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The Transformation Of Teacher Education Using Three-Dimensional Science Instruction

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THE TRANSFORMATION OF TEACHER EDUCATION USING THREE-DIMENSIONAL SCIENCE INSTRUCTION

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Patricia Ann Arnold
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ABSTRACT

The impact of the *Next Generation Science Standards (NGSS)* on K-12 science education has gained significant momentum over the last several years. Evidence of the *NGSS* can be seen in revised state science content standards and amended teacher preparation standards. Due to this growing impetus, a holistic redesign of teacher preparation to systemically implement three-dimensional science teaching and learning needs to be prioritized. Based on this premise, this study investigated the change in pre-service teachers' perceived self-efficacy in teaching science using three-dimensional instruction upon completion of an *NGSS*-designed intervention incorporated into an introductory science methods course. Designed as a "working shop" where participants became three-dimensional learners themselves, the intervention incorporated three-dimensional science instructional pedagogies and materials accessed from established open-sourced resources found online. Results support the use of this innovative approach as a "best practice" for preparing teachers in becoming professionally competent to implement three-dimensional science instruction in their future classrooms.

Keywords: three-dimensional instruction, *Next Generation Science Standards (NGSS),* scientific and engineering practices (SEPs), disciplinary core ideas (DCIs), cross-cutting concepts (CCCs), pre-service teachers, elementary teachers, teacher education

CHAPTER I

RE-IMAGINING SCIENCE TEACHER EDUCATION

Since the release of the *National Science Education Standards (NSES)* in 1996, the reform movement in K-12 science education has focused on embedding inquiry into classroom instruction to increase students' conceptual understanding of scientific principles (National Research Council [NRC], 1996). The goal has been to move students from passive participants to active generators of knowledge in becoming more scientifically literate. However, in the *2012 National Survey of Science and Mathematics Education Report*, the authors argue that the inquiry reform movement resulting from the *NSES*'s rollout did not produce any significant change in science instructional practices as anticipated (Banilower et al., 2013, 2018).

In an attempt to move science education beyond such failed reforms, the National Research Council (NRC) published *A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas* (2012) which built on a growing body of teaching and learning research in hopes of generating "Inquiry 2.0–not a replacement for inquiry but rather a second wave that articulated more clearly what successful inquiry looked like when it results in building scientific knowledge" (Schwarz et al., 2017, p. 5) while also increasing scientific literacy throughout the nation's populace. From this seminal publication, the *NGSS* were proposed, revised, and finally published in April 2013, presenting a complete re-boot on how science should be taught in the nation's K-12 science classrooms (*NGSS* Lead States, 2013).

From Learning Science to Figuring Out Science

The structure and content of the NRC's (2012) *Framework* are grounded in core ideas and practices based on the following key principles of teaching and learning: (a) that children are naturally born investigators, (b) that understanding develops over time, (c) that science and engineering require knowledge and practice, (d) that connections need to be made with students' interests and experiences, and (e) that equity needs to be preserved (National Research Council [NRC], 1999, p. 24). Of these key principles, the furthest removed from current practice in K-12 science education is the integration of scientific knowledge and scientific practices, meaning that the NRC's (2012) *Framework* suggests that the teaching of scientific disciplinary core ideas (DCIs) should be done in concert with eight scientific and engineering practices (SEPs), not as separated pedagogies within instructional practice. Additionally, this type of science teaching should simultaneously embed seven cross-cutting connections (CCCs) that link the three main science disciplines of Life Science, Physical Science, and Earth and Space Science cohesively when teaching science in any K-12 classroom.

This innovative approach to science education was quite different from how the *NSES* presented its vision of K-12 science education in 1996. As released, the *NSES* were a collection of national science standards that prioritized science content through an organizational structure presented as specific grade level objectives. Ultimately, the collective interpretation of the *NSES* was that they were to be systematically checked off as science curriculum was covered in K-12 classrooms. Although the *NSES* initiated the "science as inquiry" movement, the implementation fell short due to its concrete separation of science content from science skills. Because the *NGSS* specifically address this overarching shortcoming, many scholarly experts have referred to them as a "paradigm shift" in science education (Banilower et al., 2013, 2018; NRC, 2012; Schwarz et al., 2017; Windschitl & Stroupe, 2017). This transformation in teaching science moves away from learning about science as discrete and unrelated facts, as presented in the *NSES* of 1996, to figuring out science through interdisciplinary, cohesive modules driven by student curiosity to explain naturally occurring phenomena, as presented by the *NGSS* of 2013 (Achieve et al., 2016). This recommended overhaul of K-12 science education presented in the NRC's (2012) *Framework* and visualized through the *NGSS* is known as three-dimensional instruction.

***NGSS* and Science Teacher Education**

Transforming K-12 science education with three-dimensional instruction is based on the NRC's (2012) vision around agreed definitions of what scientists do when they engage in scientific inquiry and what students need to do "to support the development of their own conceptual understanding of science and their engagement with science" (Schwarz et al., 2017, p. 23). In April 2013, the final draft of the *NGSS* was released for use in K-12 education throughout the United States. Since then, many states have adopted them in full form or as very similar permutations (Thompson, 2019). For the states that have adopted the *NGSS* or something similar, science teacher education programs are faced with a formidable challenge, one that surpasses any recommendation generated by an accreditation review committee. This challenge lies in the successful implementation of three-dimensional instruction throughout teacher preparation as outlined in the NRC's (2012) *Framework* to meet the intent of the *NGSS*.

In its 2015 publication, *Guide to Implementing the NGSS,* the National Research Council (NRC) strongly recommended that all levels of teacher education engage in a holistic review and revision of their "programs and requirements for teacher pre-service training and introductory undergraduate science courses to ensure these are responsive to teachers' needs under the *Next Generation Science Standards*, at both the elementary and secondary levels" (p. 80). According to the NRC's (2012) *Framework*, elementary teacher education needs to be prioritized as the authors found that prospective elementary teachers typically only encountered one science methods course and a very limited number of science content courses in their pre-professional careers. This specific NRC (2012) concern lies in the reality that pre-service teachers, especially elementary, can only attain comfortable confidence in teaching science using three-dimensional instruction when they gain experiences that provide a "thorough grounding in all three of the framework's dimensions" over time (p. 257). As reported in the NRC's (2012) *Framework*, this is not the case in the typical elementary pre-service program where the traditional preparation pathway begins with the study of theory, followed by non-participant observations, and then culminates with an individualized practicum. This method of pre-service programming results in the historical segregation of the three components during teacher preparation. Based on the nature of three-dimensional instruction as outlined by the NRC's (2012) *Framework*, this approach does not meet the intent of the *NGSS* as presented by its authors.

Consequently, following this disconnected approach will not lead to graduates who are comfortably confident in teaching science using three-dimensional instruction. According to Trygstad et al. (2013), less than half of in-service K-2 grade teachers and one third of in-service 3-5 grade teachers report that they feel prepared to teach science in their classrooms. When their data is disaggregated by scientific discipline, the authors report that only one third of in-service K-2 grade teachers and only one quarter of in-service 3-5 grade teachers feel that they are very well prepared to teach Life and Earth Science. Only 16% of K-2 grade teachers and 19% of 3-5 grade teachers indicate that they are very well prepared to teach Physical Science. Additionally, the authors disaggregated their participant responses to report their perceptions of their preparedness to engage in engineering practices in their classrooms and found that elementary teachers across grade bands reported not being adequately prepared to do so (77% of in-service K-2 grade teachers and 69% of in-service 3-5 grade teachers). Clearly, this data indicates that elementary teacher education is failing to prepare teachers to teach science across its three main disciplines. The data shows that elementary teacher education is not addressing the need to prepare pre-service teachers in how to engage in the science and engineering practices with their students. Additionally, Trygstad et al.'s (2013) data supports the NRC's (2015) recommendation that teacher education needs to prioritize the restructuring of their programs to ensure that pre-service elementary teachers are professionally ready for teaching science using three-dimensional instruction in the age of the *NGSS*.

As teacher education engages in the daunting task of implementing three-dimensional instruction throughout its programs, nurturing the self-efficacy of pre-service teachers will need to be a strong centralized focus. Research suggests a positive correlation between self-efficacy and teacher commitment to implementing instructional reforms, especially when the instructional reforms are far removed from current practice (Flores, 2015; Ghaith & Yaghi, 1997; Guskey, 1988). As mentioned previously, the most significant change within the *NGSS* is the transition from learning about science to figuring out science through the reiterative use of the science and engineering practices (SEPs) such as creating and revising models through investigations, researching and asking questions, constructing explanations, arguing from evidence, finding solutions to real-world problems, and making sense of everyday phenomenon (NRC, 2012). In three-dimensional instruction, these science and engineering practices are essential to students becoming active, engaged participants in their own sensemaking as they construct their scientific knowledge (Reiser, 2013; Schwartz et al., 2017) and develop scientific literacy. Without intentional, authentic training in the use of the science and engineering practices in the classroom, teachers resort to more traditional instructional pedagogies of lecture, then lab, then test. This process leaves students typically disenfranchised from the study of science (Avery & Meyer, 2012; Windschitl et al., 2018).

Statement of the Problem

Even at the height of the science inquiry movement of the 1990s, learning science for the everyday K-12 student did not look, feel, nor sound like the three-dimensional model presented by the NRC's (2012) *Framework* (Schwarz et al., 2017) and the *NGSS*. Pre-service teachers are no exception for they cannot teach what they do not know or have not experienced for themselves (National Academies of Sciences, Engineering, and Medicine, 2015). If they do not experience how to learn science using three-dimensional instruction during their pre-professional careers, they will not be able to confidently teach science according to the intent of the *NGSS* in their future classrooms (Ricketts, 2014). For prospective teachers, enacting this model of teaching science in their future classrooms requires the reconstructing of their preparation programs away from the traditional pathway of theory, then observation, then practice where all three components are typically disconnected experiences. The process needs to be reconstructed into a more integrated 21st century model based on the *NGSS* where future teachers experience science as three-dimensional learners themselves. Doing so will ultimately generate pre-service teachers who can comfortably attend to the pedagogical demands of three-dimensional instruction while becoming self-efficacious teachers of three-dimensional science (NRC, 2015).

Purpose of the Study

The purpose of this study was to develop an innovative instructional model for preparing teachers to teach science using three-dimensional instruction that was theoretically and conceptually derived from Bandura's (1977, 1986) Theory of Self-Efficacy. Once developed, this novel instructional model was implemented as a “working shop” intervention within an introductory science methods course, where prospective teachers engaged as three-dimensional learners and reflective practitioners concurrently. It is the intention of this study to inform teacher education constituents of high impact instructional practices to improve pre-service teachers’ self-efficacy in teaching science using three-dimensional instruction, as well as provide evidence that supports the holistic integration of three-dimensional science pedagogies within all aspects of teacher education programming. Lastly, this study aims to present a rich, comprehensive narrative of the prospective teachers’ experiences as they navigated their initiation into becoming effective three-dimensional teachers of science.

Research Questions

Based on the intent of this study, the following research questions were generated:

1. To what extent does an *NGSS*-designed “working shop,” centered on the Science and Engineering Practices (SEPs) within an introductory science methods course, impact pre-service teachers’ perceptions of their self-efficacy in teaching science using three-dimensional instruction?
2. To what extent does an *NGSS*-designed “working shop,” centered on the Science and Engineering Practices (SEPs) within an introductory science methods course, impact pre-service teachers’ perceptions of self-efficacy to enact three-dimensional instruction in their field experience practicum?

Theoretical Framework

Self-efficacy in teaching science has long been a concern for elementary teacher education (Palmer, 2006). Many pre-service teachers report negative science experiences in high school and often lack confidence in their skills to teach science content (Kazempour, 2014;

Palmer, 2006). Addressing low self-efficacy in teaching science needs to be prioritized in the preparation of elementary teachers as it has been linked to avoidance of inquiry science and the increased use of teacher-centered strategies such as textbook driven worksheets (Palmer, 2006). In the age of the *NGSS*, this concern is exacerbated due to the fundamental premise within three-dimensional instruction to engage students in the science and engineering practices (SEPs) to learn the disciplinary content ideas (DCIs) and make cross-cutting connections (CCCs). Prior research shows that teachers "who possess high self-efficacy with regard to science and teaching science, have been identified as the key to the success of science education reforms" (Kazempour, 2014, p. 79). Therefore, the reconstruction of elementary teacher preparation to meet the intent of the *NGSS* should be theoretically grounded in self-efficacy which is the main construct of Bandura's (1977, 1986) Social Cognitive Theory. This must be done in order to maximize the professional preparedness of pre-service teachers to teach science using three-dimensional instruction.

The main construct within Bandura's (1977, 1986) Social Cognitive Theory is the concept of a "self-system" used to explain how individuals cognitively process and interpret outside influences and how particular patterns of behavior are adopted and maintained. According to Bandura (1986), how individuals work and perform is based on an interaction among personal, behavioral, and environmental factors. An individual's sense of self determines the amount of effort, perseverance, and flexibility put forth in performance. "Perceived self-efficacy," as defined by Bandura (1977), is an individual's beliefs about their ability to perform at expected levels and how their performances influence personal outcomes in their lives. Said another way, Bandura's (1977) theory proposes that individuals are inspired to perform an action by two expectations: (1) if they believe the action will have a favorable result known as their "outcome expectation" and (2) if they are confident that they can perform that action successfully which is known as their "self-efficacy expectation" (Bleicher, 2004, p. 384). Furthermore, Bandura (1977, 1986) posits that personal development of these two prongs is context specific, which means that in order to attain high self-efficacy in a particular context, an individual needs to complete challenging tasks successfully within that context and believe their actions produce favorable results. This supposition within Bandura's (1977, 1986) theory supports the notion that developing pre-service elementary teachers' self-efficacy in teaching science using three-dimensional instruction needs to be situated in authentic pre-professional experiences that are delivered in a three-dimensional manner as described in the NRC's (2012) *Framework.*

Also, an individual's development of their self-efficacy within these two prongs is driven by the interaction of their personal well-being, individual accomplishments, and level of motivation. The development of the individual's self-efficacy is achieved when they believe in their capacity to succeed in a given situation, identify and pursue goals, rebound from minor setbacks, and persevere in the face of adversity (Flores, 2015). All four of these self-regulating behaviors are indicative of high self-efficacy according to the tenets of Bandura's (1977, 1986) theory, supporting the claim that nurturing the self-efficacy of pre-service elementary teachers may play an important part in their achievement of professional preparedness to teach science using three-dimensional instruction.

According to Tschannen-Moran et al. (1998), developing self-efficacy in pre-service teachers requires promoting the belief that they will be able to engage competently in teaching science in their future classrooms. This claim is supported by Bandura's (1977, 1986) postulation that high self-efficacy is the result of maximizing an individual's exposure to the following four sources of influence: (a) enactive mastery experiences (success in challenges), (b) vicarious experiences (observations of others as role models), (c) physiological and emotional cues (emotional arousal), and (d) verbal persuasion (specific performance feedback). Tschannen-Moran et al. (1998) and Hoy and Spero (2005) posit that enactive mastery experiences are considered the most robust source of self-efficacy knowledge, although all four “may contribute significantly to perceptions of self-efficacy if presented appropriately” (Morrell & Carroll, 2010, p. 246).

As described by Menon and Sadler (2018), enactive mastery experiences are those personal experiences that represent past successes that cultivate self-confidence to succeed in similar situations and increase coping mechanisms in challenging situations. For pre-service elementary teacher education, mastery experiences such as authentic classroom teaching opportunities in concert with reflective writing exercises about one’s own teaching can positively influence an individual’s self-efficacy in teaching science (Menon & Sadler, 2018). Within the context of an introductory science methods course, other learning experiences such as engaging in (a) inquiry-based science investigations, (b) whole class discussions, and (c) inquiry-based science lesson plans and implementing them in the field have also been reported as productive mastery experiences (Menon & Sadler, 2018).

In addition to enactive mastery experiences, Menon and Sadler (2018) describe vicarious experiences as “belief in oneself to succeed after seeing evidence of others being successful in similar situations” (p. 839). In preparing prospective elementary teachers to teach science, vicarious experiences may include observing other teachers’ successful performance of teaching science in a classroom setting or watching videos of teachers using effective science teaching pedagogies (Menon & Sadler, 2018). They may also include self-modeling where pre-service teachers video record their own science teaching followed by a written reflection or critique of their observations (Menon & Sadler, 2018).

The third influence on self-efficacy is a person's affective and physiological state that may impact their levels of anxiety and stress which can additionally frame their performance. Research states that affective and physiological states of individual teachers may influence their ability to handle stress and anxiety while teaching science and often determine how well teachers can handle unanticipated or challenging situations in a classroom (Bandura, 1997; Menon & Sadler, 2018). Mitigating the possible negative effect of this third influence on elementary pre-service teachers' self-efficacy may be accomplished through the administration of a diagnostic assessment prior to commencement of an introductory science methods course to establish a baseline for prospective teachers' feelings and beliefs about teaching science. Such knowledge would allow teacher educators to meet students "where they are at" on the science teaching continuum to create science learning experiences that nurture their self-confidence in teaching science rather than diminishing it.

Bandura's (1977, 1986) final influence of self-efficacy is verbal persuasions which references the "positive feedback received from others on teaching performance that increases an individual's performance skills" (Menon & Sadler, 2018, p. 839). Positive feedback and encouragement received from instructors, peers, school supervisors, mentor teachers, and family members are all examples in this domain for pre-service teachers (Menon & Sadler, 2018). However, lack of timely, ongoing, and goal-referenced feedback results in the inability of pre-service teachers to create clear interconnections between the three-dimensions of the *NGSS*, and thus results in the incapacity to authentically integrate each of the three dimensions into professional practice (Wiggins, 2012).

Conceptual Framework

The hypothesized impact of the *NGSS*-designed learning modules on pre-service teachers' self-efficacy for teaching science using three-dimensional instruction depended on how well it nurtured the two prongs of Bandura's (1977, 1986) Social Cognitive Theory in the participants: (a) their self-efficacy – the belief that they can accomplish teaching science using three-dimensional instruction in their pre-professional practicum experiences and in their future classrooms, and (b) their outcome expectancy – the belief that their students will experience academic success when they can teach science using three-dimensional instructional. With Bandura's (1977, 1986) construct of self-efficacy in mind, the design, revision, and implementation of the *NGSS*-designed "working shop" intervention delivered during this study included the following components to increase the likelihood of a positive impact on the participants' perception of their self-efficacy in teaching science using three-dimensional instruction:

(a) increased opportunities to experience positive performance outcomes which had the potential to develop and nurture the pre-service teachers' professional competence;

(b) increased possibilities to receive positive verbal persuasion through the encouraging words from the researcher and their teacher educator acting as instructional facilitators rather than content depositors;

(c) continuous exposure to positive vicarious experiences elicited through the socially active learning model; and

(d) an increased likelihood of classroom interactions that produced positive physiological feedback as pre-service teachers, the researcher, and their teacher educator celebrate academic achievements over the course of the eight learning modules within the *NGSS*-designed "working shop" intervention.

Table 1 displays how these four components aligned with each of the four influences on Bandura's (1977, 1986) Theory of Self-Efficacy. To further clarify this conceptualized relationship, Figure 1 presents how these four components were materialized into purposeful learning experiences within the "working shop" intervention.

Figure 1

Four Influences on Science Teaching Self-Efficacy

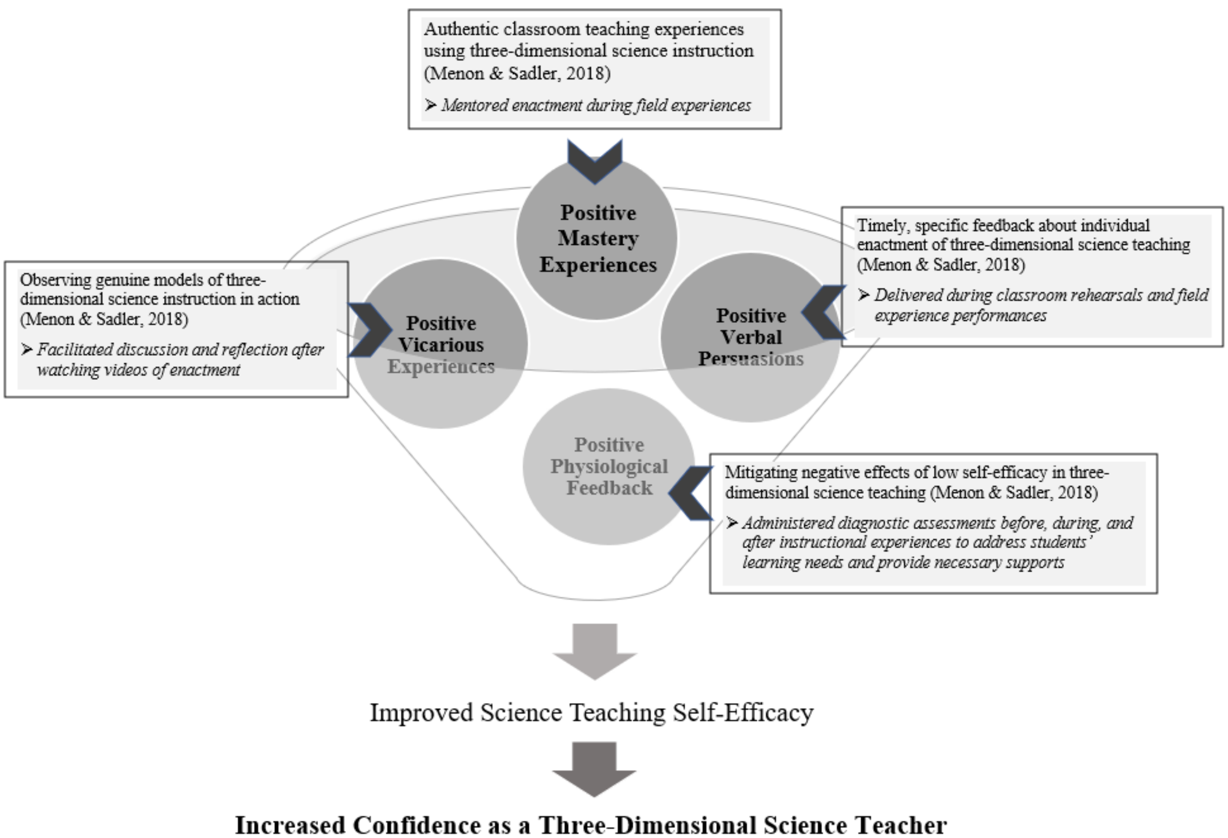

Table 1

Alignment of Bandura's (1977, 1986) Four Influences with the "Working Shop" Intervention

Influence on Self-Efficacy	Description	Intervention Component
Mastery Experiences	Engaging in authentic classroom teaching using three-dimensional science instruction	Field Experience Practicum
Vicarious Experiences	Observing successful models of three-dimensional science instruction	Video Discussions and Reflections
Verbal Persuasion	Providing timely, specific feedback on teaching rehearsals and performance	Oral, written, and non-verbal feedback from teacher educator and mentor teacher
Physiological and Emotional Cues	Mitigating the negative effects of low self-efficacy in teaching science	Instructional modifications based on exit ticket responses

Through the reiterative nature of the "working shop" intervention, pre-service teachers gained significantly more experience using three-dimensional science instruction than they would have received through a traditionally designed elementary science methods course. The main hypothesis of this study was that participants' self-efficacy in teaching science using three-dimensional instruction, as well as their self-efficacy to enact three-dimensional instruction in their field experience practicum, would improve due to their authentic experience as three-dimensional learners in the *NGSS*-designed "working shop" within their introductory science methods course.

Research Rationale

The rationale for this study lies in the monumental challenge of preparing teachers in the era of the *NGSS* and three-dimensional instruction. Described as a "paradigm shift" in science education, the *NGSS* calls all aspects of K-12 education to re-tool how science is taught in U.S. classrooms – from higher education in preparing teachers to teach science, to states in how they hold school districts and certified teachers accountable, to schools in their pursuit to produce high quality graduates who are scientifically competent (Windschitl & Stroupe, 2017). Since the release of the *NGSS* in 2013, educational research has produced numerous resources for helping in-service teachers transition to the *NGSS* and three-dimensional instruction including the practical development of *NGSS*-designed lessons and assessments, the effective design of professional development across the three dimensions, and even the modification of teacher certification and evaluation (National Academies of Sciences, Engineering, and Medicine, 2015). However, this expansive body of educational literature has very little to offer in the realm of how to effectively prepare prospective teachers to teach science using three-dimensional instruction. There are numerous printed resources that support the need for teacher education to drastically change in order to produce novice teachers who are adequately prepared to teach science using three-dimensional instruction (NRC, 2012, 2015; National Academies of Sciences, Engineering, and Medicine, 2015; Rhoton, 2018); there are very few, if any, that present empirical research of how to effectively achieve that goal. Therefore, this study intends to fill the research gap by providing evidence that supports an effective "what" and "how" in transitioning the preparation of elementary teachers into the brave new world of the *NGSS* and three-dimensional instruction.

Methodological Overview

In the age of the *NGSS*, teacher educators need to engage in program re-design to create educational experiences that ensure the development of pre-service teachers' familiarity with three-dimensional science instruction, as well as their professional readiness to enact it in their future classrooms. To that end, this study investigated the impact of a reformulated introductory science methods course that included an *NGSS*-designed "working shop" intervention administered at the midterm of the semester which extended over eight consecutive class meetings, right up until the regularly scheduled field experience practicum. The *NGSS*-designed learning modules within the "working shop" intervention incorporated three-dimensional science instructional pedagogies and materials accessed from established open-sourced resources found online. For this study, the decision to employ a mixed method approach was made for three main reasons: (1) to embrace both the objective and subjective points of view within a pragmatic research paradigm; (2) to mitigate the limitation of a small sample size (*N*=12), and (3) to collect rich, comprehensive data that included the perspectives of the participants' experiences (Creswell & Creswell, 2018; Robson & McCartan, 2016). Because this study was grounded in Bandura's (1977, 1986) Theory of Self-Efficacy, a concurrent triangulation approach to data collection was utilized where both quantitative and qualitative data were considered equally important in the analysis of this study's findings (Creswell & Creswell, 2018; Robson & McCartan, 2016). Due to the segregated nature of this study's two research questions, data collected from all instruments was "mixed" during the interpretation phase, as described in Chapter V. Ultimately, the rationale for mixing quantitative data with qualitative data was to triangulate interpretation as a means to increase the trustworthiness of this study's findings.

Quantitative evaluation of the participants' perceptions of their self-efficacy was accomplished using an online survey compiled from Bleicher's (2004) modified Science Teaching Efficacy Belief Instrument-Preservice (STEBI-B) and a modified version of Kang et al.'s (2018) *NGSS* Science and Engineering Practices Survey. The combined survey was administered prior to the start of the *NGSS*-designed "working shop" intervention and then at the culmination of the intervention to capture data related to the participants' perceptions of their ability to enact three-dimensional instruction during their field practicum. Qualitative data was collected through: (a) pre-/post- administration of a "Draw Yourself as a Science Teacher" assignment, (b) participant answers to open-ended questions at the end of the online survey, and (c) focus group interviews where the participants were grouped by grade bands. Additionally, four exit tickets were administered at strategic points throughout the intervention to triangulate the collection of qualitative data to improve its reliability and validity. Quantitative data analysis included descriptive statistics, a bivariate Pearson's r correlation, and a Cohen's d analysis since the variables were normally distributed. Qualitative data analysis included content analysis and thematic coding of participant responses to open-ended online survey questions, pre-/post-drawings, exit tickets, and focus group interview questions.

