems and phenomena across lessons, etc.). ii. Providing strategies for ensuring student sense-making and/or problem-solving is linked to learning in all three dimensions. G. **Scaffolded differentiation over time**: Provides supports to help students engage in the practices as needed and gradually adjusts supports over time so that students are increasingly responsible for making sense of phenomena and/or designing solutions to problems.	E. **Coherent Assessment system:** Includes pre-, formative, summative, and self-assessment measures that assess three-dimensional learning. F. **Opportunity to learn**: Provides multiple opportunities for students to demonstrate performance of practices connected with their understanding of disciplinary core ideas and crosscutting concepts and receive feedback.

across science domains is highlighted. F. **Math and ELA:** Provides grade-appropriate connection(s) to the Common Core State Standards in Mathematics and/or English Language Arts & Literacy in History/Social Studies, Science and Technical Subjects.		