Definition of Terms

- *National Science Education Standards (NSES)* – guidelines for K-12 science education in United States schools. They were established by the National Research Council in 1996 to outline what students need to know, understand, and be able to do to be scientifically literate at different grade levels. The *NSES* significantly influenced various states' own science learning standards and state-wide standardized testing (Herr, 2007).
- *Next Generation Science Standards (NGSS)* – The *Next Generation Science Standards (NGSS)* are K-12 science content standards. Standards set the expectations for what students should know and be able to do. The *NGSS* were developed by states to improve science education for all students. A goal for developing the *NGSS* was to create a set of research-based, up-to-date K-12 science standards. These standards give local educators the flexibility to design classroom learning experiences that stimulate students' interests in science and prepares them for college, careers, and citizenship (Achieve, n.d.).
- *A Framework for K-12 Science Education (The Framework)* – foundational report produced by the National Research Council (NRC) that forms the basis for the *NGSS*. It

calls for a new approach to science education based in scientific and educational research. The *NGSS* draws its content across the three dimensions, as well as the three-dimensional approach to learning, from *The Framework* (Achieve, n.d.).

- *Three-Dimensional Instruction* – instructional pedagogy that teachers use to create students' experiences in classrooms while implementing the *NGSS*: developing and using elements of the three dimensions, together, purposefully (i.e., to explain phenomena or design solutions to problems). Teachers generate lessons aligned to the standards that are three-dimensional; that is, they should allow students to actively engage with the practices and apply the cross-cutting concepts to deepen their understanding of core ideas across science disciplines (Achieve, n.d.).
- *Disciplinary Core Ideas (DCIs)* – the fundamental ideas that are necessary for understanding a given science discipline. The core ideas all have broad importance within or across science or engineering disciplines, provide a key tool for understanding or investigating complex ideas and solving problems, relate to societal or personal concerns, and can be taught over multiple grade levels at progressive levels of depth and complexity (Achieve, n.d.).
- *Science and Engineering Practices (SEPs)* – these practices are what students actively do to make sense of phenomena. They are both a set of skills and a set of knowledge to be internalized. The SEPs reflect the major practices that scientists and engineers use to investigate the world and design and build systems (Achieve, n.d.).
- *Cross-Cutting Concepts (CCCs)* – the concepts that hold true across the natural and engineered world. Students can use them to make connections across seemingly disparate disciplines or situations, connect new learning to prior experiences, and more deeply

engage with material across the other dimensions. The *NGSS* require that students explicitly use their understanding of the CCCs to make sense of phenomena or solve problems (Achieve, n.d.).

Summary

This research study sought to determine the impact of an *NGSS*-designed “working shop” intervention as part of an introductory science methods course on pre-service teachers’ perceptions of their self-efficacy in teaching science using three-dimensional instruction. The intent of this research endeavor is to provide insight into “best practices” for preparing teachers to teach science according to the goals of the *NGSS*, as well as give “voice” to the pre-professional experiences of prospective teachers. Most previous research on implementing three-dimensional science instruction focused on in-service teachers, so there is little to no research presented on how to best prepare prospective teachers for using three-dimensional instruction to teach science according to the intent of the *NGSS*. The results of this study may serve multiple K-12 stakeholders such as teacher educators, mentor teachers, science content coordinators, state licensing boards, and most of all pre-service teachers themselves.

Chapter II is a thorough review of the literature on three-dimensional science instruction with a special focus on the development of the United States’ national science standards. Chapter III discusses this study’s procedure, study participants, research instruments, data collection, and data analysis plan. The remaining two chapters focus on the actual research performed for this study; Chapter IV presents the results, and Chapter V presents an interpretation of the findings.

CHAPTER II

LITERATURE REVIEW

With the release of the *NGSS* (*NGSS* Lead States, 2013) which emerged from the vision presented in the NRC's (2012) *Framework*, the conversation has dramatically changed about "best practices" for science teaching and learning in classrooms throughout the United States. Not only has this renewed discourse engaged all levels of K-12 education, but it also has intensified the conversation around changes that need to take place in teacher education regarding the design of teacher preparation programs. The conversation focuses on how the programs plan to deliver science content and how field experiences are structured (Rhoton, 2018). Because of the pervasive nature of this dialogue, all areas of science teaching and learning are affected by the *NGSS* from pre-service teacher preparation to in-service professional development to statewide assessment and accountability (Bybee, 2014). Ultimately, the goal of the NRC's (2012) *Framework* and the *NGSS* is to improve science learning for all students beyond just developing scientific literacy as endorsed by the previous *NSES* (Rhoton, 2018).

This renewed vision for K-12 science education presented by the NRC's (2012) *Framework* and the *NGSS* has been shaped by decades of research on teaching and learning (Michaels et al., 2008; National Research Council [NRC], 2007), specifically in the domain of constructivism. As defined by Richardson (2003), constructivism is known as the "theory of learning or meaning making, that individuals create their own new understandings on the basis of an interaction between what they already know and believe and ideas and knowledge with which they come into contact” (p. 1623-24). In other words, learning is constructed, where learners build new knowledge on the foundation of existing knowledge (McLeod, 2019). However, the influence of constructivism on the NRC’s (2012) *Framework* and the *NGSS* does not end at such a one-dimensional definition. Both publications are heavily influenced by two other theoretical threads within constructivism: Jean Piaget’s (1959) theory of cognitive constructivism and Lev Vygotsky’s (1978) theory of social constructivism. Piaget’s (1959) theory of cognitive constructivism states that students actively construct knowledge over time, meaning that intelligence is not a fixed trait. According to Piaget (1959), a student’s cognitive development is not solely about acquiring knowledge, but it is also about developing or constructing mental models of the natural world around them. Another dimension to constructivism was added by Vygotsky (1978) where he posited that learning is an active process of collaboration, where a student’s knowledge evolves from personal interactions with society through the lens of their culture. Based on this constructivist perspective, the NRC’s (2012) *Framework* and the *NGSS* are grounded in the following five essential understandings of how students learn: (a) children are naturally born investigators, (b) understanding develops over time, (c) science and engineering require knowledge and practice, (d) connections need to be made to students’ interests and experiences and (e) equity needs to be preserved (NRC, 1999, p. 24). From these five core ideas, the NRC’s (2012) *Framework* and the *NGSS* recommend a global transformation in K-12 science education, where teaching science moves away from learning about science to doing science (Banilower et al., 2013, 2018; National Academies of Sciences, Engineering, and Medicine, 2015; NRC, 2012; Schwarz et al., 2017; Windschitl & Stroupe, 2017). This recommendation from the NRC’s (2012) *Framework* has been realized through the release of the *NGSS* which offers a 21st century model of K-12 science education known as three-dimensional instruction.

Three-Dimensional Instruction

Of the five essential understandings of how students learn proposed by the NRC (1999), the furthest removed from current practice in K-12 science education is the integration of scientific knowledge and scientific practices. Attempting to move K-12 science education beyond the failed standard-based reforms born from the *NSES*, the NRC's (2012) *Framework* suggests that K-12 science education moves toward a 21st century model known as three-dimensional instruction where students learn science through figuring out science. In practice, three-dimensional instruction requires the teaching of scientific disciplinary core ideas (DCIs) through simultaneous engagement in the eight scientific and engineering practices (SEPs), not as separated domains of instructional practice (Banilower et al., 2013, 2018). Additionally, three-dimensional instruction intentionally embeds seven cross-cutting connections (CCCs) that link the three main science disciplines of Life Science, Physical Science, and Earth and Space Science cohesively. If one of the primary goals of science education is to "cultivate habits of mind and develop [students'] ability to engage in scientific inquiry and teach them how to reason in a scientific context" (p. 41), then K-12 science education needs to move away from the traditional approach of content, then lab, then test as propagated through the myopic interpretation of the *NSES* (NRC, 2012).

According to the NRC's (2012) *Framework*, implementing three-dimensional instruction throughout K-12 education leads to student learning in science that departs from "naïve conceptions of scientific inquiry and the impression that science is simply a body of isolated facts" (p. 41). The intentional use of the word "practices" rather than "skills" throughout the NRC's (2012) *Framework* and the *NGSS* is based on the supposition that "scientific inquiry requires the coordination of both knowledge and skill" (p. 41). Additionally, the NRC (2012) posits that through an emphasis on both content and skill in the K-12 science classroom, "students gain a better understanding of how scientific knowledge is produced and how engineering solutions are developed" (p. 41). In turn, students' knowledge becomes transferable across science content areas as they achieve true conceptual understanding of scientific phenomenon through authentic investigative experiences, just as actual scientists and engineers do.

Three Dimensions of the *NGSS*

Before a discussion can ensue about the implications of three-dimensional instruction on science teaching and learning, each of its three dimensions needs to be further explicated. These three dimensions are science and engineering practices (SEPs), disciplinary core ideas (DCIs), and cross-cutting concepts (CCCs).

For the first dimension of three-dimensional instruction, the NRC's (2012) *Framework* and the *NGSS* present eight science and engineering practices (SEPs):

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Ultimately, through the reiterative use of these eight science and engineering practices (SEPs) in K-12 science classrooms, the NRC (2012) maintains that students become critical consumers of scientific information and can therefore make more informed decisions as they navigate society in the 21st century.

Due to the present information age, the NRC (2012) states that science education cannot "teach all the ideas related to a given discipline in exhaustive detail during the K-12 years" (p. 30). A key goal of science education should not be to "cover" all the content in each discipline, but rather to provide students with enough foundational knowledge so that they can become lifelong learners, users, and possibly producers of scientific knowledge. According to the NRC (2012), a science education that emphasizes an unlimited number of ideas should "enable students to evaluate and select reliable sources of scientific information and allow them to continue their development well beyond their K-12 school years" (p. 31).

Selection of the DCIs for the NRC's (2012) *Framework* followed a specific set of criteria, where each core idea had to meet at least two of the following to be selected:

1. Have broad importance across multiple sciences or engineering disciplines or be a key organizing principle of a single discipline;
2. Provide a key tool for understanding or investigating more complex ideas and solving problems;
3. Relate to the interests and life experiences of students or be connected to societal or personal concerns that require scientific or technological knowledge; and
4. Be teachable and learnable over multiple grades at increasing levels of depth and sophistication. That is, the idea can be made accessible to younger

students but is broad enough to sustain continued investigation over years (p. 31).

Once selected, the DCIs were grouped into four major domains for ease in organization: the physical sciences; the life sciences; the earth and space sciences; and engineering, technology, and applications of science (p. 31). The NRC's (2012) selection of a small number of DCIs was premised on the belief that building a strong base of scientific knowledge that is understood in depth best prepares students for success in the 21st century.

In the third dimension of the *Framework*, the cross-cutting concepts (CCCs), the NRC (2012) addresses these as seven "touchstones" (p. 83) that connect each of the four major domains within the disciplinary content ideas (DCIs) and blur the lines of demarcation between them:

1. *Patterns*: Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them;
2. *Cause and effect*: Mechanism and explanation. Events have causes, sometimes simple, sometimes multi-faceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts;
3. *Scale, proportion, and quantity*: In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance;

4. *Systems and system models*: Defining the system under study, specifying its boundaries, and making explicit a model of that system provides tools for understanding and testing ideas that are applicable throughout science and engineering;
5. *Energy and matter*: Flows, cycles, and conservation. Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations;
6. *Structure and function*: The way in which an object or living thing is shaped and its substructure determines many of its properties and functions; and
7. *Stability and change*: For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study (p. 84).

Connecting the four major DCI domains together makes it easier for students to see the commonalities across many areas of science and engineering, which in turn strengthens their foundational scientific knowledge. Additionally, these cross-cutting concepts (CCCs) allow for congruency in the development of science standards, curricula, instruction, and assessments throughout all levels of K-12 science education. Using these seven CCCs, students can see the interplay of physics throughout all science domains, rather than a stand-alone subject that simply is meant to define forces and motion.

Although knowledge of each dimension as separate entities is key to a conceptual understanding of them, the prescribed intent of the NRC's (2012) *Framework* and the *NGSS* is the simultaneous integration of all three dimensions in the teaching of science in K-12 classrooms. Due to the *NGSS*'s substantial departure from how science education was represented in the *NSES* of 1996, all levels of K-12 science education from early childhood to higher education need to reimagine how students are taught in a three-dimensional manner (National Academies of Sciences, Engineering, and Medicine, 2015). Therefore, the challenge becomes making this reformation a reality across all levels of K-12 science education to meet the intent of the NRC's (2012) *Framework* and the *NGSS*.

Science Education Before the *NGSS*

The "Science as Inquiry" movement that characterized science education before the *NGSS* was initiated with the release of the *National Science Education Standards (NSES)* of 1996, which were a direct result of the Goals 2000 project created by the National Governors Association (Labov, 2006). Beginning in the early 1990s, their annual conferences became historical events where President George H.W. Bush and the nation's governors articulated eight National Education Goals, where Goal 4 specifically targeted science education by declaring that by the year 2000, "U.S. Students will be first in the world in mathematics and science achievement" (Labov, 2006). To achieve this goal, the governors decided that national standards for science needed to be developed based on the following objectives of what K-12 students should be able to do:

a) Use scientific principles and processes appropriately in making personal decisions;
b) Experience the richness and excitement of knowing about and understanding the natural world;
c) Increase their economic productivity;
d) Engage intelligently in public discourse and debate about matters of scientific and technological concern; and

e) Be aware of careers in science, technology, and the medical sciences (Labov, 2006, p. 205).

Based on these directives from the Goals 2000 project, science education needed to change in very fundamental ways. To begin, these objectives called for teaching science beyond just facts. Instead, students needed to understand the interconnections between science and other types of knowledge and how science is critically important to their daily lives. Also, rather than prioritizing science education for those students who are most apt to follow scientific careers, these objectives emphasized science for all students. Lastly, these objectives called for students to be exposed to science much earlier in their academic careers. These proposed reforms presented significant repercussions for K-12 science education in the U.S. including the preparation of pre-service teachers, the professional development of in-service teachers, the recruitment of qualified teachers to teach science, the development and implementation of science curricula, and even the design of science classrooms across K-12 schools (Labov, 2006). This new approach to science education was greatly influenced by the work of the American Association for the Advancement of Science (AAAS) through its program called Project 2061.

Project 2061

In 1985, the AAAS launched a program known as Project 2061, a long-term effort to improve education so that all citizens attain scientific literacy. This collaborative effort was meant as a national strategic plan for all U.S. citizens to reach a better understanding of how the natural sciences, social sciences, mathematics, and technology all interact within the world and how they affect all human endeavors (American Association for the Advancement of Science [AAAS], 2001). As the 21st century approached, AAAS released two seminal reports: *Science* *for All Americans* (1991) and *Benchmarks for Science Literacy* (1993). They were meant as preludes to *Atlas of Scientific Literacy* (2001).

The first report *Science for All Americans* (American Association for the Advancement of Science [AAAS], 1991) described the specific knowledge and abilities that define and characterize science literacy. This report documented the need for all citizens to become scientifically literate based on several provocative arguments, including the following: (1) science provides humanity with the knowledge of their environment and of social behavior needed to develop effective solutions to its global and local problems; without that knowledge, progress toward a safe world will be severely hampered; (2) science explains the dependency of living things on each other and on their physical environment and fosters intelligent respect for nature that should inform decisions on the uses of technology; without that respect, the physical environment becomes recklessly endangered and will cease to support life; and (3) scientific habits of mind can help every citizen to sensibly handle challenges that often involve evidence, quantitative considerations, logical arguments, and uncertainty; without the ability to think critically and independently, citizens fall prey to the trappings of pseudo-science (AAAS, 1991). With this report, the AAAS established a strong case against maintaining status quo regarding U.S.'s science educational plan.

After presenting its arguments for the need to reform the nation's science education programs, the AAAS released its second report *Benchmarks for Science Literacy* (1993). *Benchmarks* specified how students should progress toward science literacy, recommending what they should know and what they should be able to do by the time they reach certain grade levels: 2, 5, 8, and 12 (AAAS, 1993). This report provided recommendations for making reasonable progress toward the goal of adult science literacy that was argued and defined in the first report *Science for All Americans* (AAAS, 1991). In summary, the first report provided the reasons why there should be a concentrated effort on behalf of the national educational system to engage in improving science literacy for all students, and the second report provided the specifics of what scientifically literate knowledge and skills look like, so teachers and administrators can help students to attain scientific literacy by the time they finish 13 years of schooling within the national system (American Association for the Advancement of Science [AAAS], 1993).

To culminate its position on the criticality of science educational reform, the AAAS released its third report *Atlas for Science Literacy* (2001). In this two-volume set, the *Atlas* attended to the challenge of making science education reform a reality (AAAS, 2001, p. 3). According to its authors, *Atlas* suggested that "science literacy should be approached not as a *collection* of isolated abilities and bits of information, but as a rich *fabric* of mutually supported ideas and skills that must develop over time" (p. 3). In this framework, the authors believed that what students learn from grade to grade "should build on what they learned before, make sense in the terms of what else they are learning, and prepare them for what they will learn next" (p. 3). To achieve adult science literacy, the authors contended that teachers need to understand the interplay between what their students learn in other grades, topics, and disciplines and what they want to teach their students in the present (AAAS, 2001). In other words, educators must understand that what their students learn in a particular classroom depends on and supports what they were taught before the students got there and has an effect on what they are going to learn in the future.

To demonstrate this interdependency among student science learning, the *Atlas* authors presented the "how-to" information as conceptual strand maps (AAAS, 2001, p. 3). These maps graphically show educators the growth of science understanding on behalf of their students as they make their way through various science, math, and technology topics from grade to grade. According to the authors, unless educators understand how scientific ideas and skills develop over time and how they relate to one another, students will be left with nothing more than a heap of unrelated, poorly understood, and quickly forgotten facts, algorithms, and technical terms (p. 3). Fortunately, the *Atlas* authors do not prescribe a specific curricular plan to follow in order for students to reach adult science literacy. Instead, they offer a framework that is meant to allow a variety of interpretations to design and organize learning experiences to meet the needs of individual student populations. In response to the *NGSS*'s growing influence on K-12 science education, the NSTA Press recently published Willard's (2020) *The NSTA Atlas of the Three Dimensions* which presents an invaluable resource for science educators in their pursuit of transforming their practice with three-dimensional instruction. Throughout its pages, Willard's (2020) *Atlas* incorporates the SEPs, the DCIs across all three science domains, and the CCCs throughout its conceptualized mapping scheme, providing science educators valuable insight into how to put three-dimensional teaching and learning into action within their classrooms.

How Students Learn Science

While the AAAS developed the Project 2061, the National Research Council (NRC) also played a significant role in the science education reform movement called for in the *NSES*. In their 1999 publication, *How People Learn: Brain, Mind, Experience, and School,* the authors emphasized three fundamental principles of learning that educators should incorporate into their instructional pedagogy when teaching science: (1) students come to the classroom with preconceptions about how the world works; (2) in order to succeed within an inquiry construct, students must have a firm foundation of factual knowledge, the comprehension of how that factual knowledge fits together, and the ability to retrieve and apply that knowledge in new settings; and (3) students need to take control of their learning through the teacher's use of a meta-cognitive approach that allows them to define learning targets and self-monitor their progress in pursuit of those targets. In addition, the NRC (1999) continued to explain four instructional design characteristics that can be used as "lenses" to evaluate the effectiveness of teaching and learning environments in science classrooms. These four design characteristics are:

- *Learner-centered* = starting instruction from where the learners are
- *Knowledge-centered* = what is taught, why it is taught, what mastery looks like
- *Assessment-centered* = formative assessment opportunities to be used as checkpoints of learning along the way
- *Community-centered* = respectful engagement that allows for questioning, risk-taking

Although these recommendations are enlightening, putting them into practice remained challenging for most educators including both pre-service and in-service teaching professionals. Recognizing this inherent roadblock to science education reform, the NRC continued their research of how people learn through an exploration into teaching "Science as Inquiry."

In its 2000 publication, the National Research Council (NRC) clarified its position on the importance of teaching science as inquiry with the following:

> "Inquiry is at the heart of the *National Science Education Standards*. The *Standards* seek to promote curriculum, instruction, and assessment models that enable teachers to build on children's natural, human inquisitiveness. In this way, teachers can help all their students understand science as a human endeavor, [through the acquisition of] the scientific knowledge and thinking skills important in everyday life." (p. 6)

In this manner, the NRC validated the work of the AAAS's Project 2061 and provided a venue of national support by which educational researchers could embark on their academic pursuits to investigate the advantages of an inquiry approach to science education.

Based on the instructional changes suggested by both the AAAS's Project 2061 (2001) and the three NRC publications (1996, 1999, 2000), moving science education toward an inquiry approach provided a plausible answer to the nation's problem of science illiteracy. Based on its inherent nature, the NRC concluded that teaching from a "science as inquiry" perspective forces students to make and evaluate decisions using careful questioning, valid evidence, and critical reasoning (NRC, 2000). According to the NRC (2000), switching the instructional focus in the science classroom from what scientists already know to pondering why they know or how they know helps students to develop the critical processing skills to successfully navigate through the global challenges that they will face in their adult lives. Studies have found that not only do students learn more science content through inquiry, but they also develop the ability to "study the natural world and propose explanations based on the evidence derived from their work" through inquiry (NRC, 1999, p. 17). Moreover, the NRC posited that "inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations (NRC, 2000, p. 23), all of which are imperative to the *NSES*'s science education reform movement towards improved scientific literacy on behalf of all citizens.

***NSES*'s "Science as Inquiry" Reform Movement**

Support for this type of reform movement within science education dates back to a pivotal event in April 1999 – the meeting of the American Educational Research Foundation in Montreal, Canada, where the underlying theme was to discuss the underdevelopment of learning within the nation's public educational system. It was at this meeting that Leon M. Lederman, Nobel Laureate (Physics 1988) and science education leader, proclaimed the disservice to students and urged for drastic changes in how primary and secondary students are educated, specifically in the area of science. At this historic meeting, Lederman (1999) presented a paper titled "On the Threshold of the 21st Century: Comments on Science Education" which defined the purpose of schools as public institutions that should "produce graduates who can cope in the world into which they emerge" (p. 2). To clarify his position, Lederman stated that "projections of the human condition, the strength of family, the level of moral and ethical behavior, the economic health, social and political stability are all subject to the advance of science and technology" (1999, p. 3). In order words, the nation's students' lack of scientific literacy affects every aspect of their lives based on the current state of a techno-savvy global existence. In addition, Lederman asserted that these issues dominate "the world into which they emerge" (1999, p. 2) and should be used as guidelines for what the nation must do within its schools so that "no matter what road they choose (work, technical, liberal arts, science, or engineering), our students will be able to 'cope'" (1999, p. 3). Therefore, it is in the best interest of the nation's future that educators critically analyze how students are being educated within the realm of science so that graduates possess the skills, attitudes, and habits of mind to successfully lead the nation toward the continued propagation of humanity beyond the 21st century.

This Montreal event in 1999 was exceptionally notable as it took place just three years after the release of the 1996 *National Science Education Standards (NSES)*, the nation's first attempt at standardizing science education based on the National Research Council's (NRC) vision of a scientifically literate populace where everyone knows how to use scientific information to make sound decisions every day. Furthermore, the National Research Council (NRC, 1996) believed that:

> "everyone needs to be able to engage intelligently in public discourse and debate about important issues that involve science and technology. And everyone deserves to share in the excitement and personal fulfillment that can come from understanding and learning about the natural world." (p. 1)

Achieving the goal of scientific literacy for all students according to the vision put forth by the *NSES* of 1996 required dramatic changes across school systems. Even then, the NRC called for a new way of teaching and learning science to reflect how science is truly done in the real world through the implementation of "science as inquiry" as a way for students to gain knowledge and understanding about their world.

"Science as Inquiry" in the Classroom

When looking at teacher preparation outcomes against the "science as inquiry" reform movement of the *NSES*, the results are underwhelming. According to Banilower et al. (2013, 2018), in-service elementary teachers report that they were rather ill-prepared for transitioning into their professional environment as science teachers from their teacher preparation programs. As seen in the *2018 National Survey of Science and Math Education (NSSME+) Report*, Banilower et al. (2013, 2018) stated that only 31% of in-service elementary teachers of self-contained classes felt very well prepared to teach science. When disaggregating the *2018 NSSME+* data across science topics, elementary teachers' feelings of preparedness to teach life science was reported at only 24%, with both Earth and space science and physical science at only 20%, respectively. With the *NGSS* fundamentally constructed around the interconnectedness of the three main science content domains, this result does not instill confidence in the transformation of teacher preparation programs toward three-dimensional science instruction. Also, merely three percent of in-service elementary teachers reported that they felt prepared to teach engineering, a significant component of the *NGSS* (Banilower et al., 2013, 2018).

Since three-dimensional science instruction prioritizes the doing of science to learn science, the 2018 *NSSME+* Survey included questions regarding particular classroom activities utilized in every science lesson, as well as the engagement of students in the practices of science. Nearly half of elementary teachers reported using teacher-centered explanations in all or almost all science lessons, followed by only a third using small group work, and less than a fifth using hands-on/laboratory work in all or almost all science lessons. When asked about the use of specific *NGSS* science and engineering practices at least once a week, the reported classroom use dropped significantly: (1) for SEP 2 Developing and Using Models, less than a fifth of elementary teachers reported engaging their students in this practice; (2) for SEP 6, Constructing Explanations, only 10 percent of elementary teachers provided opportunities for their students to engage in this practice; and (3) for SEP 7, Engaging in Argument from Evidence, less than a fifth of elementary teachers enacted this practice for their students during their science lessons (Banilower et al., 2013, 2018).

Although these 2018 *NSSME+* Survey results are discouraging from a teacher education reform perspective, they are not at all surprising. As reported by the National Research Council (NRC) (2003), engaging in-service teachers—including those in teacher education—in science standard reform as presented by the *NSES* was thwarted by two main factors: (1) lack of familiarity with the reformed standards as a whole and (2) pressure to “cover” content due to state mandated science achievement tests. According to 2000 National Survey of Science and Mathematics Education, only a third of elementary teachers reported being somewhat familiar with the *NSES* standards document (NRC, 2003). Interestingly, two thirds of elementary teachers who were familiar with the *NSES* agreed or strongly agreed with the vision of science education put forth by the *NSES*, leading to an increased predisposition to implement instructional reforms when teaching science (NRC, 2003). Due to the strict accountability measures placed on school districts during the era of the No Child Left Behind Act (2002-2015), in-service teachers used science curriculum alignment to state mandated science achievement tests as a barometer for instructional use in the classroom. Unfortunately, the reported unfamiliarity of the *NSES* standards compounded that belief; thus, leading to the *NSES* and its "science as inquiry" movement never really taking hold in K-12 science education. In addition, this prior negative experience with the *NSES* and its "science as inquiry" approach has led to an unwarranted scrutiny of the *NGSS* throughout K-12 education when promoted as "Inquiry 2.0" (Schwarz et al., 2017).

Challenges to Three-Dimensional Instruction

To meet the intent of the *NGSS*, K-12 science education has the daunting task of reconfiguring its entire system toward three-dimensional science instruction. Unlike previous standards-based reforms, the *NGSS* integrates inquiry with content, not separate from it, as a means for students to achieve conceptual understanding of scientific principles. In prior reforms within the *NSES*, the sensemaking aspects of developing explanations through the use of scientific inquiry were rarely emphasized (Reiser, 2013). In most K-12 classrooms, teachers and textbooks taught facts and definitions as a means in and of themselves rather than to relate concepts together toward the generation of an explanatory model that explains the how and why phenomena occur (Reiser, 2013). In the *NGSS*, the science and engineering practices (SEPs) are used as a means to build knowledge around the disciplinary core ideas and to experience the coherence that unifies the main scientific disciplines of life, physical, and Earth and space sciences. Very few teacher educators have direct experience with scientific inquiry that incorporates sensemaking through the reiterative use of the SEPs, creating several areas of discordance between current science teacher practices and three-dimensional instruction (National Academies of Sciences, Engineering, and Medicine, 2015). According to Reiser (2013), addressing these areas of concern require four essential transformations in teaching science implicated by the *NGSS*:

1. From memorizing facts to explaining phenomena;
2. From separate standards to integrated practices, with a centralized focus on developing and revising models, constructing explanations, and arguing from evidence;
3. From inquiry as confirming activity to inquiry as developing explanatory knowledge; and
4. From discrete, disconnected facts to cohesive progressions built over time and between disciplines.

Engaging in these four essential transformations will create many challenges for most teacher educators as three-dimensional instruction may be a type of science teaching that they have never encountered themselves (National Academies of Sciences, Engineering, and Medicine, 2015).

As a whole, these four essential transformations are quite imposing as they reflect a culmination of several decades of research on how students learn science (NRC, 2012). More explicitly, Reiser (2013) analyzed the implications set forth by the *NGSS* for science teaching practices and identified the following list of challenges for teacher educators:

(a) “Lessons should be structured so that the work is driven by questions arising from phenomena, rather than topics sequentially pursued according to the traditional breakdown of lessons.

(b) “The goal of investigations is to guide construction of explanatory models rather than simply testing hypotheses.

(c) “Answers to science investigations are more than whether and how two variables are related but need to help construct an explanatory account.

(d) “Students should see what they are working on as answering explanatory questions rather than learning the next assigned topic.

(e) “A large part of the teachers’ role is to support the knowledge building aspects of practices, not just the procedural skills in doing experiments.

(f) “Extensive class focus needs to be devoted to argumentation and reaching consensus about ideas, rather than having textbooks and teachers present ideas to students.

(g) “Teachers need to build a classroom culture that can support these practices, where students are motivated to figure out rather than learning what they are told, where they expect some responsibility for this work of figuring out rather than waiting for answers, and where they expect to work with and learn with their peers.” (p.11)

For teacher educators to overcome these unsettling challenges, there will need to be an extensive system of support in place where they can develop lessons, try them out, and receive targeted feedback for improvement. Although these challenges are extensive in scope, research supports the feasibility of teacher educators developing high self-efficacy themselves in teaching science using three-dimensional instruction and having a positive impact on student learning when they do so (NRC, 2007; Reiser, 2013).

Preparing Teachers for Three-Dimensional Instruction

For those higher education institutions committed to reconfiguring their teacher education programs according to the intent of the *NGSS*, the NRC (2015) suggests prioritizing the integration of the following five innovations:

(a) *Three-Dimensional Learning*: integrating the three equally important, distinct dimensions to learning science – Scientific and Engineering Practices (SEPs), Cross-Cutting Concepts (CCCs), and Disciplinary Core Ideas (DCIs) – that are interconnected in the *NGSS*; structuring student experiences to facilitate the application of scientific principles to real-world situations and providing more engaging and relevant instruction that explores complicated topics;

(b) *Coherent Learning Progressions*: providing multiple opportunities to engage in and develop a deeper understanding of each of the three dimensions of science where students revisit and expand their knowledge, skills, and understanding of all three dimensions as they progress from year to year within their programs;

(c) *Real-World Engagement*: allowing students to explain real-world phenomena, design solutions based on their understanding of the DCIs, engagement in the SEPs, and application of the CCCs;

(d) *Integration of Engineering Design*: engaging students in the unique aspects of engineering such as identifying problems, researching solutions, testing prototypes, and redesigning based on unexpected outcomes; and

(e) *Connection to Math and Literacy*: maintaining curricular connections with mathematics and English Language Arts which provides a substantive overlapping of skills and knowledge that provides all students with equitable access to the learning standards. (*NGSS* Fact Sheet, 2016, p. 2)

As shown in Table 2, these five *NGSS* innovations have profound implications on the instructional pedagogies used by teacher educators to prepare prospective teachers for three-dimensional instruction, further complicating the *NGSS* implementation process within teacher education. In addition to considering these pedagogical implications, many teacher educators will also need to reevaluate their characteristic practices within the context of the *NGSS* such as "modeling strong examples of science teaching to novices, showing how to attend to the thinking of students, and providing feedback to novices as they attempt to approximate instruction" (Windschitl et al., 2014, p. 2) due to their lack of professional experience using three-dimensional instruction. In order for pre-service teachers to become self-efficacious in their science teaching using three-dimensional instruction, teacher educators will need to create reiterative, cohesive learning experiences that allow their pre-service teachers to participate in the full range of science and engineering practices (SEPs), to develop a strong foundation of content knowledge across the three main science disciplines, and to apply the cross-cutting connections in authentic, meaningful ways (NRC, 2015). Table 2 shows the profound implications for the NRC's (2012) *Framework* for K-12 science education and the *NGSS*.

Table 2

Implications for the NRC's (2012) Framework for K-12 Science Education and the NGSS

Science Education will involve LESS:	Science Education will involve MORE:
Rote memorization of facts and terminology	Facts and terminology learned as needed while developing explanations and designing solutions supported by evidence-based arguments and reasoning
Learning of ideas disconnected from questions about phenomena	Systems thinking and modeling to explain phenomena and to give a context for the ideas to be learned
Teachers providing information to the whole class	Students conducting investigations, solving problems, and engaging in discussions with teachers' guidance
Teachers posing questions with only one right answer	Students discussing open-ended questions that focus on the strength of the evidence used to generate claims
Students reading textbooks and answering questions at the end of the chapter	Students reading multiple sources, including science-related magazine and journal articles and web-based resources; students developing summaries of information
Pre-planned outcome for "cookbook" laboratories or hands-on activities	Multiple investigations driven by students' questions with a range of possible outcomes that collectively lead to a deep understanding of established core scientific ideas
Worksheets	Student writing of journals, reports, posters, and media presentations that explain and argue
Oversimplification of activities for students who are perceived to be less able to do science and engineering	Provision of supports so that all students can engage in sophisticated science and engineering practices

National Research Council (NRC, 2015, pp. 8-9)

Furthermore, the NRC's (2012) *Framework* and the *NGSS* present three-dimensional instruction as an expansion on the four proficiencies of what students should be able to do when learning science as presented by an earlier NRC (2007) report titled *Taking Science to School*:

a) understand, use, and interpret scientific explanations of the natural world

b) generate and evaluate scientific evidence and explanations

c) understand the nature and development of scientific knowledge

d) participate productively in scientific practices and discourse. (NRC, 2012, p. 251)

These four proficiencies are quite the departure from the traditional science education approach that stresses "vocabulary acquisition, the development of procedural skills, the use of labs that have known outcomes, and the reproduction of textbook explanations (Windschitl & Stroupe, 2017).

Pre-service teachers often report that they are not proficient in these four domains as their K-12 science experience aligned well with the traditional science approach, making it difficult to teach what they do not know or have not experienced for themselves (National Academies of Sciences, Engineering, and Medicine, 2015). If they do not experience learning science as three-dimensional learners during their pre-professional careers, they will not know what three-dimensional science instruction looks like, sounds like, or feels like in their future classrooms (Ricketts, 2014). For prospective teachers, enacting this model of teaching science in their future classrooms requires the reconstructing of their preparation programs away from the traditional pathway of theory, then observation, then practice where all three components are typically disconnected experiences. The process needs to be reconstructed into a more integrated 21st century model based on the five *NGSS* innovations where future teachers experience science as three-dimensional learners themselves. Doing so will ultimately generate pre-service teachers who can comfortably attend to the pedagogical demands of three-dimensional instruction while becoming self-efficacious teachers of three-dimensional science (NRC, 2015).

Based on this body of research, the intent of this mixed method study was to propose an instructional model for use in teacher preparation programs that meets the intent of the *NGSS* by intentionally embedding the five *NGSS* innovations in a “working shop” intervention, where the pre-service teachers became three-dimensional learners themselves throughout the teaching of learning modules. The novelty of this proposed approach was evident in the pedagogical change in instructional delivery from the pre-service teachers learning about science to the pre-service teachers figuring out science. Throughout the “working shop” intervention, pre-service teachers were tasked with performing key science and engineering practices driven by their exploration of a naturally occurring phenomenon to gain conceptual understanding of the science content presented. Engaged in an authentic real-world task, the pre-service teachers made sense of their learning motivated by their own curiosities, developed and used models of their own making, constructed explanations, and engaged in argument based on their own evidence. Although the participants gained a better understanding of what three-dimensional science instruction looks like, feels like, and sounds like, they were only able to participate in this type of science teaching and learning for the final eight weeks of the semester.

In order for prospective teachers to learn how to teach science using three-dimensional instruction, they need sufficient time engaged in authentic learning experiences to do so throughout all aspects of their preparation programs. According to Lortie (1975), learning to teach science begins when the pre-service teacher participates as an observer and learner throughout their K-12 career, where they indirectly learn how to teach science based on their own student experiences. What pre-service science teachers believe science teaching is, what it should be, and what it looks like in practice are strongly influenced by these prior K-12 science experiences. Nevertheless, these perceptions of science teaching must be examined, and prospective science teachers must be given ample time and multiple opportunities to learn and understand the practice of teaching three-dimensional science in order to successfully implement this practice in their future classrooms (Feiman-Nemser, 2001). According to the NRC (2015), the process of challenging and reforming these prior beliefs and attitudes can be difficult and often requires time to develop and mature. This means that the process needs to begin at the start of the pre-service teachers' education rather than at the end. Integrating three-dimensional science teaching and learning throughout all aspects of teacher preparation is a novel idea and is not the norm for preparing teachers to teach science in this nation's K-12 classrooms. However, this integration must be a priority for successful navigation beyond the 21st century.

Final Call for Reform

The conversation regarding teacher education reform is not new as it began long ago with the Holmes Group, a collection of education deans and chief academic officers from research institutions across 50 states who met to discuss the "enduring problems associated with the generally low quality of teacher preparation in the United States" (Holmes Group, 1995, p. i). From its collective work, the Holmes Group published a trilogy of reports: *Tomorrow's Teachers* (1986), *Tomorrow's Schools* (1990), and *Tomorrow's Schools of Education* (1995). The reports presented a call-to-arms for schools and universities to rally around a set of two common goals: the reform of teacher education and the reform of the teaching profession in the United States.

In its final installment, *Tomorrow's Schools of Education*, the Holmes Group (1995) challenged colleges of education to resurrect their programs by (a) designing a new curriculum, (b) developing a new faculty, (c) recruiting a new student body, (d) creating new locations for much of their work, and (e) building a new set of connections to those they serve (p. 2-3). The premise of the third argument was founded on the collective belief that "education students for too long have been learning too little of the right things in the wrong places at the wrong time" (Holmes Group, 1995, p. 2). Further, the Holmes Group (1995) strongly encouraged:

> "universities that develop education knowledge, influence education policy, and prepare teachers and other leaders for our nation's schools [to] overcome 'business as usual' to meet the challenge of these truly unusual times in education. The indisputable link between the quality of elementary and secondary schools and the quality of the education schools must be acknowledged—and we must respond." (p. 3)

As the trilogy ended, the Holmes Group (1986, 1990, 1995) provided schools and universities with a solid rationale for engaging in the reform of teacher education sooner rather than later.

Summary

The aim of this study was to inform teacher education constituents of the most impactful instructional practices to improve pre-service elementary teachers' self-efficacy in teaching science using three-dimensional instruction, as well as provide evidence that supports the successful integration of three-dimensional pedagogies within an introductory science methods course. Additionally, a goal of this study was to capture the perspective of pre-service elementary teachers through their self-reported perceptions on how well their program prepared them for engaging in three-dimensional instruction while participating in their field experience practicum. The addition of their personal, collective narrative provided depth and dimension to the quantitative results generated through the conduction of this research. Driven by the aforementioned research goals, the following chapter presents an overview of this research study's mixed method approach grounded in Bandura's (1977, 1986) Theory of Self-Efficacy.

CHAPTER III

METHODOLOGY

The purpose of this chapter is to introduce the research methodology for this mixed method study regarding the impact of an *NGSS*-designed "working shop" intervention on pre-service teachers' perceptions of their self-efficacy in teaching science using three-dimensional instruction. This pragmatic approach allowed for a deeper understanding of the participants' experiences within their introductory science methods course as they engaged as three-dimensional learners and reflective practitioners and for the validation of a novel instructional model as "best practice" in preparing teachers to teach science using three-dimensional instruction. The research plan, including methodology selection, description of the participants, details of implemented procedures, methods of analysis, and discussion of ethical concerns are all key components of this chapter.

Purpose of the Study

The purpose of this study was to develop an innovative instructional model for preparing teachers to teach science using three-dimensional instruction that was theoretically and conceptually derived from Bandura's (1977, 1986) Theory of Self-Efficacy. Once developed, this novel instructional model was implemented as a "working shop" intervention within an introductory science methods course, where prospective teachers engaged as three-dimensional learners and reflective practitioners concurrently. A primary goal of this study was to inform teacher education constituents of high impact instructional practices to improve pre-service teachers' self-efficacy in teaching science using three-dimensional instruction, as well as provide evidence that supports the holistic integration of three-dimensional science pedagogies within all aspects of teacher education programming. Lastly, this study aimed to present a rich, comprehensive narrative of the prospective teachers' experiences as they navigated their initiation into becoming effective three-dimensional teachers of science.

Research Questions

This study sought to develop an original instructional model of "best practice" for preparing teachers to teach science in answer to the following questions:

1. To what extent does an *NGSS*-designed "working shop," centered on the Science and Engineering Practices (SEPs) within an introductory science methods course, impact pre-service teachers' perceptions of their self-efficacy in teaching science using three-dimensional instruction?
2. To what extent does an *NGSS*-designed "working shop," centered on the Science and Engineering Practices (SEPs) within an introductory science methods course, impact pre-service teachers' perceptions of self-efficacy to enact three-dimensional instruction in their field experience practicum?

Selection of Methodology

This study simultaneously combined quantitative and qualitative methods with equal emphasis in order to take advantage of the strengths of each approach. Creswell and Creswell (2018) stated mixed method designs provide more complete answers to a particular study's research questions. They also argued that research designs that integrate different methods are more likely to produce better results in terms of scale and quality. According to Robson and McCartan (2016), a mixed method design goes beyond the constraints of a single approach because it integrates both quantitative and qualitative research methods. Specifically, this study used a convergent mixed method approach known as concurrent triangulation which was framed within a pragmatic research paradigm.

According to Creswell and Creswell (2018), researchers need to consider the philosophical worldview assumptions that they bring into their research designs. When selecting a research model, Creswell and Creswell (2018) suggests that the researcher choose a method that aligns with their epistemological stance, defined as a "basic set of beliefs that guide action" (p. 5). Due to the context of this study as problem-centered and real-world practice oriented, a pragmatic mixed method approach allowed for the exercise of epistemological relativism and placed equal value on both the objective and subjective points of view in this study, providing a rationale for the combining of quantitative methods with qualitative methods to answer the research questions within this study (Tashakkori & Teddlie, 2010). Additionally, this pragmatically situated mixed method approach acknowledged the subjective role of the researcher's beliefs and values in the interpretation of this study's results and ontologically balanced the belief in one single objective truth with the belief that there may be multiple "truths" in the understandings of the experienced phenomena within the findings generated from this study (Tashakkori & Teddlie, 2010).

Positionality of the Researcher

In undertaking this study, the researcher's professional experiences as a three-dimensional science teacher, as an experienced mentor teacher, and as a state science content standard reviewer inspired the decision to research the topic of transforming science teacher education to align with the intent of the *NGSS*. The researcher's perspectives and beliefs about this research, the methodologies selected, and the questions asked have been built on prior knowledge, experience, and expertise in K-12 science education. Based on this perspective, researcher bias needed to be carefully examined and routinely checked throughout all stages of this study so that it did not interfere in such a way that data was compromised. A prioritized goal of this research was to give voice to the participants' experiences as three-dimensional learners without the influence of the researcher's assumptions and beliefs about science education. One way that researcher bias and reactivity was minimized in this study was using virtual technology for both the instructional delivery and administration of research instruments. The interface of Zoom, Google classroom, and Qualtrics allowed the one-on-one interactions between the researcher and the participants to be tempered by the delayed interpersonal interactions and the frequent informational relay from researcher to on site instructor and vice versa. Additionally, participation in this study was the first encounter the researcher had with all 12 participants. The researcher and the participants did not have any previous personal interactions with each other at any level of K-12 education, neither formally nor informally.

"Working Shop" Intervention

The independent variable for this study was an original compilation of *NGSS*-designed learning modules incorporated three-dimensional science instructional pedagogies and materials accessed from established open-sourced resources found online. Specifically, the learning modules were presented as a "working shop" where the participants were purposefully engaged in doing science to learn science where they were encouraged to become three-dimensional learners themselves throughout the experiences presented. The "working shop" intervention focused on phase changes of water where a time lapse video of icicles forming off a house's eave was used as the anchoring phenomenon to begin the participants' journey as three-dimensional learners. The Driving Question of "How do icicles form?" guided the instruction for the duration of the “working shop” with each learning module purposefully aligned to the eight implications for K-12 science education presented by the NRC’s (2015) *Guide to Implementing the Next Generation Science Standards* (p. 8-9) as displayed in Table 3.

Table 3

Alignment of the Learning Modules to NRC’s (2015) Implications for K-12 Science Education and the NGSS

Implication	Aligned Tasks
Facts and terminology learned as needed while developing explanations and designing solutions supported by evidence-based arguments and reasoning	Phenomenon Forward Instruction with Student Driven Explanations of Icicle Formation Video
Systems thinking and modeling to explain phenomena and to give a context for the ideas to be learned	Student Driven Incremental Modeling of Phase Changes of Water
Students conducting investigations, solving problems, and engaging in discussions with teachers’ guidance	Student Driven Exploration to Answer Essential Question
Students discussing open-ended questions that focus on the strength of the evidence used to generate claims	Instruction Driven by Essential Question, Student Driven Explanations, and Argument from Evidence (Adaptions from Windschitl et al.’s [2018] *Ambitious Science Teaching)*
Students reading multiple sources, including science-related magazine and journal articles and web-based resources; students developing summaries of information	Video Discussions Graphic Organizers Foldables
Multiple investigations driven by students’ questions with a range of possible outcomes that collectively lead to a deep understanding of established core scientific ideas	Student Driven Exploration with Icicles (Adapted from Icicles from Koch’s [2018] *Science Stories* [6th ed.], pp. 50-55)
Student writing of journals, reports, posters, and media presentations that explain and argue	Interactive Science Notebooks Writing of Claim-Evidence-Reasoning (CER)
rovision of supports so that all students can engage in sophisticated science and engineering practices	Student Handouts and Electronic Access to Repository of Resources through Learning Management System

The *NGSS*-designed learning modules focused on the following three science and engineering practices: (SEP 1) Developing and Using Models; (SEP 6) Constructing Explanations; and (SEP 7) Engaging in Argument from Evidence. These practices have been identified as the most challenging for in-service teachers to enact in their classrooms (Kang et al., 2018; Next Generation Science Exemplar Program, n.d.). Additional instructional materials were integrated throughout the learning modules from established open-sourced resources available on the internet. All "working shop" materials were housed in a shared folder within the researcher's personal Google Drive. All participants were enrolled in a course within Google Classroom for ease of administration of the finalized participant survey, the "Draw Yourself as a Science Teacher" assignment, and the four exit tickets, as well as dissemination of "working shop" instructional and supplemental materials. Privacy settings were set to high priority within Google Drive and Google Classroom to assure security of participant submissions.

Due to COVID pandemic protocols, delivery of the *NGSS*-designed learning modules was completed using Zoom, an online video conferencing platform as per university guidelines, and occurred over eight consecutive, 75-minute class meetings. Each class meeting during the study period was facilitated in person by the instructor of record for the introductory science methods course. The instructional sequence and key tasks for the "working shop" intervention implemented during this study is represented in Table 4.

Instructional Modality

For the duration of the "working shop" intervention, instructional delivery for each of the eight consecutive whole class meetings was accomplished virtually using an

Table 4

Description of the Learning Modules within the NGSS-designed "Working Shop" Intervention

Learning Module	Instructional Focus	Key Tasks	Science and Engineering Practice
1	Overview of *NGSS* and Three-Dimensional Instruction	K-W-L Chart: Three-Dimensional Learning; Scavenger Hunt of NSTA's *NGSS* Hub	SEP 1-8
2	Anchoring Phenomenon, Asking Questions, and Developing and Using Models	Science Story: Icicles from Koch's (2018) *Science Stories* (6th ed.), pp. 50-55	SEP 1, SEP 2
3	Developing and Using Models	Incremental Student Modeling: Solid to Liquid	SEP 2
4	Developing and Using Models	Incremental Student Modeling: Liquid to Solid	SEP 2
5	Using Student Models for Constructing Explanations	Writing CERs (Claim-Evidence-Reasoning)	SEP 2, SEP 6
6	Using Student Constructed Explanations for use in Arguing from Evidence	Peer Review and Consensus CER Nine Talk Moves (Michaels & O'Connor, 2012)	SEP 6, SEP 7
7	Planning for Engaging Students with the SEPs – Individual Learning Plans	Developing 3D Learning Sequences with BSCS's 5E Instructional Model	SEP 1-8
8	Preparing for Engaging Students in the SEPs – Individual Learning Plans	Developing 3D Learning Sequences with BSCS's 5E Instructional Model	SEP 1-8

online video platform known as Zoom. The decision to remotely deliver the "working shop" intervention was made according to the university's COVID protocols in place when this study's research was conducted. Using Zoom, the instructor of record projected the online video stream of the principal investigator delivering instruction on a large viewing screen at the front of the on-campus classroom for each of the eight consecutive whole class meetings. As instruction was delivered by the principal investigator, the instructor of record facilitated the in-class activities in the on-campus classroom. Audio during instructional delivery was linked to in-class speakers, allowing the participants to easily hear the principal investigator for the duration of the whole class meeting. However, due to technical difficulties with the on-campus audiovisual equipment, the principal investigator could not engage in direct verbal interaction with the participants unless the instructor of record's laptop was placed directly in front of an individual participant or a small group of participants. Most of the verbal interactions between the principal investigator on Zoom and the participants in the on-campus classroom needed to be relayed by the instructor of record.

Instructional materials were provided to the participants using Google Classroom, primarily using Google docs and Google forms to capture participant responses to research instruments utilized throughout this study. Participant privacy was maintained using the highest security settings within Google Classroom, Google docs, and Google forms as deemed appropriate by UND's IRB Committee. Instructional materials that needed to be in paper form were sent to the instructor of record via email. Copies were made and disseminated appropriately based on directions given by the principal investigator.

Research Timeline

For this study, the "working shop" learning modules began after Spring Break of the Spring 2021 semester during Week 9 and ended during Week 12 which was the week prior to the participants' field experience practicum. This start date was requested by the instructor of record for the introductory science methods course based on the need to attend to specific assessment requirements for the institution's elementary teacher preparation program. The participants engaged in their field experience practicum during Week 13. The close of this study occurred during Week 14 when the participants returned to their introductory science methods course classroom. During the two class meetings for Week 14, the participants completed the post-administration of this study's finalized participant survey, the post-administration of the "Draw Yourself as a Science Teacher" assignment and Exit Ticket #4 Field Experience Practicum Reflection. All research instruments are described in further detail in the following sections.

Participants

The participants for this study were 12 pre-service elementary teachers (*N*=12) enrolled in their introductory science methods course facilitated by their private, liberal arts university located in the Northern Great Plains. Demographic data was collected in the first seven questions using the same survey administration as the combined Bleicher (2004)/Kang et al. (2018) survey through University of North Dakota's (UND) Qualtrics online platform and were as follows: q1 gender, q2 race, q3 age bracket, q4 institution type, q5 prior undergraduate science coursework, q6 prior teaching experience, and q7 prior science experiences. Following the example of other studies (Bleicher, 2004; Kang et al., 2018), categorical dummy-coded variables were created for participant demographics (example: mostly positive = 1; mostly negative = 2). These demographic questions were presented on the second page of the finalized participant survey and are shown in Appendix A.

Sample Demographics

The sample utilized for this study was comprised of 12 pre-service teachers, of which nine were female and three were male. Four of the 12 participants reported that they were seniors in the university's teacher preparation program, seven of the 12 reported as juniors, and one participant reported being a sophomore. Nine out of 12 participants identified as White, Non-

Hispanic, two of the 12 identified as White, Non-Hispanic, and Black, and the one out of the 12 identified as Native Hawaiian/Other Pacific Islander. Seven of the 12 participants reported taking four or more science courses, and nine of the 12 reported as having "some" teaching experience prior to enrolling in the introductory science methods course. The most notable demographic in this sample population was that all 12 participants reported having "mostly positive" science experiences in their K-12 careers. Participant demographics collected via the finalized online survey are summarized in Table 5.

Table 5

Frequencies and Percentages of Participants' Demographics

Item	Responses	*N*	%
Q1: Gender	Female	9	75.0
	Male	3	25.0
Q2: Race	White, Non-Hispanic	9	75.0
	White, Non-Hispanic, and Black	2	16.7
	Native Hawaiian/Other Pacific Islander	1	8.3
Q3: Year in School	Senior	4	33.3
	Junior	7	58.3
	Sophomore	1	8.3
Q4: Prior Science Coursework	0-3 Science Courses	5	41.7
	4+ Science Courses	7	58.3
Q5: Prior Teaching Experience	Some	9	75.0
	None	3	25.0
Q6: Past Science Experiences	Mostly Positive	12	100.0
	Mostly Negative	0	0.0

Note. $N = 12$.

Recruitment of Participants

After obtaining IRB approval via email (Appendix B), recruitment of participants was initiated through voluntary participation in the survey administration prior to the commencement of the *NGSS*-designed learning module within their introductory science methods course. The survey was administered during a regularly scheduled class meeting time and facilitated in-person by their instructor of record. There were no additional recruitment flyers posted in any location on campus nor any additional advertisements through social media platforms (i.e., Facebook, Instagram, Tik Tok, Marco Polo, etc.). The consent to participate was embedded in the online survey, presented on the first page of the finalized participant survey as shown in Appendix C. Participation of the pre-service teachers was voluntary where non-participation did not result in penalty. However, the instructor of record for their introductory science methods course exempted an assignment for those students who did participate in the study. Additionally, participants were invited to choose a book from a collection of authors for use in their future classrooms once this study concluded.

Quantitative Instruments

To answer both research questions within this study, data collection was completed using an adapted survey that combined Bleicher's (2004) modified version of Enochs and Riggs's (1990) Science Teaching Efficacy Belief Instrument-B (STEBI-B) (Appendix D) and a modified version of Kang et al.'s (2018) *NGSS* Science and Engineering Practices Survey (Appendix E). Both questionnaires were combined into one cohesive online survey administered via UND's Qualtrics platform in a pre-/post- fashion, where pre-administration was done during the whole class meeting immediately prior to the start of the "working shop" intervention, and the post-administration was done during the whole class meeting immediately following the participants' completion of their field experience practicum.

The finalized participant survey used for this study's collection of quantitative data was constructed in the following manner: (a) page one contained the Participant Consent Form as shown in Appendix C; (b) page two presented seven demographic questions as shown in Appendix A; (c) page three offered the 23 questions from Bleicher's (2004) modified version of Enochs and Riggs's (1990) Science Teaching Efficacy Belief Instrument-B (STEBI-B) as shown in Appendix D; (d) page four contained 19 questions that comprised a modified version of Kang et al.'s (2018) *NGSS* Science and Engineering Practices Survey as shown in Appendix G; and (e) page five offered three open-ended questions regarding the participants' experiences in their introductory science methods course as it related to preparation to teach three-dimensional science in their future classrooms as shown in Appendix H.

To answer this study's first research question, *"To what extent does an* NGSS-*designed 'working shop,' centered on the Science and Engineering Practices (SEPs) within an introductory science methods course, impact pre-service teachers' perceptions of their self-efficacy in teaching science using three-dimensional instruction?"*, the third page of the finalized participant survey included all of Bleicher's (2004) questions from his modified STEBI-B which was composed of the original 23 questions found in Enochs and Riggs's (1990) STEBI-B instrument with a minor modification in both Question 10 and Question 13 (Appendix F). Based on his analysis, Bleicher (2004) improved the item-total correlation to well above .30 for both Questions 10 (.53) and 13 (.47) from Enochs and Riggs's (1990) original Science Teaching Efficacy Belief Instrument-B (STEBI-B) by removing the qualifier "some" before the word "students." Bleicher (2004) then concluded that this revision clarified the intent of the survey items and improved the reliability of the instrument. The decision to use Bleicher's (2004) modified STEBI-B was made due to its high reliability and validity as a research instrument for measuring pre-service teachers' self-efficacy throughout the literature.

These 23 questions from Bleicher's (2004) modified STEBI-B were grouped according to the two constructs of Bandura's (1977, 1986) Social Cognitive Theory: Personal Science Teaching Efficacy (PSTE) – captured by Questions 2, 3, 5, 6, 8, 12, and 17-23 collectively and Science Teaching Outcome Expectancy (STOE) – captured by Questions 1, 4, 7, 9-11, and 13-16 collectively. For each of the 23 survey questions found on page three of the finalized survey, participants were asked to respond using the following 6-point Likert scale: Strongly Agree (1), Agree (2), Somewhat Agree (3), Somewhat Disagree (4), Disagree (5), and Strongly Disagree (6). The pattern of numeric assignment of Strongly Agree as (1) and Strongly Disagree as (6) was intentional to mimic the respondent organization found in Bleicher's (2004) modified version of Enochs and Riggs's (1990) Science Teaching Efficacy Belief Instrument-B (STEBI-B) (Appendix D).

To answer this study's second research question, *"To what extent does an* NGSS-*designed 'working shop,' centered on the Science and Engineering Practices (SEPs) within an introductory science methods course, impact pre-service teachers' perceptions of self-efficacy to enact three-dimensional instruction in their field experience practicum?"*, participants responded to another 19 questions, completely separated from Bleicher's (2004) modified STEBI-B questions, that were modified from Kang et al.'s (2018) *NGSS* Science and Engineering Practices Survey. The 19 questions were offered on page four of the finalized participant survey as shown in Appendix G. These additional 19 questions contained the same 6-point Likert scale used for Bleicher's (2004) modified STEBI-B questions of Strongly Agree (6), Agree (5), Somewhat

Agree (4), Somewhat Disagree (3), Disagree (2), and Strongly Disagree (1). The pattern of numeric assignment of Strongly Agree as (1) and Strongly Disagree as (6) for these 19 questions was also intentional to maintain the readability of the survey for ease of interpretation by the respondents. These 19 survey questions focused on the participants' perceptions of their self-efficacy in teaching science according to the intent of the *NGSS* and across each of the eight science and engineering practices (SEPs). These 19 questions were designed around two constructs measured for each individual science and engineering practice: (1) perceived conceptual understanding of each practice (example: "I am familiar with the intent of [Science Practice 1 – Asking Questions].") and (2) perceived confidence to enact each practice when teaching science during their field experience practicum (example: "I feel confident in my ability to teach science content integrated with [Science Practice 1 – Asking Questions]."). Based on an exhaustive search of the literature, Kang et al.'s (2018) *NGSS* Science and Engineering Practices Survey was the only instrument used to measure conceptual understanding and confidence of enactment of the SEPs by teachers; however, the sample population used in Kang et al.'s (2018) study was a collection of in-service teachers rather than pre-service teachers. Using Cronbach's alpha, Kang et al. (2018) reported their survey's reliability across two constructs, knowledge and confidence, as they pertained to each of the eight SEPs, where the lowest score was on SEP 6 Constructing Explanations across both constructs (.52 and .61, respectively) and the highest score was on SEP 7 Engaging in Argument from Evidence across both constructs as well (.89 and .90, respectively). Based on these results, as well as similar research application, the decision was made to utilize Kang et al.'s (2018) *NGSS* Science and Engineering Practices Survey but modified to fit this study's research design.

The last page of the finalized participant survey included three open-ended questions that were added to capture individual participant perceptions of how well their current science experience in their introductory methods course was preparing them to teach science according to the intent of the *NGSS* using three-dimensional instruction. These last three survey questions can be seen in Appendix H.

Qualitative Instruments

"Draw Yourself as a Science Teacher" Assignment

To capture the participants' perceptions of themselves as science teachers, they were asked to draw themselves teaching science. For this research instrument, a Google doc assignment was created based on Thomas et al.'s (2001) Draw-A-Science-Teacher-Test Checklist (DASTT-C) instrument (Appendix I) and was posted in this study's Google Classroom. As shown in Appendix J, the "Draw Yourself as a Science Teacher" assignment included two open-ended questions as seen in Thomas et al.'s (2001) version of the DASTT-C: (1) Describe what you are doing, and (2) Describe what the students are doing. The answers to these questions served as short, personal narratives to help with interpretation of each participant's drawing. Also, a modification was made to Thomas et al.'s (2001) DASTT-C instrument to capture the participants' perspectives on their prior school science experiences as part of the pre-administration assignment. Additionally, the modifications were made to capture the participants' perspective on how their view of themselves as a "science teacher" changed after the "working shop" intervention as part of the post-administration. Appendix J shows these reflection questions added as a modification to Thomas et al.'s (2001) DASTT-C instrument. Administration of the "Draw Yourself as a Science Teacher" assignment was accomplished in a similar manner as the finalized online participant survey described earlier. The pre-administration was completed during the whole class meeting immediately prior to the start of the “working shop” intervention, and the post-administration was completed during the whole class meeting immediately following the participants’ completion of their field experience practicum.

The decision to use the “Draw Yourself as a Science Teacher” assignment as a research instrument was based on Finson’s (2001) research that posited “how preservice teachers perceive themselves and their roles in science teaching is at least partially derived from their self-efficacy” (p. 31-32). According to Finson (2001), elementary teachers with low self-efficacy in teaching science sporadically teach science. They often teach science within too tight of a timeline and omit science instruction from the school day altogether. In addition, Finson (2001) stated that elementary teachers with low self-efficacy as science teachers took a more authoritative, teacher-centered approach to teaching science because they were typically weak in science content knowledge and frequently lacked understanding of their students’ level of cognitive development in conceptualizing scientific ideas. Said another way, elementary teachers with minimal self-efficacy to teach science did not have a clue as to their students’ abilities regarding their understanding of scientific concepts (Finson, 2001). On the other hand, Finson (2001) postulated that elementary teachers with high self-efficacy in teaching science did so using various inquiry-based instructional approaches. They taught science from a more student-centered focus, believing that any student could overcome learning barriers and academically succeed in science, and regularly displayed a strong understanding of their students’ level of cognitive development in science. Consequently, these teachers knew exactly where their students stood regarding their understanding of scientific concepts and principles.

In his discussion, Finson (2001) concluded that the components of pre-service teachers' perceptions about their own science teaching could be revealed through their drawings of themselves as a science teacher. From his results, Finson (2001) concluded that pre-service elementary teachers with high self-efficacy for teaching science often drew themselves in an outdoor environment, with students engaged in doing hands-on activities as small groups and included captions to clarify the details of their portraits as science teachers at work. Alternatively, Finson (2001) concluded that the drawings propagated from pre-service elementary teachers with low self-efficacy for teaching science excluded students entirely and drew themselves working indoors as the central figure of the classroom. They included very few captions to clarify components of their sketch of themselves as teachers of science. Ultimately, Finson (2001) states that elementary teachers with a higher level of self-efficacy for teaching science drew less stereotypical pictures of themselves teaching science. Based on Finson's (2001) research in the domain of pre-service teachers conceptualizing their perceptions of how they view themselves as a science teacher as a correlation to their self-efficacy, this study included a "Draw Yourself as a Science Teacher" assignment as a qualitative measure to assess participants' perceptions of their self-efficacy to teach science, as well as to include mental reconstructions and personal narratives from the participants regarding how they perceived themselves as science teachers in support of any significant quantitative findings, or lack thereof, from Bleicher's (2004) modified STEBI-B within the finalized online survey.

Exit Tickets

During this study, four exit tickets were delivered to the participants as Google forms within this study's Google Classroom. The four exits tickets were administered at various points throughout this study's "working shop" intervention: (1) before the participants began planning their science lessons for their field experience practicum focusing on their perceptions of their self-efficacy in teaching science using three-dimensional instruction; (2) in the mid-point of the planning of their science lessons for their field experience practicum to assess any planning needs; (3) at the end of their practicum immediately after delivering their science lessons to assess their successes and challenges using three-dimensional instruction, as well as any factors that affected their implementation; and 4) during their whole class meeting immediately following the completion of their field experience practicum as a reflection of their field experience practicum on their self-efficacy in teaching science using three-dimensional instruction.

Primarily, these four exit tickets were administered as research instruments for triangulation of the data collected from this study. According to Maxwell (2013), triangulating data within a mixed method study "reduced the risk of chance associations and of systemic biases due to a specific method and allows a better assessment of the generality of the explanations a [researcher] develops" (p. 128).

Exit Ticket #1 Proposed Plan for Field Experience Practicum, shown in Appendix K, focused on participants' perceptions of how they incorporated the SEPs into their science unit for their field experience practicum and how confident they felt to incorporate their chosen SEPs into their science unit for their field experience practicum. This first exit ticket was administered with the intention of triangulating the data collected from the finalized participant survey and the semi-structured questions offered during the focus group interviews.

Exit Ticket #2 Planning for Engagement with the SEPs, shown in Appendix L, centered on the participants' needs for implementing the SEPs in their science unit during their field experience practicum. This second exit ticket was intentionally delivered at the mid-point of the “working shop” intervention to assess if the instructional plan needed to be altered for the remaining learning modules.

Exit Ticket #3 Field Experience Practicum with the SEPs, shown in Appendix M, concentrated on evaluating the successes and challenges that the participants faced while using the SEPs during their field experience practicum, as well as identifying key factors that may have played a role in the implementation process. This third exit ticket was designed to triangulate data collected from the finalized participant survey, as well as the semi-structured questions offered during the focus group interviews.

With the final exit ticket, Exit Ticket #4 Field Experience Practicum Reflection (Appendix N), the participants responded to similar questions found within the “Draw Yourself as a Science Teacher” assignment and their answers to the semi-structured questions offered during the focus group interviews as a means to triangulate the data collected from these qualitatively derived research instruments. Specifically, Exit Ticket #4 presented questions regarding the participants’ perceptions of their self-efficacy in teaching science using the SEPs, as well as assessing their future needs in their teacher preparation to continue on their quest of becoming self-efficacious three-dimensional science teachers.

Focus Group Interviews

Upon return to the on-campus classroom in Week 14, focus group interviews were conducted in the privacy of the instructor of record’s campus office via Zoom. There were four focus groups broken up by grade band with the following compositions:

- Kindergarten – two participants, both female, one junior and one senior
- Grades 1 and 2 – four participants, all female, three seniors and one junior
- Grade 4 – two participants, both female, one sophomore and one junior

- Grade 5 – three participants, all male, all juniors

Only 11 of the 12 participants engaged in the focus group interviews, with one participant absent due to attendance at a university sponsored activity that occurred during the regularly scheduled class meeting in which the focus group interviews were conducted. As each participant group terminated their interview, they were sent back to the classroom to retrieve the next grade band group for their interview in the instructor of record's on-campus office. The focus group interviews were not audio nor video recorded due to the constraints of the IRB approval. Data was captured by the principal investigator through notetaking as each participant individually responded to the questions presented. Once the focus group interview began, participants were asked five semi-structured questions as seen in Appendix O. An additional semi-structured question was asked at the end of each focus group interview that allowed participants to clarify any of their answers to the previous five questions once their individual responses were paraphrased back to them. Each focus group interview lasted 10 minutes or less due to the time constraint of the whole class meeting of 75 minutes and the instructor of record's instructional needs for the participants. Table 6 shows the sequence of quantitative and qualitative data collection.

Quantitative Data Analysis

For this study, the independent variable was the "working shop" intervention comprised of eight consecutive *NGSS*-designed learning modules, while the dependent variable was the participants' perceived self-efficacy in teaching science using three-dimensional instruction. Data analysis was performed using IBM's Statistical Package for the Social Sciences (SPSS) Version 27.0 provided by UND. Based on Warner's (2013) contextual definitions and parameters for statistical analysis of research data, statistical analysis of the participants' responses to this study's quantitative research instrument – an adapted survey that was a compilation of Bleicher's

Table 6

Sequence of Quantitative and Qualitative Data Collection

Research Instrument	Time of Administration
PRE-Administration of Online Survey: STEBI-B and NGSS Practices	Before the commencement of the "working shop" intervention
PRE-Administration: "Draw Yourself as a Science Teacher"	At the start of Learning Module 1
Exit Ticket #1: Proposed Unit Plan for Field Experience	At the end of Learning Module 2
Exit Ticket #2: Planning for Engagement with the SEPs	At the end of Learning Module 6
Exit Ticket #3: Post-Field Experience with the SEPs	At the close of the Field Experience Practicum
Exit Ticket #4: POST-Field Experience Reflection	During the whole class meeting following completion of the Field Experience Practicum
POST-Administration: "Draw Yourself as a Science Teacher"	During the whole class meeting following completion of the Field Experience Practicum
POST-Administration of Online Survey: STEBI-B and NGSS Practices	During the whole class meeting following completion of the Field Experience Practicum

(2004) modified Science Teaching Efficacy Belief Instrument-Preservice (STEBI-B) and a modified version of Kang et al.'s (2018) *NGSS* Science and Engineering Practices Survey – included the following:

(a) *descriptive statistics* (parametric) to calculate the frequency, mean, and standard deviation of respondents' pre-/post- answers to increase the chance of obtaining statistically significant results;

(b) *paired samples* t *test* to determine statistical significance between respondents' pre-/post- answers, which included Cohen's *d* to determine the effect size between the groups of respondent answers since there were two collection events for survey responses (pre-test and post-test), where 0.8 indicates a large effect size meaning that there is a strong relationship between the variables, 0.5 indicates a medium effect size, and 0.3 indicates a small effect size; and

(c) *bivariate correlation* (Pearson's *r*) to determine the strength of the relationship between the survey constructs and between pre- and post-respondent answers, where 0.00-0.05 demonstrates no association, 0.06-0.29 demonstrates a weak association, 0.30-0.49 demonstrates a moderate association, and 0.50 and above demonstrates a strong association.

Due to the modifications to Kang et al.'s (2018) *NGSS* Science and Engineering Practices Survey, an item analysis (Cronbach's alpha) was performed to assess the internal consistency (as a means to measure reliability) of the survey items within each of the two survey constructs: (a) the participants' perceived conceptual understanding of each practice and (b) the participants' perceived confidence to enact each practice when teaching science during their field experience practicum. In this analysis, 0.6-0.7 demonstrated an acceptable level of reliability, and 0.8 demonstrated a greater (or very good) level of reliability. This approach mirrors what Kang et al. (2018) conducted with their original *NGSS* Science and Engineering Practices Survey which included a sample size of only 17 in-service elementary teachers, similar in size to this study's sample population.

Qualitative Data Analysis

Analysis of the qualitative data generated from this mixed method study was done through a mosaic of coding methods suggested by Saldaña (2016). Qualitative coding is a process of systematically cataloging passages within a set of qualitative data to find the "'critical link' between data collection and their explanation of meaning" (Saldaña, 2016, p. 4). Coding of qualitative data took the semi-structured data from (1) the open-ended questions at the end of the finalized online survey, (2) the participant responses to the exit tickets, (3) the "Draw Yourself as a Science Teacher" pre-/post- assignments, and (4) the field notes generated from the focus group interviews and categorized them into themes and patterns for analysis. The use of coding in this mixed method study made the analysis more systematic and rigorous whereby the data collected was initially coded using open coding. Then those exploratory codes and their possible subcodes were categorized by topic. Finally, the analysis included the examination of the categories for identification of overarching themes. This analytic process was performed to "lump the data rather than split it" as recommended by Saldaña (2016, p. 79). Conducting the data analysis in such a systematic fashion provided clarity and reflexivity for the duration of the process and enabled the discovery of insights that were truly representative of the data and the human stories behind them. The codes, categories, and subsequent themes generated from this systematic analysis are presented in Chapter IV.

Analysis of the qualitative data generated by this mixed method study began with attribute coding, where notations were made of basic descriptive information regarding the data collected such as the setting, participant demographics, and data format (i.e., open-ended questions from the finalized online survey, the four exit tickets, the "Draw Yourself as a Science Teacher" pre-/post- assignments, and the field notes generated from the focus group interviews). As a first cycle of coding this study's qualitative data, initial coding was done using analytical memoing to break down the data into discrete parts for closer examination and comparison to elicit similarities and differences across the various collection modes. Throughout the analysis of this study's data, analytic memoing continued to be used as an evaluation tool beyond this initial cycle to maintain reflexivity in the evolution of meaning making across the various data collection modes utilized in this study. After attribute coding and an initial round of analytical memoing was complete, descriptive coding was done to produce a "bigger picture" of the data where macro levels of meaning were assigned into codes based on broad topics (Saldaña, 2016). Additionally, in vivo coding was conducted to capture any population specific language used throughout data collection that might provide insights into the participants' perceptions on their self-efficacy in teaching science using three-dimensional instruction (Saldaña, 2016). This thematic analysis plan was conducted on the open-ended questions from the finalized online survey, the participants' answers to the four exit tickets, the open-ended questions in the "Draw Yourself as a Science Teacher" assignments, and the field notes taken during the focus group interviews. These findings are presented in Chapter IV.

Merging Quantitative and Qualitative

As mentioned previously, a concurrent triangulation design was used during this study to gather both quantitative and qualitative data simultaneously and to integrate the two forms of data to gain a better understanding of the posited research questions. This mixed method design gave equal priority to both the quantitative and qualitative data and analysis, involved concurrent collection of data, and integrated both quantitative and qualitative data in the results, interpretation, and analysis phases (Creswell & Creswell, 2018). In the first round of interpretation of results, the researcher conducted separate initial data analysis for each of the qualitative and quantitative data collections, which included descriptive analysis of the quantitative data and the coding, theme development, and interrelationship analysis of the qualitative data. In the second round of interpretation of results, the researcher merged the two sets of data and used a triangulation design that utilized comparison, interrelation, and further analysis of the two sets of data which allowed for a thorough picture of this study to emerge. According to Creswell and Plano Clark (2017), this concurrent triangulation approach helped the researcher "to directly compare and contrast quantitative statistical results with qualitative findings" (p. 62) to construct well-corroborated conclusions about the problem being investigated.

Trustworthiness

Safeguards were taken to ensure that this study's design aligned with accepted qualitative practices of scholarly research. Common challenges of qualitative methods involving triangulation, credibility, and transferability were properly handled to ensure the trustworthiness of this study.

According to Robson and McCartan (2016), two proven methods to triangulate data are the use of different methods of data collection (data triangulation) and the use of different sources for data collection (methodological triangulation). This study utilized both strategies by collecting quantitative data through the administration of an online survey and collecting qualitative data through open-ended survey questions, an introspective course assignment, exit tickets, and semi-structured interview questions. The purpose of these triangulation strategies within this study was to improve the accuracy of the data collected, thereby increasing the credibility and transferability of results.

Three strategies were used to address the credibility and the transferability of the results from this study: (1) thick descriptions, (2) reflexive journaling, and (3) peer debriefing. As defined by Denzin (1989), thick descriptions are "deep, dense, detailed accounts […] Thin descriptions, by contrast, lack detail, and simply report facts" (p. 83). For this study, thick descriptions were used throughout the methodological details in Chapter III, the interpretation phase detailed in Chapter IV, and the analysis phase described in Chapter V. Reflexive journaling, as described by Lincoln and Guba (1985), is the researcher's act of recording within a personalized journal that contains the daily logistics of the research study, the documenting of methodological decisions and rationales, and the capturing of the researcher's personal reflections of their beliefs and values about self as the "human" instrument. Peer debriefing, also described by Lincoln and Guba (1985), is the review of either the collected data and/or the research process by someone who is familiar with the study being executed. Creswell and Miller (2000) describe the peer reviewer as someone who "provides support, plays devil's advocate, challenges the researchers' assumptions, pushes the researchers to the next step methodologically, and asks hard questions about methods and interpretations" (p. 129). Reflexive journaling and peer debriefing were used throughout all aspects of this study, from initial conceptualizations to the final critiques and edits of this manuscript, especially during the interpretation and analysis phases of this concurrent triangulation mixed method study.

Ethical Considerations

As suggested by Maxwell (2013), reciprocity was enacted by both the researcher and the participants throughout this research study. The purpose of this research project was made explicit to the participants from the initiation of recruitment via email. Participants were guaranteed confidentiality throughout the study and were encouraged to provide honest, candid, and open responses to the research questions presented in all instruments. Parameters of this reciprocity were identified in the informed consent letter approved by UND's Internal Review Board and the university used as the research site; all aspects of the research protocols and methodologies were disclosed and approved. Participants were assured of both anonymity and confidentiality of their responses and were given the opportunity not to have information that they provided included in the final manuscript of this study.

Summary

The goal of this chapter was to outline the research method used to answer this study's two research questions:

1. To what extent does an *NGSS*-designed "working shop," centered on the Science and Engineering Practices (SEPs) within an introductory science methods course, impact pre-service teachers' perceptions of their self-efficacy in teaching science using three-dimensional instruction?
2. To what extent does an *NGSS*-designed "working shop," centered on the Science and Engineering Practices (SEPs) within an introductory science methods course, impact pre-service teachers' perceptions of self-efficacy to enact three-dimensional instruction in their field experience practicum?

A discussion of the procedure, study participants, research instruments, data collection, and data analysis plan outlined the specifics of how this study was conducted and who was represented in the sample population. A mixed method approach was used to capture sufficient qualitative data to add the participants' collective narrative to the survey results. This approach presents a model of "best practice" in preparing pre-service elementary teachers for teaching science using three-dimensional instruction. All study participants contributed to this research study by sharing their experiences using three-dimensional science instruction during their field experience practicum. Chapter IV provides the results from this research study and demonstrates that the methodology described in Chapter III was followed.

CHAPTER IV

PRESENTATION OF RESULTS

This chapter presents the analysis of both the quantitative and qualitative data collected from this concurrent triangulation mixed method study. The purpose of this study was to determine the impact of an *NGSS*-designed "working shop" as part of an introductory science methods course on pre-service teachers' perceptions of their self-efficacy in teaching science using three-dimensional instruction. The intention of the data collected from this study was to inform teacher education constituents of the most impactful instructional practices to improve pre-service elementary teachers' self-efficacy in teaching science using three-dimensional instruction, to provide evidence that supports the successful integration of three-dimensional pedagogies within an introductory science methods course, and to capture the unique perspective of the pre-service elementary teachers through their self-reported perceptions on the successes and challenges of implementing three-dimensional instruction during their field experience practicum. The analysis presented in this chapter was driven by this mixed method's two research questions:

1. To what extent does an *NGSS*-designed "working shop," centered on the Science and Engineering Practices (SEPs) within an introductory science methods course, impact pre-service teachers' perceptions of their self-efficacy in teaching science using three-dimensional instruction?

2. To what extent does an *NGSS*-designed "working shop," centered on the Science and Engineering Practices (SEPs) within an introductory science methods course, impact pre-service teachers' perceptions of self-efficacy to enact the SEPs in their field experience practicum?

Analysis of Bleicher's (2004) Modified STEBI-B

To answer research question 1, "To what extent does an *NGSS*-designed "working shop," centered on the Science and Engineering Practices (SEPs) within an introductory science methods course, impact pre-service teachers' perceptions of their self-efficacy in teaching science using three-dimensional instruction?", Bleicher's (2004) modified STEBI-B (Appendix D) was administered to measure the science teaching self-efficacy and outcome expectations of the participants before engagement in an *NGSS*-designed "working shop" intervention within the introductory science methods course and after completing their field experience practicum. Based on Bandura's (1977, 1986) two-component model, the Bleicher's (2004) modified STEBI-B was composed of two scales: Personal Science Teaching Efficacy (PSTE) and Science Teaching Outcome Expectancy (STOE). The first scale, PSTE, measured personal science teaching self-efficacy and contained 13 items, while the second scale, STOE, measured science teaching outcome expectancy and contained 10 items. A strongly agree choice was rated as 1 point, somewhat agree as 3, down to strongly disagree as 6. Some of the items were reversed scored (items 3, 6, 8, 10, 13, 17, 19, 20, 21, 23) during statistical analysis with SPSS 27.0.

Determining Normality of Data

For questions 1, 2, 3, 5, 8, 10, 13, 14, 17, and 20-23 of Bleicher's (2004) modified STEBI-B, there were no outliers as assessed by inspection of a boxplot for values greater than 1.5 box-lengths from the edge of the box. For questions 4, 6, 7, 9, 11, 12, 15-16, and 18-19 of

Bleicher's (2004) modified STEBI-B, outliers were detected that were more than 1.5 box-lengths from the edge of the box in a boxplot. However, inspection of their values did not reveal them to be extreme, and they were kept in the analysis. Additionally, the assumption of normally distributed difference scores for both the PSTE and the STOE constructs of Bleicher's (2004) modified STEBI-B were examined. This assumption was satisfied as both the skewness and kurtosis were reported within normal ranges [i.e., skew and kurtosis $< |2.0|$ (Warner, 2013)] for both the PSTE (.539 and .339 respectively) and the STOE (.386 and .819, respectively) constructs. Therefore, a paired samples *t* test was utilized for statistical analysis in SPSS 27.0 for data collected by Bleicher's (2004) modified STEBI-B.

Paired Samples *t* Tests

Results from conducting a paired samples *t* test across both the PSTE and the STOE constructs from Bleicher's (2004) modified STEBI-B determined that there were no statistically significant differences between the means [$t(11) = -0.438$, $p = .670$ and $t(11) = -0.143$, $p = .889$, respectively] and therefore, the null hypothesis for research question 1 (H_0: The *NGSS*-designed "working shop" intervention had no effect on pre-service teachers' perceptions of their self-efficacy when teaching science using three-dimensional instruction) cannot be rejected. Table 7 shows a detailed summary of this analysis.

A second paired samples *t* test was run across each of the 13 questions within the PSTE construct and the 10 questions within the STOE construct from Bleicher's (2004) modified STEBI-B. Results from conducting this second round of a paired samples *t* test determined that there were no statistically significant differences between the pre- and post- means within each of the construct's questions from Bleicher's (2004) modified STEBI-B. This second paired samples *t* test supports the determination that the null hypothesis for research question 1 (H_0: The

Table 7

Paired Samples t Test Across Both Constructs of Bleicher's (2004) Modified STEBI-B

CONSTRUCT	*Pre*		*Post*		$t(11)$	p	Cohen's d
	M	*SD*	*M*	*SD*			
Personal Science Teaching Efficacy (PSTE) 2, 3[a], 5, 6[a], 8[a], 12, 17[a], 18, 19[a], 20[a], 21[a], 22, 23[a] (TOTAL = 13)	2.47	0.494	2.57	0.611	-0.438	.670	0.797
Science Teaching Outcome Expectancy (STOE) 1, 4, 7, 9, 10[a], 11, 13[a], 14, 15, 16 (TOTAL = 10)	2.75	0.358	2.77	0.355	-0.143	.889	0.313

Note: [a] reflects reversed scored survey items.

NGSS-designed "working shop" intervention had no effect on pre-service teachers' perceptions of their self-efficacy when teaching science using three-dimensional instruction) cannot be rejected. Table 8 shows a detailed summary of the analysis of the 13 questions within the PSTE construct, and Table 9 shows a detailed summary of the analysis of the 10 questions within the STOE construct from Bleicher's (2004) modified STEBI-B.

Correlations

Correlations (Pearson's *r*) between pre-/post- response means collectively across both of the PSTE and STOE constructs were examined. Results of this analysis demonstrated that there was no collective association between the pre- and post- response means to the 13 questions within the PSTE construct, $r(11) = -.032$, $p < .05$, $p = .922$; however, there was a strong positive collective association between the pre- and post- response means to the 10 questions within the STOE construct, $r(11) = .613$, $p < .05$, p = .034, meaning that there is less than a five percent chance that the strength of the association between the pre- and post- STOE means happened by chance. Table 10 shows a detailed summary of the descriptive statistics and correlations between the pre- and post- response means to the PSTE and STOE constructs questions, collectively.

Table 8

Paired Samples t Test Across Individual Questions in the PSTE Construct

Item #	Question	*Pre*		*Post*		*t*(11)	*p*	Cohen's *d*
		M	*SD*	*M*	*SD*			
2	I will continually find better ways to teach science.	1.50	0.522	1.75	0.452	1.149	.275	0.753
3	Even if I try very hard, I will not teach science as well as I will most subjects.	2.58	0.996	3.17	1.11	1.400	.189	1.44
5	I know the steps necessary to teach science concepts effectively.	2.83	0.577	2.33	0.492	-2.171	.053	0.797
6	I will not be very effective in monitoring science experiments.	2.41	1.08	2.92	1.08	1.483	.166	1.16
8	I will generally teach science ineffectively.	2.08	0.900	2.67	1.23	1.629	.131	1.24
12	I understand science concepts well enough to be effective in teaching elementary science.	2.67	0.651	2.25	0.621	-1.449	.175	0.996
17	I will find it difficult to explain to students why science experiments work.	2.81	1.16	2.91	1.22	0.184	.858	1.64
18	I will typically be able to answer students' science questions.	2.67	0.651	2.42	0.668	0.897	.389	0.965
19	I wonder if I will have the necessary skills to teach science.	3.91	1.24	3.50	1.16	-.714	.490	2.02
20	Given a choice, I will not invite the principal to evaluate my science teaching.	2.50	0.797	2.58	1.08	0.200	.845	1.44
21	When a student has difficulty understanding a science concept, I will usually be at a loss as to how to help the student understand.	2.41	0.720	2.58	1.24	0.364	.723	1.58
22	When teaching science, I will usually welcome student questions.	1.33	0.492	1.67	0.651	1.483	.166	0.778
23	I do not know what to do to turn students on to science.	2.58	0.996	2.75	1.14	0.456	.658	1.26

Table 9

Paired Samples t Test Across Individual Questions in the STOE Construct

Item #	Question	*Pre*		*Post*		*t*(11)	*p*	Cohen's *d*
		M	*SD*	*M*	*SD*			
1	When a student does better than usual in science, it is often because the teacher exerted a little extra effort.	2.58	0.514	2.33	0.492	-1.393	.191	0.621
4	When the science grades of students improve, it is often due to their teacher having found a more effective teaching approach.	2.36	0.504	2.18	0.603	-0.690	.506	0.873
7	If students are underachieving in science, it is most likely due to ineffective science teaching.	3.17	0.717	2.83	0.717	-1.301	.220	0.887
9	The inadequacy of a student's science background can be overcome by good teaching.	2.36	0.504	2.18	0.750	-1.000	.341	0.603
10	The low science achievement of students cannot generally be blamed on their teachers.	3.41	0.900	3.41	0.996	0.000	1.00	1.53
11	When a low-achieving child progresses in science, it is usually due to extra attention given by the teacher.	2.91	0.668	2.75	0.753	-0.692	.504	0.834
13	Increased effort in science teaching produces little change in students' science achievement.	2.91	1.37	3.67	1.30	1.750	.108	1.48
14	The teacher is generally responsible for the achievement of students in science.	2.75	0.452	2.67	0.651	-0.364	.723	0.792
15	Students' achievement in science is directly related to their teacher's effectiveness in science teaching.	2.58	0.668	2.75	0.621	0.692	.504	0.834
16	If parents comment that their child is showing more interest in science, it is probably due to the child's teacher.	2.41	0.792	2.83	0.577	1.820	.096	0.792

Table 10

Descriptive Statistics and Correlations for Pre- vs. Post- PSTE and STOE Constructs

Variable	*M*	*SD*	1	2	3
1. Pre PSTE	2.47	0.49			
2. Post PSTE	2.58	0.61	-.032		
3. Pre STOE	2.76	0.36	.593*	-.278	
4. Post STOE	2.77	0.35	.132	.171	.613*

* $p < 0.05$ (2-tailed); *N*=12; PSTE=Personal Science Teaching Efficacy; STOE=Science Teaching Outcome Expectancy

Examining the correlations (Pearson's *r*) between pre-/post- responses across the 13 survey questions within the PSTE construct generated a various range of correlations; however, none of the correlational relationships were shown to be statistically significant. An overview of the results for the 13 PSTE questions are as follows:

a) There were no correlations between the pre- and post- responses for question 3, $r(12) = -.068$, $p < .05$, $p = .833$; question 17, $r(12) = .057$, $p < .05$, $p = .867$; and question 18, $r(12) = -.070$, $p < .05$, $p = .830$;

b) There was a small positive correlation between the pre- and post- responses for question 22, $r(12) = .094$, $p < .05$, $p = .770$;

c) There were moderately positive correlations between the pre- and post- responses for question 6, $r(12) = .419$, $p < .05$, $p = .175$; question 8, $r(12) = .355$, $p < .05$, $p = .257$; and question 23, $r(12) = .301$, $p < .05$, $p = .342$;

d) There was a small negative correlation between the pre- and post- responses for question 2, $r(12) = -.192$, $p < .05$, $p = .549$; question 5, $r(12) = -.107$, *p* <

.05, *p* = .742; question 12, *r*(12) = -.225, *p* < .05, *p* = .483; question 20, *r*(12) = -.158, *p* < .05, *p* = .624; and question 21, *r*(12) = -.177, *p* < .05, *p* = .582;

e) There was a moderately negative correlation between the pre- and post- responses for question 19, *r*(12) = -.408, *p* < .05, *p* = .188.

None of the correlations between any of the pre-/post- means across all 13 PSTE questions were statistically significant. Appendix P shows the full correlational analysis report for the 13 PSTE survey questions.

Examining the correlations (Pearson's *r*) between pre-/post- responses across the 10 survey questions within the STOE construct generated a various range of correlations; however, none of the correlational relationships were shown to be statistically significant. An overview of the results for the 10 STOE questions are as follows:

a) There was no correlation between the pre- and post- responses for question 14, *r*(12) = .000, *p* < .05, *p* = 1.000;

b) There were small positive correlations between the pre- and post- responses for question 1, *r*(12) = .239, *p* < .05, *p* = .454; question 7, *r*(12) = .235, *p* < .05, *p* = .462; and question 15, *r*(12) = .164, *p* < .05, *p* = .610;

c) There were moderately positive correlations between the pre- and post- responses for question 11, *r*(12) = .316, *p* < .05, *p* = .318; question 13, *r*(12) = .388, *p* < .05, *p* = .213; and question 16, *r*(12) = .364, *p* < .05, *p* = .245;

d) There was a large correlation between the pre- and post- responses for question 9, *r*(12) = .600, *p* < .05, *p* = .051;

e) There was a small negative correlation between the pre- and post- responses for question 4, *r*(12) = -.239, *p* < .05, *p* = .479; and

f) There was a moderately negative correlation between the pre- and post-responses for question 10, $r(12) = -.313$, $p < .05$, $p = .323$.

Only one of the correlations between the pre-/post- means across the 10 STOE questions was statistically significant, which was for question 9, “The inadequacy of a student’s science background can be overcome by good teaching,” $r(12) = .600$, $p < .05$, $p = .051$. The large positive correlation between the pre-/post- means for question 9 means that there is less than a five percent chance that the strength of the relationship happened by chance. Appendix Q shows the full correlational analysis report for the 10 STOE survey questions.

The lack of statistically significant results from Bleicher’s (2004) modified STEBI-B can be attributed to three main factors: (1) the participants’ perceptions of having high self-efficacy for science before the commencement of the study, (2) not all four influences on participants’ self-efficacy were accounted for during the intervention, and (3) not enough time transpired during the intervention to produce any measurable changes in participants’ PSTE or STOE. Evidence for the first main factor, participants’ perceptions of having high self-efficacy for science, can be seen in their responses to the demographic questions of the finalized online survey where all 12 participants reported that their prior K-12 science experiences were “mostly positive.” The correlation between prospective teachers who had prior positive science experiences and their perceptions of more self-efficacy as teachers of science is supported by Canipe and Coronado Verdugo (2020). Morrell and Carroll (2010) called this phenomenon the “ceiling effect” where pre-service teachers who entered their introductory science methods course reporting high self-efficacy in science teaching in the pre-test did not show any significant change in either their PSTE or STOE in the post-test.

For the second main factor, not all four influences on participants' self-efficacy were accounted for during the intervention, the ability to attend to positive verbal persuasions was limited due to the instructional modality employed during the intervention. Due to COVID restrictions, in-person delivery of the intervention was not possible, resulting in the participants receiving feedback from the instructor of record rather than the principal investigator. This situation was problematic as the instructor of record possessed low self-efficacy in the delivery of three-dimensional science instruction as she did not have any professional training in that domain. Thus, delivery of positive verbal persuasions as the participants engaged as three-dimensional learners was often lost in translation as they were relayed to the participants from the principal investigator on Zoom through the instructor of record in the campus classroom.

The third main factor, not enough time transpired during the intervention to produce any measurable changes in participants' PSTE or STOE, is supported in the literature, specifically by Morrell and Carroll (2010). According to Morrell and Carroll (2010), generating an impact on science teaching self-efficacy across both the PSTE and the STOE constructs requires time and experience. In their study, the results showed a statistically significant increase in their participants' science teaching self-efficacy after completing the entire semester of their introductory science methods course. This suggests that this study's "working shop" intervention should have been administered over the entire 16 weeks of the semester in order to increase the probability of obtaining statistically significant results with Bleicher's (2004) modified STEBI-B. Interestingly, these two authors concluded that science content courses alone did not increase the science teaching self-efficacy in their pre-service participants (n=394). Rather, their repeated statistically significant results occurred after the conclusion of the science methods semester each fall from 1997 to 2000.

Analysis of Kang et al.'s (2018) Modified *NGSS* Practices Survey

To answer research question 2, "To what extent does an *NGSS*-designed "working shop," centered on the Science and Engineering Practices (SEPs) within an introductory science methods course, impact pre-service teachers' perceptions of self-efficacy to enact the SEPs in their field experience practicum?", Kang et al.'s (2018) modified *NGSS* Practices Survey (Appendix G) was administered before the participants engaged in an *NGSS*-designed "working shop" intervention within their introductory science methods course and after completing their field experience practicum. Kang et al.'s (2018) modified *NGSS* Practices Survey contained 19 questions split between two constructs: FAMILIARITY with *NGSS* and each SEP, and CONFIDENCE to enact *NGSS* and each SEP. A strongly agree choice was rated as 1 point, somewhat agree as 3, down to strongly disagree as 6. None of the items were reversed scored during statistical analysis with SPSS 27.0.

Determining Normality of Data

There were no outliers in the data collected through the administration of Kang et al.'s (2018) modified *NGSS* Practices Survey, as assessed by inspection of a boxplot for values greater than 1.5 box-lengths from the edge of the box for questions 1, 3, 4, 5, and 7-19. For questions 2 and 6, outliers were detected that were more than 1.5 box-lengths from the edge of the box in a boxplot. Inspection of their values did not reveal them to be extreme, and they were kept in the analysis. Additionally, the assumption of normally distributed difference scores for both the FAMILIARITY and the CONFIDENCE constructs of Kang et al.'s (2018) modified *NGSS* Practices Survey were examined. This assumption was satisfied as both the skewness and kurtosis were reported within normal ranges [i.e., skew and kurtosis < |2.0| (Warner, 2013)] for both the FAMILIARITY (-0.524 and -0.390 respectively) and the CONFIDENCE (-0.280 and -

0.920, respectively) constructs. Therefore, a paired *t* test was utilized for statistical analysis in SPSS 27.0 for data collected by Kang et al.'s (2018) modified *NGSS* Practices Survey.

Paired Samples *t* Tests

Results from conducting a paired samples *t* test across both the FAMILIARITY and the CONFIDENCE constructs from Kang et al.'s (2018) modified *NGSS* Practices Survey determined that there was a statistically significant difference between the means [$t(11) = -3.03$, $p = .011$, $d = .667$ and $t(11) = -4.817$, $p = <.001$, $d = .546$, respectively] and therefore, the null hypothesis for research question 2 (H_0: The *NGSS*-designed "working shop" intervention has no effect on pre-service teachers' perceptions of their self-efficacy to enact the SEPs in their field experience practicum) can be rejected. The alternative hypothesis (H_2: The *NGSS*-designed "working shop" intervention has a positive effect on pre-service teachers' perceptions of their self-efficacy to enact the SEPs in their field experience practicum) can be accepted. Table 11 shows a detailed summary of this analysis.

Table 11

Paired t *Test Across Both Constructs of Kang et al.'s (2018) Modified NGSS Practices Survey*

CONSTRUCT	*Pre*		*Post*		*t*(11)	*p*	Cohen's *d*
	M	*SD*	*M*	*SD*			
FAMILIARITY with *NGSS* and SEPs Q1, Q4, Q6, Q8, Q10, Q12, Q14, Q16, and Q18 (TOTAL = 9)	2.67	0.536	2.08	0.367	-3.03	.011	0.667
CONFIDENCE with *NGSS* and SEPs Q2, Q5, Q7, Q9, Q11, Q13, Q15, Q17, and Q19 (TOTAL = 9)	2.89	0.538	2.13	0.412	-4.817	<.001	0.546

A second paired samples *t* test was run across each of the nine questions within the FAMILIARITY construct from Kang et al.'s (2018) modified *NGSS* Practices Survey. Results from conducting this second round of a paired samples *t* test determined that there were statistically significant differences between the pre- and post- means for Question 6, "I am familiar with the intent of Science Practice 2 - Developing and Using Models," [t(11) = -4.750, *p* = <.001, *d* = 0.668], Question 10, "I am familiar with the intent of Science Practice 4 - Analyzing and Interpreting Data," [t(11) = -3.023, *p* = .012, *d* = 0.668], Question 12, "I am familiar with the intent of Science Practice 5 - Using Mathematics and Computational Thinking," [t(11) = -3.079, *p* = .010, *d* = 0.937], and Question 18, "I am familiar with the intent of Science Practice 8 - Obtaining, Evaluating, and Communicating Information," [t(11) = -2.602, *p* = .025, *d* = 0.887]. This second paired samples *t* test supports that the null hypothesis for research question 2 (H_0: The *NGSS*-designed "working shop" intervention has no effect on pre-service teachers' perceptions of their self-efficacy to enact the SEPs in their field experience practicum) can be rejected. The alternative hypothesis (H_2: The *NGSS*-designed "working shop" intervention has a positive effect on pre-service teachers' perceptions of their self-efficacy to enact the SEPs in their field experience practicum) can be accepted. Table 12 shows a detailed summary of this analysis of the nine questions within the FAMILIARITY construct from Kang et al.'s (2018) modified *NGSS* Practices Survey.

Included in the second run of a paired samples *t* test was each of the pre-/post- response means from the nine questions within the CONFIDENCE construct from Kang et al.'s (2018) modified *NGSS* Practices Survey. Results from this analysis determined that all nine questions within the CONFIDENCE construct of Kang et al.'s (2018) modified *NGSS* Practices Survey demonstrated a statistically significant difference between the pre- and post- response means ($t(11) = -4.817$, $p = <.001$, $d = .546$). This second paired samples *t* test supports that the null hypothesis for research question 2 (H_0: The *NGSS*-designed "working shop" intervention has no

Table 12

Paired Samples t Test Across Individual Questions in the FAMILIARITY Construct

Item #	Question	Pre *M*	Pre *SD*	Post *M*	Post *SD*	*t*(11)	*p*	Cohen's *d*
1	I am familiar with three-dimensional instruction as presented in the *Next Generation Science Standards (NGSS).*	2.41	0.515	2.17	0.389	-1.149	.275	0.753
4	I am familiar with the intent of Science Practice 1 - Asking Questions.	2.41	0.792	2.00	0.426	-1.820	.096	0.792
6	I am familiar with the intent of Science Practice 2 - Developing and Using Models.	2.91	0.514	2.00	0.426	-4.750	<.001	0.668
8	I am familiar with the intent of Science Practice 3 - Planning and Carrying Out Investigations.	2.58	0.668	2.08	0.515	-1.915	.082	0.904
10	I am familiar with the intent of Science Practice 4 - Analyzing and Interpreting Data.	2.58	0.668	2.00	0.426	-3.023	.012	0.668
12	I am familiar with the intent of Science Practice 5 - Using Mathematics and Computational Thinking.	3.00	0.738	2.16	0.389	-3.079	.010	0.937
14	I am familiar with the intent of Science Practice 6 - Constructing Explanations.	2.75	0.753	2.16	0.577	-1.865	.089	1.083
16	I am familiar with the intent of Science Practice 7 - Engaging in Argument from Evidence.	2.58	0.668	2.08	0.514	-2.171	.053	0.797
18	I am familiar with the intent of Science Practice 8 - Obtaining, Evaluating, and Communicating Information.	2.75	0.753	2.08	.514	-2.602	.025	0.887

effect on pre-service teachers' perceptions of their self-efficacy to enact the SEPs in their field experience practicum) can be rejected. The alternative hypothesis (H_2: The *NGSS*-designed "working shop" intervention has a positive effect on pre-service teachers' perceptions of their self-efficacy to enact the SEPs in their field experience practicum) can be accepted. Table 13 shows a detailed summary of this analysis of the nine questions within the CONFIDENCE construct from Kang et al.'s (2018) modified *NGSS* Practices Survey.

Correlations

Correlations (Pearson's *r*) between pre-/post- response means collectively across both the FAMILIARITY and CONFIDENCE constructs within Kang et al.'s (2018) modified *NGSS* Practices Survey were examined. Results of this analysis demonstrated that there was no collective association between the pre- and post- response means to the nine questions within the FAMILIARITY construct, $r(12) = -.057$, $p < .01$, $p = .860$; however, there was a moderately positive collective association between the pre- and post- response means to the nine questions within the CONFIDENCE construct, $r(12) = .364$, $p < .05$, p = .234 that was found to not be statistically significant. Table 14 shows a detailed summary of the descriptive statistics and correlations between the pre- and post- response means to the FAMILIARITY and CONFIDENCE constructs within Kang et al.'s (2018) modified *NGSS* Practices Survey.

Determining the correlations (Pearson's *r*) between pre-/post- responses across the nine survey questions within the FAMILIARITY construct within Kang et al.'s (2018) modified *NGSS* Practices Survey generated a various range of correlations; however, none of the correlational relationships were shown to be statistically significant. An overview of the results for the nine FAMILIARITY questions are as follows:

a) There were no correlations between the pre- and post- responses for question 6, $r(12) = .000$, $p < .05$, $p = 1.000$; and question 18, $r(12) = .059$, $p < .05$, $p = .857$;

Table 13

Paired Samples t Test Across Individual Questions in the CONFIDENCE Construct

Item #	Question	*Pre*		*Post*		*t*(11)	*p*	Cohen's *d*
		M	*SD*	*M*	*SD*			
2	I feel confident in my ability in teaching science using three-dimensional instruction according to the intent of the *NGSS*.	3.50	0.904	2.41	0.668	-4.168	.002	0.900
5	I feel confident in my ability to teach science content integrated with Science Practice 1 - Asking Questions.	2.75	0.621	2.00	0.426	-4.180	.002	0.621
7	I feel confident in my ability to teach science content integrated with Science Practice 2 - Developing and Using Models.	2.91	0.514	2.08	0.514	-4.022	.002	0.717
9	I feel confident in my ability to teach science content integrated with Science Practice 3 - Planning and Carrying Out Investigations.	2.75	0.621	2.16	0.577	-2.548	.027	0.792
11	I feel confident in my ability to teach science content integrated with Science Practice 4 - Analyzing and Interpreting Data.	2.83	0.717	2.08	5.14	-4.180	.002	0.621
13	I feel confident in my ability to teach science content integrated with Science Practice 5 - Using Mathematics and Computational Thinking.	3.08	0.668	2.25	0.452	-3.458	.005	0.834
15	I feel confident in my ability to teach science content integrated with Science Practice 6 - Constructing Explanations.	2.75	0.753	2.08	0.514	-2.966	.013	0.778
17	I feel confident in my ability to teach science content integrated with Science Practice 7 - Engaging in Argument from Evidence.	2.75	0.621	2.08	0.514	-4.690	<.001	0.492
19	I feel confident in my ability to teach science content integrated with Science Practice 8 - Obtaining, Evaluating, and Communicating Information.	2.66	0.778	2.00	0.426	-2.602	.025	0.887

Table 14

Descriptive Statistics and Correlations for FAMILIARITY and CONFIDENCE Constructs

Variables	*M*	*SD*	1	2	3
1. Pre-Familiarity	2.67	0.54			
2. Post-Familiarity	2.08	0.37	-.057		
3. Pre-Confidence	2.89	0.54	.763**	.097	
4. Post-Confidence	2.13	0.41	.162	.937**	.364

** $p < 0.01$ level (2-tailed), N=12

b) There were small positive correlations between the pre- and post- responses for question 4, $r(12) = .269$, $p < .05$, $p = .398$; and question 16, $r(12) = .110$, $p < .05$, $p = .734$;

c) There was a moderately positive correlation between the pre- and post- responses for question 10, $r(12) = .319$, $p < .05$, $p = .312$;

d) There was a small negative correlation between the pre- and post- responses for question 8, $r(12) = -.154$, $p < .05$, $p = .633$; and

e) There were moderately negative correlations between the pre- and post- responses for question 1, $r(12) = -.378$, $p < .05$, $p = .226$; question 12, $r(12) = -.316$, $p < .05$, $p = .317$; and question 14, $r(12) = -.313$, $p < .05$, $p = .321$.

Appendix R shows the full correlational analysis report for the nine FAMILIARITY survey questions within Kang et al.'s (2018) modified *NGSS* Practices Survey.

Examining the correlations (Pearson's *r*) between pre-/post- responses across the nine survey questions within the CONFIDENCE construct within Kang et al.'s (2018) modified *NGSS* Practices Survey generated a various range of positive correlations, with question 17, "I feel confident in my ability to teach science content integrated with Science Practice 7 - Engaging in Argument from Evidence," demonstrating a statistically significant correlation between the pre- and post- responses, $r(12) = .639$, $p < .05$, $p = .020$. However, the remainder of the correlational relationships between the pre- and post- responses to the CONFIDENCE questions were not statistically significant. An overview of the results for the nine CONFIDENCE questions are as follows:

a) There were no correlations between the pre- and post- responses for question 7, $r(12) = .029$, $p < .05$, $p = .930$; question 13, $r(12) = -.075$, $p < .05$, $p = .816$; and question 19, $r(12) = .000$, $p < .05$, $p = 1.000$;
b) There were small positive correlations between the pre- and post- responses for question 9, $r(12) = .127$, $p < .05$, $p = .695$; and question 15, $r(12) = .293$, $p < .05$, $p = .356$;
c) There were moderately positive correlations between the pre- and post- responses for question 2, $r(12) = .376$, $p < .05$, $p = .229$; and question 5, $r(12) = .343$, $p < .05$, $p = .275$; and
d) There were large positive correlations between the pre- and post- responses for question 4, $r(12) = .533$, $p < .05$, $p = .074$; and question 17, $r(12) = .639$, $p < .05$, $p = .020$.

Appendix S shows the full correlational analysis report for the nine CONFIDENCE survey questions from Kang et al.'s (2018) modified *NGSS* Practices Survey.

Reliability

To determine the reliability of Kang et al.'s (2018) modified *NGSS* Practices Survey, a correlation between both the FAMILIARITY and CONFIDENCE constructs was performed, and the internal consistency between all questions within each construct was determined using Cronbach's alpha. Both constructs demonstrated strong correlation with each other as seen in Table 15. Based on the results from these calculations, the questions within Construct 1 FAMILIARITY and Construct 2 CONFIDENCE had a strong internal consistency (α = .923 and .915, respectively). Due to the small sample size (N=12) within this research study, it was determined that performing an exploratory factor analysis (EFA) of Kang et al.'s (2018) modified *NGSS* Practices Survey was not necessary.

Table 15

Correlation of Subscale Constructs and Measures of Internal Consistency

Construct Number	Subscale Constructs	C1.	C2.	α
C1.	**Familiarity** Q1,Q4,Q6,Q8,Q10,Q12,Q14,Q16,Q18			.923
C2.	**Confidence** Q2,Q5,Q7,Q9,Q11,Q13,Q15,Q17,Q19	.763**		.915

** $p < 0.01$ level (2-tailed), $p = .004$, N=12

The statistical significance between the pre-/post- response means across the FAMILIARITY construct of Kang et al.'s (2018) modified *NGSS* Practices Survey can be attributed to the instructional changes made by the instructor of record for the introductory science methods course before the commencement of this study. In preparation for the "working shop" intervention in the second half of the semester, the instructor of record updated the course textbook to the newest *NGSS*-aligned edition and added course readings from *Ambitious Science Teaching* by Windschitl et al. (2018), a highly recommended three-dimensional science teaching resource by the NSTA. In the first half of the semester, participants were assigned weekly readings with written reflections based on key chapters within both texts that explained the *NGSS* and specifics of its three dimensions (DCIs, CCCs, and SEPs).

The statistical significance between the pre-/post- response means across the CONFIDENCE construct of Kang et al.'s (2018) modified *NGSS* Practices Survey can be attributed due to the instructional focus of the "working shop" intervention on the SEPs, as well as the expectation of the instructor of record to implement the SEPs in their field experience practicum. For the duration of the study, participants were told by the instructor of record that the "working shop" intervention was a specialized training for them so they could successfully incorporate the SEPs into their lesson plans for their field experience practicum. Additionally, the statistical significance of the pre-/post- means across all nine questions within the CONFIDENCE construct can be attributed to intentional design of the "working shop" intervention to embed all four positive influences on self-efficacy as posited by Bandura (1977, 1986). Positive verbal persuasions regarding their ability to implement the SEPs in their field experience practicum were provided by the instructor of record. Positive vicarious experiences were provided using the public access videos from Mark Windschitl's Vimeo profile (2020) and the NSTA's *NGSS in the Elementary Classroom* webpage (National Science Teaching Association, 2014). Enactive mastery experiences were provided by their field experience practicum with the expectation from their instructor of record to implement the SEPs during that time. Positive physiological cues and emotions arose from their familiarity with the SEPs from their readings and exemplar hands-on activities from the first eight weeks of the introductory science methods course.

Because the nine questions within the CONFIDENCE construct of the modified Kang et al. (2018) *NGSS* Practices Survey were specific to the SEPs, they were able to capture a measurable difference between pre- and post- responses of participants' perceptions of their self-efficacy to enact the SEPs in their future classroom. Since the questions within the PSTE and the STOE constructs of Bleicher's (2004) modified STEBI-B were broader in their interpretation across all aspects of science teaching rather than specific to the nuances of the *NGSS*, they were not able to capture any measurable differences between the pre- and post- responses of participants' perceptions of their self-efficacy to teach science using three-dimensional instruction. Perhaps, a recommendation for future research from this study may be to investigate the redesign of the STEBI-B for use as an assessment tool in preparing pre-service teachers to teach science using three-dimensional instruction.

Qualitative Analysis

For this study, there were four sources of qualitative data: (1) open-ended questions at the end of the finalized online survey, (2) "Draw Yourself as a Science Teacher" assignment, (3) four exit tickets, and (4) semi-structured questions administered during the focus group interviews. These four data sources provided detailed information about the participants' perceptions of their prior K-12 science experiences, the participants' perceptions of the impact of the "working shop" intervention on their self-efficacy for teaching science, their perceptions of enactment of three-dimensional science instruction, and perceptions of their preparedness for teaching three-dimensional science instruction. The demographic characteristics of the sample population remained the same for the qualitative portion of this study as seen in Table 5.

Perceptions of Prior K-12 Science Experiences

Pre-service science teachers' perceptions of their self-efficacy to teach science is strongly influenced by their prior K-12 science experiences. According to Canipe and Coronado Verdugo (2020), prospective teachers who report having positive prior K-12 science experiences also report having a perception of higher self-efficacy in teaching science. To capture participants' perceptions of their prior science experiences, the finalized online survey contained demographic Question 6, "Prior K-12 Science Experiences" with binary answer choices of "mostly positive" or "mostly negative," and the pre-administration of the "Draw Yourself as a Science Teacher" assignment included Question 5, "As a K-12 student, what has been your experience with science?" that asked for an open-ended response. The repetition of this question across two qualitative instruments served to triangulate the data collected, as well as add thick description to the participants' binary response to demographic question 6 of the finalized online survey.

All 12 participants responded to demographic Question 6 in the finalized online survey and to Question 5 in the "Draw Yourself as a Science Teacher." For demographic Question 6, all 12 participants reported having "mostly positive" prior K-12 science experiences. Participants responded similarly to the open-ended Question 5 of the "Draw Yourself as a Science Teacher," where only two participants reporting a somewhat negative perception of their K-12 experience, "A lot of reading and copying of answers" and "It wasn't my favorite…being outside and not in the traditional classroom was beneficial to me." Four other participants reported having traditional K-12 science experiences as well but did not report them as negative. Four out of the 12 participants reported having a strong science background by naming three or more science classes taken in high school. Interestingly, two of the 12 participants reported "loving science" when their lessons were "hands-on and very involved in the science behind an experiment" and describing fond science memories as "my favorite moments in science were when we would interact with materials in a hands-on way."

Perceptions of Science Teaching Self-Efficacy

Participant responses to the "Draw Yourself as a Science Teacher" assignment and Exit Ticket #4 were analyzed to further explicate the change in participants' self-efficacy in teaching science using three-dimensional science instruction beyond the inconclusive results from Bleicher's (2004) modified STEBI-B. All 12 of the study participants completed the pre-administration "Draw Yourself as a Science Teacher" presented as a Google doc through Google Classroom, as well as Exit Ticket #4 Field Experience Practicum Reflection administered as a Google form via email. Appendix J shows the actual Google doc used for the pre-administration of the "Draw Yourself as a Science Teacher" assignment, and Appendix N displays the questions offered in Exit Ticket #4. Analysis of these two qualitative instruments began with open coding, followed by descriptive coding into main categories, and then ending in elucidating common themes from the main categories.

Examining the characteristics of both the pre- and post- submissions for the "Draw Yourself as a Science Teacher" assignment revealed three categories most prevalent throughout participant drawings: (1) teacher role, (2) student role, and (3) use of scientific tools. Further analysis then revealed that these three categories could be divided into teacher-centered versus student-centered perceptions of science teaching as posited by Finson (2001). The delineation of the thematic codes captured by the analysis of pre-/post- responses to the "Draw Yourself as a Science Teacher" assignment into teacher-centered versus learner-centered categories originated from the work of Thomas et al. (2001) who validated Finson's (2001) Draw-A-Science-Teacher-Test Checklist (DASTT-C) in the same manner. The same thematic emergence of teacher-centered and student-centered as seen in the analysis of the open-ended questions in the "Draw

Yourself as a Science Teacher" assignment was also seen in participant responses to the three questions offered in Exit Ticket #4.

Visual Representations of Increased Self-Efficacy in Teaching Science

For the "Teacher Role" category, the drawing of the teacher needed to include the presence of a science tool to be considered student-centered based on the assumption that the artist meant the science tool as a means of "doing science." For the "Student Role" category, the drawing had to include images of students "doing science" to be considered student-centered. For the "Use of Science Tools" category, the inclusion of science tools used to show "doing science" in the classroom was considered student-centered. For the pre-administration of the "Draw Yourself as a Science Teacher" assignment, 11 out of the 12 participant drawings were teacher-centered, where the teacher was alone, there were no students included, and there were no indications of the teacher using any scientific tools when teaching. However, the post-administration of the "Draw Yourself as a Science Teacher" assignment indicated a significant shift in participants' perceptions of themselves as student-centered science teachers, where seven out of 11 drawings depicted the teacher doing science and three out of 11 included students doing science. Ultimately, five out of the 11 displayed a shift from teacher-centered to student-centered depictions of themselves as science teachers when comparing individual participant's pre-/post- submissions. According to Finson's (2001) definition, 63.6% of the participants reported a positive shift in their self-efficacy for teaching science using three-dimensional instruction based on the parameters described above. Table 16 provides a comparison of the participants' pre- and post- responses to the "Draw Yourself as a Science Teacher" assignment broken down by category.

Table 16

Pre-/Post- Responses to "Draw Yourself as a Science Teacher" Drawings

Administration	Teacher Role		Student Role		Use of Scientific Tools	
	TC	SC	TC	SC	TC	SC
Pre-Test	12	0	12	0	9	3
Post-Test*	4	7	8	3	5	6

Note: *N*=12; *only 11 images were analyzed; TC = Teacher-centered; SC = Student-centered

Moving from Teacher-Centered to Student-Centered

Analysis of the two open-ended questions of the "Draw Yourself as a Science Teacher" assignment supports the shift of the participants' perceptions of themselves as science teachers from teacher-centered to student-centered only in response to the first open-ended question, "Describe what YOU are doing as you teach science using 3D instruction." Analysis of the second open-ended question, "Describe what your STUDENTS are doing as you teach science using 3D instruction" did not indicate any positive shift in participants' perceptions of themselves as science teachers using three-dimensional instruction. Analysis of the participants' responses to the two open-ended questions of the "Draw Yourself as a Science Teacher" assignment followed the same coding protocol as performed in the analysis of the participants' drawings, except that the initial open coding was completed on their textual responses rather than their visual depictions.

After open coding both the pre- and post- participant responses to the open-ended questions, four student-centered categories emerged: (1) student driven explorations, (2) student constructed models and explanations, (3) student led discussions, and (4) teacher as facilitator. Only direct instruction arose as the sole category in the teacher-centered domain. Of the 11 participant responses analyzed in the pre-administration for Question 1, "Describe what YOU are doing as you teach science using 3D instruction," five out of 11 reported using student-centered strategies, and six out of 11 reported using teacher-centered strategies. Upon analysis of the post-responses to Question 1, there was a significant shift toward participants using student-centered strategies with 10 out of 12 reporting the use of student driven explorations, student constructed models and explanations, student led discussions, and acting as a facilitator of knowledge rather than a depositor. However, the same positive swing was not seen between the pre-/post-responses to Question 2, "Describe what your STUDENTS are doing as you teach science using 3D instruction," where the frequencies of teacher-centered versus student-centered responses remained the same as shown in Table 17. A possible explanation for no change of perceptions relating to students' learning and engagement could be due to minimal classroom experiences in the pre-professional careers of the participants. The disconnect between participants' view of themselves as more learner-centered and their students as more teacher-centered may be a result of lack of authentic teaching experience with students in a real-life classroom. With very little classroom experience, participants may have had a hard time visualizing what student-centered learning looks like from the teacher's perspective.

The same four student-centered themes from the open-ended questions in the "Draw Yourself as a Science Teacher" assignment were seen in participant responses to the three questions offered in Exit Ticket #4. However, two additional teacher-centered themes emerged from the first question in Exit Ticket #4, teacher content knowledge and locus of control. As described in Chapter III, Exit Ticket #4 was administered after the participants had completed their field experience practicum and served to capture their perspectives on their self-efficacy in the enactment of three-dimensional science instruction in a real classroom. In response to Question 1, "Thinking about your incorporation of the science and engineering practices (Developing and Using Models, Constructing Explanations, and/or Engaging in Argument from

Table 17

Frequencies and Percentages of Teacher-Centered Versus Student-Centered

Qualitative Instrument	Teacher-Centered		Student-Centered	
	Frequency	Percentage	Frequency	Percentage
Pre-Test DYaaST*				
OE Question 1				
Describe what YOU are doing as you teach science using 3D instruction.	6/11	54.5	5/11	*45.5*
OE Question 2				
Describe what your STUDENTS are doing as you teach science using 3D instruction.	3/11	27.3	8/11	72.7
Post-Test DyaaST				
Question 1				
Describe what YOU are doing as you teach science using 3D instruction.	2/12	16.7	10/12	*83.3*
Question 2				
Describe what your STUDENTS are doing as you teach science using 3D instruction.	3/11	27.3	8/11	72.7
Exit Ticket #4				
Question 1				
During your field experience, what did you learn about yourself as a science teacher after delivering your lessons?	4/12	33.3	7/12	66.7
Question 2				
During your field experience, what surprised you the most after delivering your lessons?	1/12	8.3	11/12	*91.7*
Question 3				
During your field experience, what would you change after delivering your lessons?	4/11	36.4	7/11	63.6

Note: *N*=12; *only 11 responses were analyzed; DyaaST = Draw Yourself as a Science Teacher; OE = Open-Ended

Evidence) during your field experience, what did you learn about yourself as a science teacher after delivering your lessons?”, seven out of 12 participants reported positive changes in their students’ learning and engagement based on their implementation of three-dimensional science teaching, rather than what they learned about the particulars of their instructional delivery. In response to Question 2, “Thinking about your incorporation of the science and engineering practices (Developing and Using Models, Constructing Explanations, and/or Engaging in Argument from Evidence) during your field experience, what surprised you the most after delivering your lessons?”, 11 out of 12 participants reported that their remarkable insights were about their students’ learning and engagement when implementing three-dimensional science instruction, rather than any surprises about their teaching. In response to Question 3, “Thinking about your incorporation of the science and engineering practices (Developing and Using Models, Constructing Explanations, and/or Engaging in Argument from Evidence) during your field experience, what would you change after delivering your lessons?”, seven out of 11 responses described making changes to improve their students’ learning experiences rather than their personal teaching experience.

Student-Centered as Proxy for High Self-Efficacy in Teaching Science

As described above, evidence from both the “Draw Yourself as a Science Teacher” and Exit Ticket #4 indicate how the participants’ perceptions of their self-efficacy in teaching science using three-dimensional instruction improved after participation in the “working shop” intervention. For purposes of this study, improvement in participants’ self-efficacy was conceptualized as a shift from teacher-centered perceptions of teaching science to student-centered perceptions of teaching science. This conceptualized definition is supported by Finson’s (2001) argument that elementary teachers with low self-efficacy as science teachers take a more authoritative, teacher-centered approach to teaching science because they were typically weak in science content knowledge and frequently lack understanding of their students’ level of cognitive development in conceptualizing scientific ideas. This conclusion is supported by the work of

Choi et al. (2018) that found a strong correlation between teacher use of learner-centered pedagogies and high self-efficacy in teaching science. Therefore, the resulting percent change of 54.6% between participant pre-/post- responses to the first open-ended question of the "Draw Yourself as a Science Teacher" is a strong indicator of increased self-efficacy in teaching three-dimensional science as a result of the participants' experience with the innovative "working shop" approach in their introductory science methods course. Also, this increase in self-efficacy in teaching science is further corroborated by responses to Question 2 of Exit Ticket #4, "During your field experience, what surprised you the most after delivering your lessons?", where 91.7% of study participants reported student-centered perceptions regarding what surprised them about enacting three-dimensional instruction during their field experience practicum. Table 18 shows the complete triangulation of the analysis between participant responses to the "Draw Yourself as a Science Teacher" open-ended questions and Exit Ticket #4's questions, as well as the concurrent themes between the "Draw Yourself as a Science Teacher" open-ended questions and Exit Ticket #4, along with exemplar participant responses.

According to Bandura (1977, 1986), confidence plays an essential role in the development of an individual's self-efficacy, demonstrated by the ability to control one's behavior, motivation, and persistence to achieve a specific performance goal. Due to its direct relationship with self-efficacy, it can be said that an increase in an individual's confidence while performing a task can be correlated to an increase in their self-efficacy. For this study, results from the paired samples *t* test of the pre-/post- response means to the nine questions within the CONFIDENCE construct of Kang et al.'s (2018) modified *NGSS* Practices Survey were found to be statistically significant ($t(11) = -4.817$, $p = <.001$, $d = .546$), as shown in Table 13.

Table 18

Themes from "Draw Yourself as a Science Teacher" Open-Ended Questions and Exit Ticket #4

THEME	CATEGORIES	POST Open-Ended Questions from "Draw Yourself as a Science Teacher"	Exit Ticket #4
STUDENT-CENTERED INSTRUCTION	Student led discussions	We did a group discussion then we went on our own and did work. After they finished their assignment, I had them share with the class	I do my best teaching when I have the students leading the discussion and leading their learning and I am just a support system keeping them on track.
	Student constructed models and explanations	Students are constructing and forming arguments, explanations, and experiencing new ideas.	That using models and constructing explanations can help students learn more efficiently
	Student driven explorations	Teaching 3D science instruction places an emphasis on students developing knowledge by using real-life scientists and engineers	I learned that I try my best to be flexible with my students as a science teacher. I had to change some activities to be more hands on and have students move more. I noticed the class I taught learned MORE when they are active.
	Teacher as Facilitator	Teaching using 3D has students looking at phenomenon and as the teacher facilitating their learning and guiding them.	Even if it is something as simple as constructing explanations, guiding students is essential for them to complete what is needed.
TEACHER-CENTERED INSTRUCTION	Direct Instruction	Students were engaged in active listening, or they were following along while conducting experiments	I learned that it is important to show visuals for students to see what you are explaining
	Content Knowledge	When using the 3D instruction model for science, I am developing a proficiency in science content knowledge	I felt I could know more about science so when students have questions about things I can have a better answer for them
	Teacher as Authority	Teaching them how energy can be transferred from one object to another	It was very hard for me to just sit back and let them figure out what was happening on their own.

Concurrently, the qualitative analysis of both the open-ended questions in the "Draw Yourself as a Science Teacher" and Exit Ticket #4 demonstrate a dramatic percent change from teacher-centered responses to student-centered responses between the pre- and post- participant submissions, as shown in Table 18, indicating an increase in participants' perceptions of their self-efficacy as suggested by Finson (2001). Merging these two data sets provides strong evidence that the participants' perceptions of their increased confidence correlated with their increased self-efficacy in teaching three-dimensional science during their field experience practicum.

Enactment of Three-Dimensional Science Instruction

To triangulate data collected from Kang et al.'s (2018) modified *NGSS* Practices Survey in answering research question 2, "To what extent does an *NGSS*-designed "working shop," centered on the Science and Engineering Practices (SEPs) within an introductory science methods course, impact pre-service teachers' perceptions of self-efficacy to enact the SEPs in their field experience practicum?", Exit Ticket #3 Field Experience Practicum with the SEPs was administered via email immediately following the close of the participants' field experience practicum. Exit Ticket #3 Field Experience Practicum with the SEPs, shown in Appendix M, concentrated on evaluating the successes and challenges that the participants faced while using the SEPs during their field experience practicum, as well as identifying key factors that may have played a role in the implementation process. All 12 participants completed Exit Ticket #3 as anticipated. Participant responses were analyzed using the same coding protocol described for the analysis of the open-ended questions in the finalized online survey, the "Draw Yourself as a Science Teacher" assignment, and Exit Ticket #4.

Successes with Enactment

In Exit Ticket #3, participants were asked to indicate which SEP was easiest to enact during their field experience practicum. Results from Exit Ticket #3 revealed that participants found SEP 2 Developing and Using Models to be the easiest to enact. According to eight out of 12 participants responding to Exit Ticket #3, enacting SEP 2 Developing and Using Models was the easiest during their field experience practicum, with the remaining five participants identifying SEP 6 Constructing Explanations as the easiest to enact for them. When asked what factors helped them to easily enact their chosen SEP, three main themes emerged from their responses: (1) *NGSS*-aligned teaching materials, (2) student led discussions, and (3) experience as a three-dimensional learner during the "working shop" intervention. Two participants added "the students were very engaged the whole time" and "the students learned quicker and created a positive learning environment" in support of their responses. Support for this result came from the analysis of participant responses in the focus group interviews which indicated that eight out of 10 respondents felt the most confident in enacting SEP 2 Developing and Using Models in their future field experience and student teaching. This well-triangulated piece of data can be attributed to the amount of instructional time spent on SEP 2 Developing and Using Models during the "working shop" intervention as shown in Table 4. Of the three prioritized SEPs, SEP 2 Developing and Using Models, SEP 6 Constructing Explanations, and SEP 7 Engaging in Argument from Evidence, four of the eight class meetings focused on engaging in SEP 2 Developing and Using Models, followed by two class meetings spent on SEP 6 Constructing Explanations.

Challenges to Enactment

In Exit Ticket #3, participants were asked to indicate which SEP was the most challenging to enact during their field experience practicum. Results from Exit Ticket #3 revealed that participants found SEP 7 Engaging in Argument from Evidence to be the most challenging to enact. According to seven out of 12 participants responding to Exit Ticket #3, enacting SEP 7 Engaging in Argument from Evidence was the most difficult during their field experience practicum. Students' lack of argumentation skills and insufficient amount of science lesson time were reported as key factors in hindering the participants to enact SEP 7 Engaging in Argument from Evidence into their lesson during their field experience practicum. This general response provided evidence that the participants held on to the perception that science skills should be taught separate from science content, rather than using the skills to teach the content. Also, the participants may have lacked the ability to scaffold their students' development of analysis skills if they have never been taught how to in their own science content courses or science methods course. It was evident that the participants did not have sufficient time at the end of the "working shop" intervention to explore what teaching analytical and argumentation skills should look like in the elementary classroom.

In support of their response of lesson time as a challenge to overcome in the enactment of the SEPs, one participant reported, "I feel like if I had more time, I could've incorporated them into my lessons more." In support of their response of lack of argumentation skills, one respondent stated, "They [students] are just learning about listening to understand and how to respond to someone." Support for this result came from the analysis of participant responses from the focus group interviews which indicated that eight out of 10 respondents felt the least confident in enacting SEP 7 Engaging in Argument from Evidence in their future field experience and student teaching. This well-triangulated piece of data can be attributed to the amount of instructional time spent on SEP 7 Engaging in Argument from Evidence during the "working shop" intervention as shown in Table 4. Of the three prioritized SEPs, SEP 2 Developing and Using Models, SEP 6 Constructing Explanations, and SEP 7 Engaging in Argument from Evidence, only one class meeting focused on SEP 7 Engaging in Argument from Evidence. At the request of the participants for more time to plan their lessons for their field experience practicum, instructional time was reduced for authentically practicing SEP 7 Engaging in Argument from Evidence which also left no instructional time spent on the synthesis of all three of the prioritized SEPs cohesively.

Support for Enactment

The last question in Exit Ticket #3 focused on mentor support for the participants' enactment of three-dimensional science instruction during their field experience practicum. All 12 participants indicated that they felt supported by their mentor teacher to enact the SEPs in their lessons, with responses such as "very supported," "super supported," and "a great amount of support from my mentor teacher, she made it easy for me to incorporate the SEPs in my science teaching." These participant responses provide evidence of three of Bandura's (1977, 1986) four influences on self-efficacy being present during the participants' field experience practicum—positive mastery experience, positive verbal persuasions, and positive physiological cues—that positively impacted their confidence to enact three-dimensional science instruction in the classroom.

Exit Ticket #4 asked the question, "Thinking about your future field experiences, what support do you think you will need to continue your pre-professional development in incorporating the science and engineering practices (Developing and Using Models, Constructing Explanations, and/or Engaging in Argument from Evidence) into your science lessons?" Four key themes were revealed upon analysis of the 12 respondent answers:

(1) access to three-dimensional designed teacher resources;

(2) three-dimensional instruction modeled by their teacher educators;

(3) more observations of three-dimensional instruction in practice, in person, and through videos; and

(4) more time to develop three-dimensional science lessons throughout their coursework.

Of these four key themes, the second and third themes, modeling and observations, align with Bandura's (1977, 1986) second influence on self-efficacy which is positive vicarious experiences.

Preparedness to Teach Three-Dimensional Science

At the end of the finalized online survey, there were three open-ended questions that asked for the participants' perceptions of how the "working shop" intervention prepared them for teaching science using three-dimensional instruction during their field experiences. The three questions offered on page five of the finalized online survey administered through UND's Qualtrics platform can be viewed in Appendix H. For the first open-ended question, "Please describe which learning experiences from this intervention MOST prepared you for teaching science using three-dimensional instruction during your field experience" and the second open-ended question, "Please describe which learning experiences from this intervention LEAST prepared you for teaching science using three-dimensional instruction during your field experience," 10 out of 12 participants answered these questions. For the third open-ended question, "Please describe any IMPROVEMENTS for this intervention that you feel might better prepare future pre-service teachers for teaching science using three-dimensional instruction during their field experience," nine out of 12 participants answered this question. Analysis of participants' responses to these three open-ended questions at the end of the finalized online survey followed the same coding protocol as described for the "Draw Yourself as a Science Teacher" assignment and the exit tickets.

Positive Preparation Experiences

According to seven out of the 10 participants who responded to the first open-ended question at the end of the finalized online survey, being a three-dimensional learner during the "working shop" intervention most prepared them for enactment of three-dimensional science instruction during their field experience practicum. This result supports Ricketts's (2014) argument that pre-service teachers will not be able to confidently teach science using three-dimensional instruction if they do not experience three-dimensional science instruction during their pre-professional careers for themselves. The last three participants reported that learning about the SEPs was what mostly prepared them for enactment of three-dimensional science instruction during their field experience practicum. This result is supported by the NRC's (2003) recommendation that increasing teacher familiarity with reformed science standards increases the likelihood of implementation of reformed instructional practices in their classrooms.

"Not-so" Positive Preparation Experiences

When asked which features of the "working shop" intervention least prepared them for their enactment of three-dimensional science teaching, only eight out of the 12 participants responded. Of the eight responses, three participants stated that the icicle lesson did not help them prepare to teach science using three-dimensional instruction. One of the three replied, "Doing the icicle model didn't help me much simply because I was teaching something completely different and did not know how I could use the ways we were doing stuff with my lesson and class subject," suggesting that the cohesiveness of the concept within the learning module was not clear and that cohesion of subject matter is essential to learning transfer when using three-dimensional science instruction as recommended by the NRC's (2015) *Guide to Implementing the Next Generation Science Standards*.

Improvements to Preparation Experiences

The final open-ended question of the finalized online survey asked participants, "Please describe any IMPROVEMENTS for this intervention that you feel might better prepare future pre-service teachers for teaching science using three-dimensional instruction during their field experience." Within the nine participant responses, three themes emerged as suggestions for improvement of the "working shop" intervention: (1) provide more three-dimensional designed resources that are grade level appropriate, (2) provide more planning time on lessons for the field experience practicum, and (3) provide more time as three-dimensional learners. Table 19 shows the coding results of participant responses to the three open-ended questions found on page five of the finalized online survey.

Table 19

Post-Response Themes to Open-Ended Questions in Finalized Online Survey

Learning Experience that MOST PREPARED	*Learning Experience that LEAST PREPARED*	*Suggested IMPROVEMENTS*
Being a 3D Learner	Misalignment of science content to field experience lesson	More planning time
Learning about SEPs	Limited time in "working shop"	More *NGSS*-aligned resources by grade level More time as 3D learners

During the focus group interviews, the improvement theme was extended into the participants' perceptions of their preparedness for student teaching when asked in Question 5, "What would you like to have seen IMPROVED in this research study to better prepare you for teaching science with the Big 3 SEPs during your student teaching?" Four themes developed from analyzing Question 5:

(1) align science content and science methods courses to three-dimensional instruction;

(2) provide three-dimensional designed teacher resources;

(3) facilitate observations of three-dimensional instruction in practice, in person, and through videos; and

(4) provide sufficient time to develop three-dimensional science lessons.

Summary

This chapter contains the results of the analysis of both the quantitative and the qualitative data collected during this mixed method study and connects that analysis back to the two research questions that defined this study's methodology. Data was collected in various forms during this mixed methods study: (a) an online survey that contained both Bleicher's (2004) modified STEBI-B and Kang et al.'s (2018) modified *NGSS* Practices Survey, (b) a "Draw Yourself as a Science Teacher" assignment, (c) four exit tickets, and (d) a focus group interview.

Consistent with analysis of pre-/post- data, paired samples *t* tests were run on the pre-/post- participant responses on the online survey, as well as correlational analyses conducted on the mean differences between the participants' pre- and post- responses. Since Kang et al.'s (2018) *NGSS* Practices Survey was modified from its original use for this study, a reliability analysis was run on the 19 items that comprised that section of the online survey with satisfactory results. Qualitative analysis using a myriad of coding strategies was performed on the data collected from the open-ended questions of the online survey, the four exit tickets, and the participant responses to the semi-structured questions from the focus group interviews. Each unique qualitative data collection method used in this mixed method study produced different numbers of common coded themes, specific to the instrument used which were further distilled into shared common themes across the various data collections.

There were no statistically significant results generated from the paired samples *t* test analysis of Bleicher's (2004) modified STEBI-B, neither across the pre-/post- means within each of the two survey constructs, nor across the pre-/post- means of each question within its respective construct (all 13 questions within the PSTE construct and all 10 questions within the STOE construct). Results from conducting a second paired samples *t* test across both the FAMILIARITY and the CONFIDENCE constructs from Kang et al.'s (2018) modified *NGSS* Practices Survey determined that there was a statistically significant difference between the means for each construct, both with medium effect sizes.

Qualitative results produced from the analysis presented in this chapter provided insight into the participants' experience as they engaged in authentic three-dimensional science instruction. Thematic analysis of participants' responses to the open-ended questions at the end of the finalized online survey, the "Draw Yourself as a Science Teacher, the four exit tickets, and the semi-structured questions of the focus group interview found that there was a significant shift in the participants' perceptions of themselves as science teachers, from describing their professional beliefs in themselves and their students as teacher-centered to student-centered, which indicated an increase in their science teaching self-efficacy by proxy. Additionally, their perceptions of their experience as three-dimensional students in the "working shop" intervention produced a strong sense of confidence to enact three-dimensional instruction in their future classrooms. Chapter V includes a critical examination of both the quantitative and qualitative results generated from this analysis, discussion on the limitations, and recommendations of this mixed method study.

CHAPTER V

DISCUSSION, LIMITATIONS, IMPLICATIONS, AND RECOMMENDATIONS

This final chapter provides a critical discussion of the pertinent findings used to answer the two research questions that directed this concurrent triangulation mixed method study. To begin, this chapter presents a brief overview of this study, which is then followed by a discussion of the most significant findings after a thorough analysis of both the qualitative and the quantitative data collected by the various research instruments administered. Additionally, this chapter includes the pertinent results from the merging of key aspects within both sets of data. After presenting this study's key limitations, this last chapter posits major implications for teacher education practice when preparing teachers to teach science using three-dimensional instruction, specifically in the design of science methods coursework. In its concluding paragraphs, this chapter offers recommendations for teacher educators and for future research.

Overview of Study

The purpose of this study was to determine the impact of an *NGSS*-designed "working shop" as part of an introductory science methods course on pre-service teachers' perceptions of their self-efficacy in teaching science using three-dimensional instruction. The intention of the data collected from this study was to inform teacher education constituents of the most impactful instructional practices to improve pre-service elementary teachers' self-efficacy in teaching science using three-dimensional instruction, to provide evidence that supports the successful integration of three-dimensional pedagogies within an introductory science methods course, and to capture the unique perspective of the pre-service elementary teachers through their self-reported perceptions on the successes and challenges of implementing three-dimensional instruction during their field experience practicum. The analysis presented in this chapter was driven by two research questions:

1. To what extent does an *NGSS*-designed "working shop," centered on the Science and Engineering Practices (SEPs) within an introductory science methods course, impact pre-service teachers' perceptions of their self-efficacy in teaching science using three-dimensional instruction?
2. To what extent does an *NGSS*-designed "working shop," centered on the Science and Engineering Practices (SEPs) within an introductory science methods course, impact pre-service teachers' perceptions of self-efficacy to enact the SEPs in their field experience practicum?

To answer both research questions within this study, data was collected both quantitatively and qualitatively using a mixed method, concurrent triangulation approach. The quantitative data was collected using an adapted survey that combined Bleicher's (2004) modified version of Enochs and Riggs's (1990) STEBI-B (Appendix D) and a modified version of Kang et al.'s (2018) *NGSS* Science and Engineering Practices Survey (Appendix E). Both questionnaires were combined into one cohesive online survey administered via UND's Qualtrics platform in a pre-/post- fashion, where pre-administration was done during the whole class meeting immediately prior to the start of the "working shop" intervention, and the post-administration was done during the whole class meeting immediately following the participants' completion of their field experience practicum. Results from analysis of participant pre-/post-response means to Bleicher's (2004) modified STEBI-B revealed that there was no statistically significant change in either the participants' PSTE or STOE. However, there was a statistically significant difference between the means across both the FAMILIARITY and the CONFIDENCE constructs, both with medium effect sizes, from Kang et al.'s (2018) modified *NGSS* Practices Survey after conducting a second paired samples *t* test.

Qualitative data for this study was collected using four research instruments: (1) open-ended questions at the end of the finalized online survey, (2) "Draw Yourself as a Science Teacher" assignment, (3) four exit tickets, and (4) semi-structured questions of the focus group interview. Thematic analysis of the qualitative data collected from these four sources found that there was a significant shift in the participants' perceptions of themselves as science teachers, from describing their professional beliefs in themselves and their students as teacher-centered to a more student-centered stance which indicated an increase in their science teaching self-efficacy. Additionally, their perceptions of their experience as three-dimensional students in the "working shop" intervention produced a strong sense of confidence to enact three-dimensional instruction in their future field experiences, which also is an indicator of high self-efficacy in teaching science. Additionally, analysis of the rich, comprehensive data gave voice to the participants' experiences as three-dimensional learners, the participants' perceptions of the successes and challenges of enacting three-dimensional instruction, and the participants' needs in becoming self-efficacious three-dimensional teachers of science in their future classrooms.

Discussion

One of the most significant results from this mixed method study was that the innovative instructional model, utilized as the "working shop" intervention in this study, was shown to be an exemplar for teacher educators in their pursuit of preparing prospective teachers to teach science using three-dimensional instruction. This claim is supported by the following three major findings from the analysis of both the quantitative and qualitative data collected during this study as presented in Chapter IV:

(1) participants' perception of their increased self-efficacy to teach science,

(2) participants' perception of their increased confidence to enact the SEPs during their field experience practicum, and

(3) participants' perceptions of their preparedness to enact the SEPs in their future classrooms.

The positive impact of this study's innovative instructional model on the participants' perceptions of their ability to teach science using three-dimensional instruction can be attributed to its evidence-based design and theoretical grounding in Bandura's (1977, 1986) Theory of Self-Efficacy.

Research Lens of "Working Shop" Intervention

According to Pruitt (2014) and Bybee (2014), aligning teacher preparation to the *NGSS* requires a strong commitment to implementing a coherent program that prioritizes the key features of three-dimensional science instruction: emphasis on the nature of science, seamless learning progressions, and integration of engineering design. These key features were the foundation of the novel instructional model used in this study during the participants' introductory science methods course, where participants did science to learn science by engaging in the SEPs throughout the learning modules within the "working shop" intervention. Furthermore, this unique instructional approach was constructed around Reiser's (2013) recommendation to cohesively embed seven instructional shifts throughout science methods coursework for preparing prospective teachers:

(a) Lessons should be structured so that the work is driven by questions arising from phenomena, rather than topics sequentially pursued according to the traditional breakdown of lessons;

(b) The goal of investigations is to guide construction of explanatory models rather than simply testing hypotheses;

(c) Answers to science investigations are more than whether and how two variables are related, but need to help construct an explanatory account;

(d) Students should see what they are working on as answering explanatory questions rather than learning the next assigned topic;

(e) A large part of the teacher educator's role is to support the knowledge building aspects of practices, not just the procedural skills in doing experiments;

(f) Extensive class focus needs to be devoted to argumentation and reaching consensus about ideas, rather than having textbooks and teacher educators present ideas to students; and

(g) Teacher educators need to build a classroom culture that can support these practices, where students are motivated to figure out rather than learning what they are told, where they expect some responsibility for this work of figuring out rather than waiting for answers, and where they expect to work with and learn with their peers.

Due to the complex nature of these seven instructional shifts, the design of the "working shop" model used in this study went beyond just aligning curricular materials and assessments to the *NGSS*; rather, it was a reconstruction of the traditional science methods course based on recommendations from Reiser's (2013) "What Professional Development Strategies Are Needed for Successful Implementation of the *Next Generation Science Standards*?", open-sourced resources from Windschitl et al.'s (2018) *Ambitious Science Teaching*, and Grossman and McDonald's (2008) Pedagogy of Enactment. The "working shop" intervention implemented in this study facilitated pre-service teachers' use of the SEPs to learn the DCIs through the integration of the CCCs, and it also allowed them to learn, practice, and get feedback on what it means to teach science using three-dimensional instruction in an experiential manner.

Moreover, the pedagogical focus of the "working shop" intervention implemented for this study was grounded in the suggestions by the National Research Council (NRC) (2005) that effective teaching and learning environments suited for implementing three-dimensional instruction are ones that are learner-centered, meaning that students become "active processors of information who have acquired concepts, skills, and attitudes that affect their thinking about the content being taught, as well as what it means to do science" (p. 414). Current research in neuroscience, biology, and cognitive psychology supports learner-centered teaching as best practice for all students based on this singular conclusion: "It is the one who does the work who does the learning" (Doyle, 2011, p. 7). According to Doyle (2011), a key feature of a learner-centered environment is its emphasis on authentic learning, which aligns perfectly with the three-dimensional design of the "working shop" intervention used in this study.

Support for the effectiveness of the evidence-based design of this study's novel instructional model can be seen in the results from the statistical analysis of Kang et al.'s (2018) modified *NGSS* Practices Survey. Results from Kang et al.'s (2018) modified *NGSS* Practices Survey showed that participants were more familiar with the *NGSS* and the SEPs and more confident to enact the *NGSS* and SEPs in their future field experiences. According to the NRC

(2003), teachers who are more familiar with instructional-based reforms are more likely to enact those reforms in their classrooms, especially when those instructional reforms are far removed from an individual's prior science experiences. Additionally, increasing a teacher's familiarity with a new instructional approach leads to an increase in their confidence to enact that approach. This phenomenon occurs because the teacher can visualize themselves incorporating that new way of teaching into how they perceive themselves as a teacher in the classroom because of their changing beliefs in themselves as capable of enactment of the new instructional approach (Canipe & Coronado Verdugo, 2020). Thematic analysis of participant responses to this study's exit tickets and the semi-structured focus group interviews corroborate these results from Kang et al.'s (2018) modified *NGSS* Practice Survey.

Theoretical Lens of "Working Shop" Intervention

The "working shop" intervention implemented during this study was grounded in Bandura's (1977, 1986) Theory of Self-Efficacy, indicated in the literature as "best practice" for ensuring that prospective teachers achieve professional readiness to teach instructional-based reforms in their future classrooms (Hoy & Spero, 2005; Menon & Sadler, 2018; Morrell & Carroll, 2010; NRC, 2003; Tschannen-Moran et al., 1998). As shown in Table 1, each learning module within the "working shop" intervention was evaluated against the four influences on self-efficacy as posited by Bandura (1977, 1986)—mastery experiences, vicarious experiences, verbal persuasion, physiological and emotional cues—to ensure that all four were embedded in the final design. Based on the purposeful inclusion of these four influences into the "working shop" intervention, there was an expectation that results from the analysis of participant responses to Bleicher's (2004) modified STEBI-B would indicate a significant difference between the pre-and post- means, indicating a significant change in participants' perceptions of their self-efficacy to teach science. This was not the case from the statistical analysis of participants' responses to Bleicher's (2004) modified STEBI-B.

A possible justification for the lack of significant difference between the pre-and post-means in participant responses to Bleicher's (2004) modified STEBI-B is that developing self-efficacy in teaching science takes time and experience. According to Bartley (2019), learning to teach science starts when the future science teacher indirectly learns how to teach science while participating as a learner and observer in the K-12 classroom. For prospective science teachers to learn and understand the practice of three-dimensional science instruction, they must be given time and opportunities to develop their self-efficacy in order to successfully implement this practice in their future classrooms. These opportunities need to be framed around natural phenomenon where the pre-service teachers are authentically engaged as three-dimensional learners in doing science to learn science. During these opportunities, they use the science and engineering practices to learn the disciplinary core ideas and make cross-cutting connections.

To positively impact pre-service teachers' self-efficacy in teaching science, these opportunities must be repeated throughout their undergraduate career, both in science content and science methods coursework, as indicated by the participants during the focus group interviews. According to Sharma and Muzaffar (2012), the more pre-service teachers participate in inquiry-oriented teaching practices, "the greater effect these practices will have on affecting how they teach and their own understanding of their selves as practitioners of inquiry-oriented science teaching" (p. 188). Said another way, the more pre-service teachers experience three-dimensional learning in their teacher preparation program, the more efficacious they become as three-dimensional teachers of science. Ultimately, prospective science teachers must be given ample time and multiple opportunities to learn and understand the practice of teaching three-dimensional science in order to successfully implement this practice in their future classrooms (Feiman-Nemser, 2001). With this study's participants experiencing the "working shop" intervention for only eight class periods, it is not surprising that analysis of Bleicher's (2004) modified STEBI-B showed no statistically significant results.

However, since this study utilized a mixed method approach where the qualitative phase "refined and explained" the quantitative phase by looking comprehensively at the participants' perspectives, the results from the qualitative analysis revealed a more optimistic view on the impact of the "working shop" intervention on the participants' self-efficacy in teaching three-dimensional science (Creswell & Creswell, 2018).

Perceptions as Student-Centered Teacher of Science

Results from this study indicated a significant shift from teacher-centered perceptions to student-centered perceptions, for both the participants' perceptions of themselves as teachers and the participants' perceptions of their students as learners. This perceptual shift reported by the participants indicates an increase in self-efficacy in teaching science as posited by Finson (2001), who argued that teachers with low self-efficacy as science teachers take a more authoritative, teacher-centered approach to teaching science. Finson's (2001) postulation is supported by the work of Choi et al. (2018) that found a strong correlation between teacher use of student-centered pedagogies and high self-efficacy in teaching science. Therefore, the positive shift in the participants' perceptions of themselves as student-centered teachers of science seen throughout the thematic analysis of all four qualitative measures utilized in this study is a strong indicator of increased self-efficacy in teaching three-dimensional science because of the participants' experience with the innovative "working shop" approach in their introductory science methods course.

Perceptions of Professional Enactment of Three-Dimensional Science Instruction

As described in Chapter IV, participants reported that they found SEP 2 Developing and Using Models to be the easiest SEP to incorporate into their field experience practicum, and that they were the most confident in enacting SEP 2 Developing and Using Models in their future classrooms. Such strong confidence to enact SEP 2 Developing and Using Models can be attributed to the impact of their positive vicarious experience during their field experience practicum when doing so, which had a positive impact on the participants' STOE. Support for this assertion is evidenced by participant responses such as "That using models can help students learn more efficiently," "That using models is really good for kids because it allows them to express themselves and their ideas," "I can see my students understanding the content and then applying it," and "After incorporating the SEPs, I think the students understood the lesson better." Also, these participant responses allude to receiving positive verbal persuasions from their students as well, providing further support for a positive impact of participants' STOE.

However, participants were not as strongly confident about incorporating SEP 7 Engaging in Argument from Evidence, claiming that students lacked the foundational skills to enact this practice well in the classroom. As mentioned previously in Chapter IV, only one class meeting out of the eight included in the "working shop" intervention was dedicated to SEP 7 Engaging in Argument from Evidence due to the request of the participants for more time to plan their lessons for their field experience practicum. This reduced instructional focus on SEP 7 Engaging in Argument from Evidence eliminated any authentic practice in a peer setting, as well as no instructional time spent on the synthesis of all three of the prioritized SEPs cohesively. Due to this shortcoming, the selection of SEP 7 Engaging in Argument from Evidence as the most challenging SEP to incorporate into the field experience practicum was not remarkable.

According to the NRC (2005), an important aspect of three-dimensional science instruction is the development of a “culture of community” where students learn through the respectful interaction with others and their ideas which allows open questioning and risk-taking (p. 20). In a community-centered learning environment, students continually strive to improve their learning through practicing the skill of argumentation and engaging in discourse, which are crucial practices in negotiating meaning while learning science (Windschitl & Stroupe, 2017). In this way, community-centered environments allow a key feature of three-dimensional learning to transpire as expected in the *NGSS*.

According to Windschitl and Stroupe (2017), providing opportunities for pre-service teachers to learn the art of argumentation and how to engage in scientific discourse is missing from science teacher preparation programs, a deficit that they feel needs to be addressed immediately as it is at the heart of teaching science using three-dimensional learning. The difficulty with reforming teacher education to include these skills is that neither the NRC nor the *NGSS* provide clear pathways to achieve these skills, and there is no consensus on how to do it in the field (Windschitl & Stroupe, 2017). However, various literature cited in the NRC’s (2012) *Framework* provide guiding principles on how teacher education programs can incorporate *NGSS*-aligned strategies to accomplish this goal such as facilitating “classroom talk, scaffolding for broader participation in science activities, adapting curricula to be relevant to students, using tools to support students’ reasoning, and helping students function as a community of learners” (Windschitl & Stroupe, 2017, p. 252). For this study, Michaels and O’Connor’s (2012) *Talk Science Primer* was used as a key resource within the “working shop” intervention when teaching the participants about argumentation in science. Specifically, participants were introduced to the “Goals for Productive Discussions” and the “Nine Talk Moves” within

Michaels and O'Connor's (2012) *Talk Science Primer* and used those two specific tools to further discuss how productive talk in a science classroom would look, feel, and sound like in the classroom.

Perceptions of Preparedness to Teach Science Using Three-Dimensional Instruction

Thematic analysis of participant responses to this study's qualitative measures revealed two pre-professional needs advocated by this study's participants to attain professional preparedness to teach science using three-dimensional instruction: (1) more authentic experience as three-dimensional learners themselves and (2) more time embedded throughout their coursework to develop three-dimensional science lessons. Further examination of these needs articulated by the participants through the theoretical lens of self-efficacy, their responses aligned well with Bandura's (1977, 1986) four influences on self-efficacy:

(1) mastery experiences: they asked for more time in their field experience practicum;
(2) vicarious experiences: they asked for more modeling from their professors and more authentic in-person observations and videos of three-dimensional science instruction in action;
(3) verbal persuasions: they asked for more practice as three-dimensional learners themselves; and
(4) physiological cues: they asked for more three-dimensional designed resources as exemplars for guidance and support.

The agency expressed by this study's participants is validated by the work of Morrell and Carroll (2010) who reported a significant positive impact on the self-efficacy of their pre-service participants when their science methods course was intentionally aligned to Bandura's (1977,

1986) four influences on self-efficacy. Ultimately, to improve pre-service teachers' perceptions of their self-efficacy in teaching science, they need science methods courses that include deliberate teaching and observing of others succeeding through their efforts, which includes observing peers' efforts resulting in achievement and a practitioner modeling three-dimensional science instruction (Bandura, 1977). Findings from this study suggest that providing opportunities for pre-service teachers to engage in authentic three-dimensional student experiences leads to a positive impact of their confidence to enact the SEPs in their future classrooms. This result, coupled with the literature positing that development of pre-service teachers' self-efficacy in teaching science requires time and experience, leaves little doubt that making these changes in science education should be initiated and modeled in teacher education programs.

Limitations

For this mixed method study, data was collected through a self-reporting online survey that was administered twice, as a pre-test prior to the start of the *NGSS*-designed "working shop" intervention and as a post-test after the participants completed their field experience practicum. The biggest challenge in using self-reporting data for evidence in a mixed method study is that of participant bias in reporting their responses through either overreporting or underreporting their data (Warner, 2013). The problem with respondent bias is that it may lead to either a Type I or Type II error in determining the statistical significance of the null hypothesis, which states that the difference between the sample mean, M, and the population mean, μ, are simply due to random chance rather than any effect of an intervention.

A Type I error is known as a false positive where the researcher rejects the true null hypothesis and reports that there is a statistically significant effect from the study when there truly is no effect (Warner, 2013). A Type II error is known as a false negative where the researcher does not reject the true null hypothesis and reports that there is not a statistically significant effect from the study when there truly is an effect (Warner, 2013). Additionally, this study only collected data from 12 participants as they were the officially enrolled students in the introductory science methods course. The limited number of participants was due to the selection of a private, liberal arts university situated in a rural setting. Another limitation is that only one institution of higher education was included within this study. To minimize the effect of these limitations, the decision was made to use a mixed method approach that included a robust collection of qualitative data to support any significant results through triangulation.

For this research study, validity may be problematic due to the use of convenience sampling and the absence of a control group. This research study simply conducted a comparison of participant responses before versus after a “working shop” intervention of eight consecutive *NGSS*-designed learning modules. According to Wagner (2013), these design limitations may weaken the evidence of possible causality, and therefore, may weaken this study’s internal validity. However, Wagner (2013) states that this study’s design may have stronger external validity (ability to generalize results beyond sample population to a greater real-world population) because the focus was on an intervention that took place in a real-world setting – a university classroom. In summary, reliability and validity were determined through multiple measures as indicated in the detailed description of the statistical analysis plan outlined in Chapter III.

Another limitation for this mixed method study was the complications due to the COVID pandemic. Due to university protocols in place at the time of this study, the “working shop” intervention could not be delivered in person by the principal investigator. Accommodations were made for each whole class meeting where the principal investigator used Zoom to deliver instruction, and the instructor of record facilitated the in-class activities in the on-campus classroom. Because the instructor of record lacked experience in three-dimensional science instruction at both the K-12 level and the university level, the fidelity of implementation may have been compromised. Additionally, the technology capabilities of the on-campus classroom restricted the interactions between the principal investigator on Zoom and the participants in the actual classroom. Many instructions had to be relayed from the principal investigator to the instructor of record to the participants in the on-campus classroom, greatly increasing the transfer loss of key information and decreasing the clarity of communications.

Implications

To significantly impact the science teaching self-efficacy of pre-service teachers, this study suggests a novel instructional model specifically for elementary methods courses that maintains two main characteristics: (1) the use of three-dimensional science instruction for the entire semester and (2) the intentional alignment of course elements to Bandura's (1977, 1986) four influences on self-efficacy. Making this a reality in teacher education requires, at minimum, the re-tooling of an introductory science methods course to include these two main characteristics. Support for this immediate deconstruction and reimagination of the introductory science methods course within elementary teacher preparation resides in the 2018 Council for the Accreditation of Educator Preparation (CAEP) Standard 2.c. that states, "Candidates demonstrate and apply understandings and integration of the three dimensions of science and engineering practices, cross-cutting concepts, and major disciplinary core ideas, within the major content areas of science" (p. 98).

Additional support for this immediate pedagogical change within introductory science method courses resides in the *2018 NSSME+: Status of Elementary School Science* report (Plumley, 2019) produced from the results from the *2018 National Survey of Science and Mathematics Education (NSSME+)*. In this report, Plumley (2019) stated that about half of elementary teachers responded that their science instruction heavily emphasizes understanding science concepts based largely on whole class discussion guided by teacher explanations. Additionally, far fewer elementary teachers responded that they placed heavy emphasis on other reform-oriented pedagogies such as learning how to do science or increasing students' interest in science and engineering. Further, elementary teachers responded that hand-on activities, small group work, and writing reflections were also fairly common, happening weekly in about half of elementary science classes. When asked about incorporating science practices into their instruction, most elementary teachers reported that they did not engage in aspects of science practices on a weekly basis. Of those that did, the most common practices reported were generating scientific questions, conducting scientific investigations, organizing and/or representing data, and making and supporting claims with evidence. However, only 10% of elementary teachers reported that they engage their students in the science practices of evaluating the strengths/limitations of evidence and the practice of argumentation once a week. According to these recent reports, preparing elementary teachers to teach science using three-dimensional instruction still has a long way to go. The instructional model offered in this study provides a possible "best practice" to move teacher education in the right direction.

Recommendations for Teacher Educators

According to Windschitl and Stroupe (2017), teacher educators face a difficult task with the gaining momentum of the *NGSS*. The transformation of K-12 science education called for by the NRC's (2012) *Framework* and the *NGSS* places an incredible responsibility on teacher educators to prepare the next generation of science teachers to teach according to the constructs of three-dimensional instruction. Windschitl and Stroupe (2017) present a vision of pre-service teacher preparation known as the "three-story challenge" where teacher educators, novice teachers, and K-12 students each have a unique responsibility to extend their own learning to realize the goals of the *NGSS* and three-dimensional instruction. As the apex of this "three-story challenge," teacher educators play a significant role in the larger interconnected system of K-12 science education in which their learning shapes the activities and responsibilities of individuals within the other two levels, novice teachers and K-12 students. Said another way, the impetus of change required to transform K-12 science education begins with teacher educators diving into what it means to teach science using three-dimensional instruction. Just as novice teachers need to experience what it means to be a three-dimensional learner in order to teach using three-dimensional instruction, the same can be said for teacher educators. Grounded in the personal narratives shared by this study's participants, a recommendation for teacher educators is to create authentic three-dimensional student experiences across different contexts within a teacher education program, namely in the science content courses and the methods courses. Teacher education programs should also ensure that institutional partners providing student teaching experiences are using three-dimensional science instruction at their sites.

As previously discussed in Chapter II, the NRC (2012) recommends that science teacher preparation programs perform a curriculum and instruction overhaul of their methods courses, especially for elementary teachers. Within their suggestions, the NRC (2012) states that prospective teachers need diverse experiences in scientific investigations, "including simple investigations in the classroom using everyday materials, field studies outside the classroom, formal experiments carried out in the laboratory, and student-designed investigations" (p. 258). Additionally, the NRC (2012) suggests that pre-service teachers will need support in broadening their knowledge on different forms of assessment by "analyzing and revising curricular materials using standards- and research-based criteria" (p. 258), facilitating appropriate and effective discourse in their classrooms, developing "explicit ways to bring the crosscutting concepts into focus as they teach disciplinary content ideas" (p. 258), and integrating science-based literacy strategies that include scientific writing and "interpretation of pictures, diagrams, and mathematical representations of information" (p. 259). These are all key aspects that were incorporated into the "working shop" intervention utilized in this study, presented as a model of what the NRC's (2012) *Framework* and the *NGSS* call for in teacher education in their pursuit of preparing three-dimensional teachers of science.

Recommendations for Future Research

The results shared in these pages show promise for future research endeavors in transforming teacher education with three-dimensional instruction where pre-service teachers learn science by figuring out science. The first recommendation for future research in this domain is to broaden the sample size to include more higher education types beyond a small, rural setting. A second recommendation, also grounded in the agency of this study's participants, is to conduct this type of research over a longer period of time, at least throughout an entire semester within an introductory methods course or through a longitudinal approach where data collection occurs within repeated semester offerings of a specific course. A longitudinal approach to data collection for research in this domain was modeled by both the Kang et al. (2018) and the Morrell and Carroll (2010) studies, two years and five years respectively.

Conclusion

For science education, the criticality of reforming how science is taught in U.S. classrooms has never been more real. As society struggles to mitigate complex global issues such as viral pandemics, water scarcity, and climate change, improving scientific literacy for all students is imperative for our continued survival on and with this planet. To engage in such conversations as independent adults, our students need to be able to successfully engage in critical thinking, to effectively collaborate across communities, to creatively problem solve in efficient ways, and to respectfully communicate to gain perspective. Additionally, for our students to be successful in this domain, they need a holistic understanding of the interrelationship of all the sciences, as well as the intricacies involved in doing science to solve such complicated human problems. This type of science education is not realized through a teacher-centered classroom where student success is simply measured by the attainment of a passing score on a paper-pencil test, but it is realized rather through the engagement of students in authentic tasks with multiple dimensions of assessment that centers around the doing of science to achieve the mastery of science. This type of science education can only be achieved through the transformation of teacher education by globally integrating three-dimensional science instruction across all aspects of teacher education. Without an innovative response to this new direction in science education, many pre-service teachers will be left underprepared to meet the intent of the *NGSS* without a clear understanding of how to successfully implement three-dimensional instruction in their future classrooms. The biggest casualty of such irresponsibility will be the most vulnerable among us—our children!

Appendix A

Demographic Questions – Page 2 of the Finalized Participant Survey

Please select your gender:

○ Male

○ Female

How would you best describe yourself (check all that apply):

☐ American Indian or Alaskan Native

☐ Asian

☐ Black or African American

☐ Hispanic or Latino

☐ Native Hawaiian or Other Pacific Islander

☐ White (non-Hispanic)

To which age bracket do you belong?

○ 21 and younger

○ 22 and older

Please select your institution type:

○ public (funded in part by federal, state, and/or local governments)

○ private (NOT funded in part by federal, state, and/or local governments)

How many undergraduate science courses have you taken so far?

○ 0 - 3

○ 4 +

How would you describe your current level of teaching experience?

○ None at all

○ Some

How would you describe your prior science experiences in in your K-12 educational career?

○ Mostly Positive

○ Mostly Negative

Appendix B
IRB Approval Letter

UND UNIVERSITY OF NORTH DAKOTA UND.edu

Institutional Review Board
Tech Accelerator, Suite 2050
4201 James Ray Drive Stop 7134
Grand Forks, ND 58202-7134
Phone: 701.777.4279
Fax: 701.777.2193
UND.irb@UND.edu

March 9, 2020

Principal Investigator:	Patricia Arnold
Project Title:	Exploring Pre-Service Elementary Teachers' Preparedness for Three-Dimensional Instruction
IRB Project Number:	IRB-202001-162
Project Review Level:	Exempt 2
Date of IRB Approval:	03/09/2020
Expiration Date of This Approval:	01/15/2023

The Protocol Change Form and all included documentation for the above-referenced project have been reviewed and approved via the procedures of the University of North Dakota Institutional Review Board.

You have approval for this project through the above-listed expiration date. When this research is completed, please submit a termination form to the IRB.

The forms to assist you in filing your project termination, adverse event/unanticipated problem, protocol change, etc. may be accessed on the IRB website: http://und.edu/research/resources/human-subjects/

Sincerely,

Michelle L. Bowles, M.P.A., CIP
IRB Manager

Appendix C

Participant Consent Form – Page 1 of Finalized Participant Survey

UND UNIVERSITY OF NORTH DAKOTA

English

Welcome to our research study sponsored by UND's Graduate School!

Title of Project:	Exploring Pre-Service Elementary Teachers' Preparedness for Three-Dimensional Instruction
Principal Investigator:	Patricia A Arnold, patricia.a.arnold@und.edu
Co-Investigator(s):	Mundi Schmidt, mundi.s.schmidt.2@und.edu
Advisor:	Julie Robinson, 701-777-3139, julie.robinson@und.edu

Purpose of the Study:
The purpose of this study is to measure pre-service elementary teachers' perceived level of self-efficacy in teaching science using three-dimensional instruction as characterized in the Next Generation Science Standards. The rationale for this study is based on the need to explore how well pre-service elementary teachers are being prepared to teach science using three-dimensional instruction to meet the intent of the Next Generation Science Standards. A goal of this study is to provide insight from the perspective of pre-service elementary teachers as to how well they feel professionally prepared to teach science according to the aims and objectives of the Next Generation Science Standards in order to improve teacher preparation programming.

Procedures to be followed:
For this study, participants will be asked to complete an online survey through UND's Qualtrics platform in a pre/post fashion after participating in a six-lesson virtual learning module focused on the Next Generation Science Standards and three-dimensional instruction. The on-line survey contains a total of twelve questions: seven questions regarding general demographic information, two matrix style questions requiring a response using a 1 - 6 Likert-scale, and three questions requiring a brief written response.

To capture prospective elementary teachers' perceptions of their self-efficacy TO ENACT three-dimensional instruction in their future classrooms, participants will be asked to complete the following tasks: (1) a reflective assignment in a pre/post fashion, (2) four exit tickets administered throughout their practicum, and (3) participate in a semi-structured interview about their prior K-12 science experiences. Participant answers will remain anonymous at all levels of data collection for the duration of the study.

Risks:
There are no risks in participating in this research beyond those experienced in everyday life.

Benefits:
- You will gain insight into how well you are prepared to teach science according to the Next Generation Science Standards, upon which the 2019 North Dakota Science Content Standards are based.
- You will gain insight into how well you are prepared to teach science according to Standard 2.c of the Council for the Accreditation of Educator Preparation (CAEP) 2018 K-6 Elementary Teacher Preparation Standards.
- You will be able to provide insight that will guide program improvement for future pre-service elementary teachers enrolled at University of Jamestown.

Duration:
Administration of this research project will take seven weeks during the second half of the introductory science methods semester. The online survey is comprised of twelve questions and can easily be completed in approximately 10 minutes which will be offered during regular class time. The reflective assignment will take approximately 15 minutes for each administration and will be completed using a Google doc. The four exit tickets will be administered using Google forms and will take no more than 5 minutes each to complete. The semi-structured interview will occur remotely through Zoom and will take no more than 30 minutes to complete. All data collection tasks will be completed during the regularly scheduled class meeting times. There is no additional time commitment beyond the regularly scheduled meeting times for the course.

Statement of Confidentiality:
The online survey does not ask for any personal identifying information that would link responses to your identity. Therefore, your responses are recorded anonymously. If this research is published, no information that would identify you will be included since your name is in no way linked to your responses.

All survey responses that we receive will be treated confidentially and stored on a secure server. However, given that the surveys can be completed from any computer (e.g., personal, work, school), we are unable to guarantee the security of the computer on which you choose to enter your responses. As a participant in our study, we want you to be aware that certain "key logging" software programs exist that can be used to track or capture data that you enter and/or websites that you visit.

Right to Ask Questions:
The researchers conducting this study are Patricia Arnold, Julie Robinson, and Mundi Schmidt. You may ask any questions you have now. If you later have questions, concerns, or complaints about the research please contact Patricia Arnold at patricia.a.arnold@und.edu. or Julie Robinson at julie.robinson@und.edu.

If you have questions regarding your rights as a research subject, you may contact The University of North Dakota Institutional Review Board at (701) 777-4279 or UND.irb@UND.edu. You may contact the UND IRB with problems, complaints, or concerns about the research. Please contact the UND IRB if you cannot reach research staff, or you wish to talk with someone who is an informed individual who is independent of the research team.

General information about being a research subject can be found on the Institutional Review Board website "Information for Research Participants" http://und.edu/research/resources/human-subjects/research-participants.html

Compensation:
Students who choose to participate in this study will receive extra credit points for their enrolled course. You may withdraw from the study at any time without losing the course points assigned by your instructor.

If you choose not to participate, please consult your course instructor on other methods to earn course points.

Voluntary Participation:
You do not have to participate in this research. You can stop your participation at any time. You may refuse to participate or choose to discontinue participation at any time without losing any benefits to which you are otherwise entitled.

You do not have to answer any questions you do not want to answer.

You must be 18 years of age older to participate in this research study.

Completion and submission of the online survey implies that you have read the information in this form and consent to participate in the research.

○ I consent, begin the study

○ I do not consent, I do not wish to participate

Appendix D

Bleicher's (2004) Modified STEBI-B from Enochs and Riggs (1990)

Please indicate the degree to which you agree or disagree with each statement below by placing an "X" on the appropriate letters to the right of each statement. SA = STRONGLY AGREE, A = AGREE ,UN = UNCERTAIN, D = DISAGREE, SD = STRONGLYDISAGREE

1.	When a student does better than usual in science, it is often because the teacher exerted a little extra effort.	SA	A	UN	D	SD
2.	I will continually find better ways to teach science	SA	A	UN	D	SD
3.	Even if I try very hard, I will not teach science as well as I will most subjects.	SA	A	UN	D	SD
4.	When the science grades of students improve, it is often due to their teacher having found a more effective teaching approach	SA	A	UN	D	SD
5.	I know the steps necessary to teach science concepts effectively.	SA	A	UN	D	SD
6.	I will not be very effective in monitoring science experiments.	SA	A	UN	D	SD
7.	If students are underachieving in science, it is most likely due to ineffective science teaching.	SA	A	UN	D	SD
8.	I will generally teach science ineffectively.	SA	A	UN	D	SD
9.	The inadequacy of a student's science background can be overcome by good teaching.	SA	A	UN	D	SD
10.	The low science achievement of students cannot generally be blamed on their teachers	SA	A	UN	D	SD
11.	When a low-achieving child progresses in science, it is usually due to extra attention given by the teacher.	SA	A	UN	D	SD
12.	I understand science concepts well enough to be effective in teaching elementary science.	SA	A	UN	D	SD
13.	Increased effort in science teaching produces little change in students' science achievement.	SA	A	UN	D	SD
14.	The teacher is generally responsible for the achievement of students in science.	SA	A	UN	D	SD
15.	Students' achievement in science is directly related to their teacher's effectiveness in science teaching.	SA	A	UN	D	SD
16.	If parents comment that their child is showing more interest in science, it is probably due to the child's teacher.	SA	A	UN	D	SD
17.	I will find it difficult to explain to students why science experiments work.	SA	A	UN	D	SD
18.	I will typically be able to answer students' science questions.	SA	A	UN	D	SD
19.	I wonder if I will have the necessary skills to teacher science.	SA	A	UN	D	SD
20.	Given a choice, I will not invite the principal to evaluate my science teaching.	SA	A	UN	D	SD
21.	When a student has difficulty understanding a science concept, I will usually be at a loss as to how to help the student understand.	SA	A	UN	D	SD
22.	When teaching science, I will usually welcome student questions.	SA	A	UN	D	SD
23.	I do not know what to do to turn students on to science.	SA	A	UN	D	SD

Appendix E

Excerpt from Kang et al.'s (2018) *NGSS* Science and Engineering Practices Survey

Teacher NGSS Practices Survey

INTRODUCTION

The primary purpose of this self-assessment is to help us to be responsive to your needs and focus our preparation of the professional development sessions. Please answer these questions as open and honestly as possible. This information is confidential and will not be provided to school administrators and is not related to the APPR.

Directions: Indicate your ability to identify each practice and your confidence on a scale from 1-5, 1(not at all) 3(somewhat) to 5 (very well). Then provide a brief example of what this could look like in a second grade science lesson.

Practice I. Asking Questions (for science) and defining problems (for engineering).					
	Not at all		Somewhat		Very well
1. Students will ask questions based on observations to find more information about the natural and/or designed world(s).					
How well do you know what this practice is describing?	1	2	3	4	5
How confident are you in enacting this practice?	1	2	3	4	5
2. Students will ask and/or identify questions that can be answered by an investigation. Do you know what this practice could look in a classroom?					
How well do you know what this practice is describing?	1	2	3	4	5
How confident are you in enacting this practice?	1	2	3	4	5
3. Students will define a simple problem that can be solved through the development of a new or improved object or tool.					
How well do you know what this practice is describing?	1	2	3	4	5
How confident are you in enacting this practice?	1	2	3	4	5
Please provide an example of how students could enact these practices in a science lesson. (e.g. What is the teacher doing to promote the practice? What are the students doing?) If unsure, type "unsure" in the box below.					

Appendix F

Bleicher's (2004) Modified STEBI-B – Page 3 of Finalized Participant Survey

Please indicate the degree to which you agree or disagree with the following statements:

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
When a student does better than usual in science, it is often because the teacher exerted a little extra effort.	○	○	○	○	○	○
I will continually find better ways to teach science.	○	○	○	○	○	○
Even if I try very hard, I will not teach science as well as I will most subjects.	○	○	○	○	○	○
When the science grades of students improve, it is often due to their teacher having found a more effective teaching approach.	○	○	○	○	○	○
I know the steps necessary to teach science concepts effectively.	○	○	○	○	○	○
I will not be very effective in monitoring science experiments.	○	○	○	○	○	○
If students are underachieving in science, it is most likely due to ineffective science teaching.	○	○	○	○	○	○
I will generally teach science ineffectively.	○	○	○	○	○	○
The inadequacy of a student's science background can be overcome by good teaching.	○	○	○	○	○	○
The low science achievement of students cannot generally be blamed on their teachers.	○	○	○	○	○	○
When a low-achieving child progresses in science, it is usually due to extra attention given by the teacher.	○	○	○	○	○	○
I understand science concepts well enough to be effective in teaching elementary science.	○	○	○	○	○	○
Increased effort in science teaching produces little change in students' science achievement.	○	○	○	○	○	○
The teacher is generally responsible for the achievement of students in science.	○	○	○	○	○	○
Students' achievement in science is directly related to their teacher's effectiveness in science teaching.	○	○	○	○	○	○
If parents comment that their child is showing more interest in science, it is probably due to the child's teacher.	○	○	○	○	○	○
I will find it difficult to explain to students why science experiments work.	○	○	○	○	○	○
I will typically be able to answer students' science questions.	○	○	○	○	○	○
I wonder if I will have the necessary skills to teach science.	○	○	○	○	○	○
Given a choice, I will not invite the principal to evaluate my science teaching.	○	○	○	○	○	○
When a student has difficulty understanding a science concept, I will usually be at a loss as to how to help the student understand.	○	○	○	○	○	○
When teaching science, I will usually welcome student questions.	○	○	○	○	○	○
I do not know what to do to turn students on to science.	○	○	○	○	○	○

Appendix G

Modified Kang et al.'s (2018) *NGSS* Science and Engineering Practices Survey – Page 4 of Finalized Participant Survey

Please indicate the degree to which you agree or disagree with the following statements:

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
I am familiar with three dimensional instruction as presented in the Next Generation Science Standards (NGSS).	○	○	○	○	○	○
I feel confident in my ability in teaching science using three dimensional instruction according to the intent of the NGSS.	○	○	○	○	○	○
It is important to teach science content integrated with science practices. (see statements below for examples of science practices)	○	○	○	○	○	○
I am familiar with the intent of Science Practice 1 - Asking Questions.	○	○	○	○	○	○
I feel confident in my ability to teach science content integrated with Science Practice 1 - Asking Questions.	○	○	○	○	○	○
I am familiar with the intent of Science Practice 2 - Developing and Using Models.	○	○	○	○	○	○
I feel confident in my ability to teach science content integrated with Science Practice 2 - Developing and Using Models.	○	○	○	○	○	○
I am familiar with the intent of Science Practice 3 - Planning and Carrying Out Investigations.	○	○	○	○	○	○
I feel confident in my ability to teach science content integrated with Science Practice 3 - Planning and Carrying Out Investigations	○	○	○	○	○	○
I am familiar with the intent of Science Practice 4 - Analyzing and Interpreting Data.	○	○	○	○	○	○
I feel confident in my ability to teach science science content integrated with Science Practice 4 - Analyzing and Interpreting Data.	○	○	○	○	○	○
I am familiar with the intent of Science Practice 5 - Using Mathematics and Computational Thinking.	○	○	○	○	○	○
I feel confident in my ability to teach science content integrated with Science Practice 5 - Using Mathematics and Computational Thinking.	○	○	○	○	○	○
I am familiar with the intent of Science Practice 6 - Constructing Explanations.	○	○	○	○	○	○
I feel confident in my ability to teach science content integrated with Science Practice 6 - Constructing Explanations.	○	○	○	○	○	○
I am familiar with the intent of Science Practice 7 - Engaging in Argument from Evidence.	○	○	○	○	○	○
I feel confident in my ability to teach science content integrated with Science Practice 7 - Engaging in Argument from Evidence.	○	○	○	○	○	○
I am familiar with the intent of Science Practice 8 - Obtaining, Evaluating, and Communicating Information.	○	○	○	○	○	○
I feel confident in my ability to teach science content integrated with Science Practice 8 - Obtaining, Evaluating, and Communicating Information.	○	○	○	○	○	○

Appendix H

Open-Ended Questions – Page 5 of Finalized Participant Survey

Please describe which learning experiences from this semester ***MOST*** prepared you for teaching science using three-dimensional instruction.

Please describe which learning experiences from this semester ***LEAST*** prepared you for teaching science using three-dimensional instruction.

Please describe any ***COURSE IMPROVEMENTS*** you might suggest for preparing future pre-service teachers for teaching science using three-dimensional instruction.

Appendix I

Thomas et al.'s (2001) Draw-A-Science-Teacher-Test-C Instrument

DASTT-C Instrument

Date: ____________________________ **ID #:** _____ _____ _____ _____

Location:_________________________ **Preservice ( ) or In-service ( )**

Draw a picture of yourself as a science teacher at work.

What is the teacher doing? What are the students doing?

____

____

____

____

____

Appendix J
"Draw Yourself as a Science Teacher" Google Doc Assignments

Pre-administration Assignment

***Name*________________________________ *Date*______________**

1. **INSERT a drawing of yourself as a 3D Science Teacher. Use the INSERT tab to create your own picture from scratch by selecting + New, or INSERT an image of a hand-drawn picture from your science notebook.**

   [INSERT DRAWING or SAVED IMAGE HERE]

2. **Describe what you are doing as you teach science using 3D instruction.**

3. **Describe what your students are doing as you teach science using 3D instruction.**

Personal Reflection:

4. **As a child, and now as an adult, what has been your experience with the natural world?**

5. **As a K-12 student, what has been your experience with science?**

6. **What is one pivotal moment you have had at any point in a science class, either positive or not-so-positive?**

Post-administration Assignment

*Name*________________________________ *Date*______________

1. INSERT a drawing of yourself as a 3D Science Teacher. Use the INSERT tab to create your own picture from scratch by selecting + New, or INSERT an image of a hand-drawn picture from your science notebook.

   [INSERT DRAWING or SAVED IMAGE HERE]

2. Describe what you are doing as you teach science using 3D instruction.

3. Describe what your students are doing as you teach science using 3D instruction.

Personal Reflection:

4. What changes do you notice between these drawings and those you did at the start of this research project?

5. What do these changes indicate about how your perceptions of teaching science have changed?

6. How do you think these perceptions will affect your teaching of science in your future classroom?

Appendix K
Exit Ticket #1 Proposed Plan for Field Experience Practicum

10/9/21, 6:53 AM EXIT TICKET #1: Proposed Unit Plan for Field Experience

EXIT TICKET #1: Proposed Unit Plan for Field Experience

* Required

1. Email *

2. Which topic would you like to teach during your science unit for your field experience? Why do you feel this topic is important to teach? *

3. What do you think might be the main objectives of your science unit for your field experience? *

https://docs.google.com/forms/d/1g_U1eN8-iypp7154IqSLgBv4j1tNhk3zLN1zOkbHm74/edit 1/3

10/9/21, 6:53 AM EXIT TICKET #1: Proposed Unit Plan for Field Experience

4. Which of the three main science and engineering practices (Developing and Using Models, Constructing Explanations, and/or Engaging in Argument from Evidence) would you like to incorporate into your science unit for your field experience? *

5. How do you think your chosen science and engineering practice(s) can be incorporated into your science unit for your field experience? *

6. On a scale of 1 to 5, with 5 being "very" and 1 being "not at all", how confident do you feel that you will be able to incorporate your chosen science and engineering practice(s) into your science unit for your field experience? Please explain your choice. *

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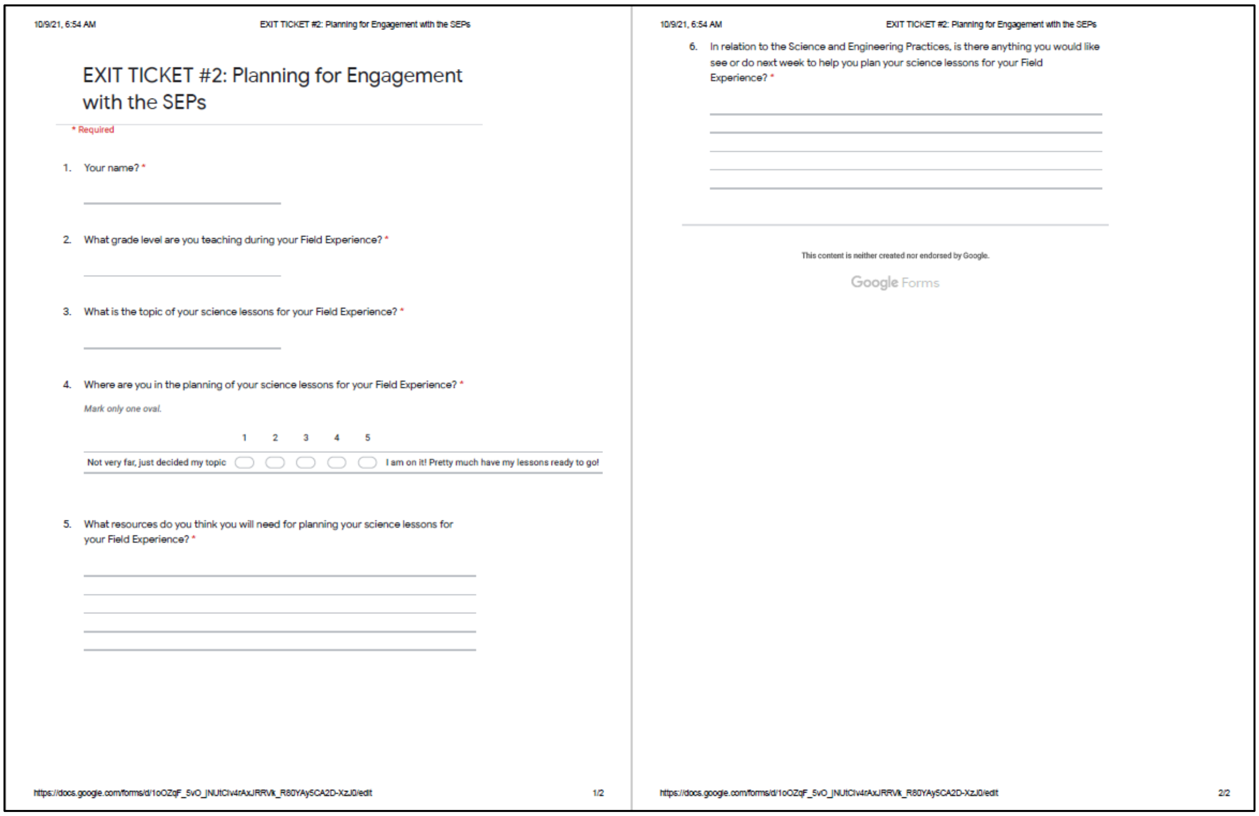
Google Forms

https://docs.google.com/forms/d/1g_U1eN8-iypp7154IqSLgBv4j1tNhk3zLN1zOkbHm74/edit 2/3

Appendix L

Exit Ticket #2 Planning for Engagement with the SEPs



10/9/21, 6:54 AM EXIT TICKET #2: Planning for Engagement with the SEPs

EXIT TICKET #2: Planning for Engagement with the SEPs

* Required

1. Your name? *

2. What grade level are you teaching during your Field Experience? *

3. What is the topic of your science lessons for your Field Experience? *

4. Where are you in the planning of your science lessons for your Field Experience? *

   Mark only one oval.

	1	2	3	4	5	
Not very far, just decided my topic	◯	◯	◯	◯	◯	I am on it! Pretty much have my lessons ready to go!

5. What resources do you think you will need for planning your science lessons for your Field Experience? *

https://docs.google.com/forms/d/1oOZqF_5vO_jNUtCIv4rAxJRRVk_R80YAy5CA2D-XzJ0/edit 1/2

10/9/21, 6:54 AM EXIT TICKET #2: Planning for Engagement with the SEPs

6. In relation to the Science and Engineering Practices, is there anything you would like see or do next week to help you plan your science lessons for your Field Experience? *

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Google Forms

https://docs.google.com/forms/d/1oOZqF_5vO_jNUtCIv4rAxJRRVk_R80YAy5CA2D-XzJ0/edit 2/2

Appendix M

Exit Ticket #3 Field Experience Practicum with the SEPs

10/9/21, 6:54 AM EXIT TICKET 3: Post-Field Experience with the SEPs

EXIT TICKET 3: Post-Field Experience with the SEPs

Please complete the following questions to the best of your ability based on your field experience for EDUC 415:

* Required

1. Email *

2. In your opinion, which science and engineering practice was easy (Developing and Using Models, Constructing Explanations, and/or Engaging in Argument from Evidence) to incorporate into your field experience? *

3. Briefly describe which factors helped you to successfully incorporate the science and engineering practices into your field experience. *

https://docs.google.com/forms/d/1B2usPtO9yqlf-c_RlbkkuryGPSFOOMgDA-ZFRPxl4qM/edit 1/2

10/9/21, 6:54 AM EXIT TICKET 3: Post-Field Experience with the SEPs

4. In your opinion, which science and engineering practice (Developing and Using Models, Constructing Explanations, and/or Engaging in Argument from Evidence) was more challenging to incorporate into your field experience? *

5. Briefly describe which factors made it more challenging for you to incorporate the science and engineering practices into your field experience. *

6. In your opinion, how supported did you feel from your mentor teacher to incorporate the science and engineering practices into your science teaching during your field experience? *

This content is neither created nor endorsed by Google.

Google Forms

https://docs.google.com/forms/d/1B2usPtO9yqlf-c_RlbkkuryGPSFOOMgDA-ZFRPxl4qM/edit 2/2

Appendix N
Exit Ticket #4 Field Experience Practicum Reflection

10/9/21, 6:55 AM EXIT TICKET 4: POST-Field Experience Reflection

EXIT TICKET 4: POST-Field Experience Reflection

Please complete the following questions to the best of your ability based on your field experience for EDUC 415:

* Required

1. Email *

2. Thinking about your incorporation of the science and engineering practices (Developing and Using Models, Constructing Explanations, and/or Engaging in Argument from Evidence) during your field experience, what did you learn about yourself as a science teacher after delivering your lessons? *

3. Thinking about your incorporation of the science and engineering practices (Developing and Using Models, Constructing Explanations, and/or Engaging in Argument from Evidence) during your field experience, what surprised you the most after delivering your lessons? *

https://docs.google.com/forms/d/1gZUH_RQhrCIRRt5S-kdyCflUSKh35I5E5IKjml4dpnI/edit 1/3

10/9/21, 6:55 AM EXIT TICKET 4: POST-Field Experience Reflection

4. Thinking about your incorporation of the science and engineering practices (Developing and Using Models, Constructing Explanations, and/or Engaging in Argument from Evidence) during your field experience, what would you change after delivering your lessons? *

5. Thinking about your future field experiences, what support do you think you will need to continue your pre-professional development in incorporating the science and engineering practices (Developing and Using Models, Constructing Explanations, and/or Engaging in Argument from Evidence) into your science lessons? *

6. On a scale of 1 to 5, with 5 being "very" and 1 being "not at all", how confident do you feel that you will be able to incorporate the science and engineering practices (Developing and Using Models, Constructing Explanations, and/or Engaging in Argument from Evidence) into your future field experiences (i.e., student teaching)? *

Mark only one oval.

	1	2	3	4	5	
Not confident at all...	◯	◯	◯	◯	◯	Very confident, I am all over it!

https://docs.google.com/forms/d/1gZUH_RQhrCIRRt5S-kdyCflUSKh35I5E5IKjml4dpnI/edit 2/3

Appendix O
Focus Group Interview Questions

1. On a scale of 1 to 5, with 5 being very prepared and 1 being not at all prepared, how would you rate your ability to teach science during your student teaching?
2. On a scale of 1 to 5, with 5 being very prepared and 1 being not at all prepared, how would you rate your ability to teach science using the Big 3 SEPs emphasized in this research study: Developing and Using Models, Constructing Explanations, and Engaging in Argument from Evidence?
3. Which of the Big 3 SEPs emphasized in this research study – Developing and Using Models, Constructing Explanations, and Engaging in Argument from Evidence – do you feel MOST confident in using in your student teaching?
4. Which of the Big 3 SEPs emphasized in this research study – Developing and Using Models, Constructing Explanations, and Engaging in Argument from Evidence – do you feel LEAST confident in using in your student teaching?
5. What would you like to have seen IMPROVED in this research study to better prepare you for teaching science with the Big 3 SEPs during your student teaching?
6. Is there anything you would like to clarify from your responses to these five questions?

Appendix P

Descriptive Statistics and Correlations for PSTE Questions

Descriptive Statistics and Correlations for PSTE Questions

Variable	*M*	*SD*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1. Pre Q2	1.50	0.52																									
2. Post Q2	1.75	0.45	-0.192																								
3. Pre Q3[a]	2.58	1.00	0.437	0.353																							
4. Post Q3[a]	3.17	1.11	-.625*	.631*	0.068																						
5. Pre Q5	2.83	0.58	0.000	0.174	0.026	-0.094																					
6. Post Q5	2.33	0.49	0.000	-0.408	-0.247	-0.110	-0.107																				
7. Pre Q6[a]	2.42	1.08	0.080	0.232	.765**	0.314	-0.315	-0.114																			
8. Post Q6[a]	2.92	1.08	-0.562	0.510	0.218	.916**	-0.024	-0.284	0.419																		
9. Pre Q8[a]	2.08	0.90	0.290	0.056	.650*	0.166	-0.496	-0.068	.800**	0.287																	
10. Post Q8[a]	2.67	1.23	-0.566	0.490	0.173	.906**	-0.213	-0.250	0.386	.931**	0.355																
11. Pre Q12	2.67	0.65	-0.267	-0.309	-0.374	-0.417	0.564	0.094	-0.429	-0.429	-0.568	-0.491															
12. Post Q12	2.25	0.62	0.140	-0.081	0.037	0.066	-0.127	.891**	0.101	-0.101	0.122	-0.119	-0.225														
13. Pre Q17[a]	2.67	1.23	0.566	-0.163	.618*	-0.420	-0.213	-0.250	0.386	-0.159	0.437	-0.140	-0.378	-0.119													
14. Post Q17[a]	2.91	1.22	-0.228	.654*	0.450	0.583	-0.161	-0.128	0.465	0.498	0.181	0.423	-0.409	0.161	0.057												
15. Pre Q18	2.67	0.65	0.267	-.617*	0.187	-0.543	0.081	-0.189	0.086	-0.301	0.207	-0.265	0.357	-0.449	0.416	-0.414											
16. Post Q18	2.42	0.67	.651*	0.075	0.557	-0.224	0.196	0.368	0.115	-0.199	0.239	-0.258	-0.278	.602*	0.405	0.173	-0.070										
17. Pre Q19[a]	3.92	1.24	0.491	-0.203	0.411	-0.252	0.106	-0.248	0.502	-0.073	0.495	-0.199	-0.038	-0.206	0.278	-0.132	0.525	0.046									
18. Post Q19[a]	3.50	1.17	-0.447	-0.086	-0.117	0.070	-0.405	0.000	-0.036	0.036	-0.043	0.190	0.120	-0.188	0.063	0.374	0.239	-0.291	-0.408								
19. Pre Q20[a]	2.50	0.80	0.436	-0.378	0.286	-0.307	0.000	0.231	0.368	-0.158	0.316	-0.185	-0.175	0.275	0.463	-0.454	0.175	0.256	0.414	-.586*							
20. Post Q20[a]	2.58	1.08	-0.080	0.510	.751**	0.439	-0.266	-0.227	.703*	0.510	0.505	0.500	-0.472	0.034	0.432	.851**	-0.086	0.261	-0.028	0.395	-0.158						
21. Pre Q21[a]	2.42	0.79	0.549	-0.444	0.240	-0.497	-0.232	0.310	0.309	-0.379	0.456	-0.310	-0.235	0.323	.621*	-0.368	0.293	0.329	0.408	-0.245	.790**	-0.097					
22. Post Q21[a]	2.58	1.24	-0.211	0.446	0.509	0.449	-0.233	0.099	0.547	0.378	0.278	0.377	-0.300	0.265	0.139	.921**	-0.188	0.228	-0.143	0.534	-0.322	.874**	-0.177				
23. Pre Q22	1.33	0.49	0.354	-0.408	0.494	-0.110	-0.426	0.250	0.568	0.057	0.547	0.050	-0.472	0.297	.650*	0.221	0.378	0.368	0.347	0.158	0.463	0.454	0.543	0.397			
24. Post Q22	1.67	0.65	-0.267	.617*	0.187	.584*	-0.161	-0.189	0.215	0.472	-0.103	0.529	-0.500	0.000	0.076	.685*	-0.500	-0.070	-0.375	0.239	-0.175	0.558	-0.235	.600*	0.094		
25. Pre Q23[a]	2.58	1.00	0.262	0.353	0.542	0.150	0.184	-0.247	.597*	0.218	0.245	0.025	-0.234	0.037	0.173	0.201	-0.234	0.148	0.484	-.664*	0.515	0.246	0.125	0.067	0.124	0.187	
26. Post Q23[a]	2.75	1.14	-0.382	0.574	0.461	0.537	0.069	-0.324	0.534	0.571	0.111	0.454	-0.123	-0.161	0.065	.875**	-0.123	-0.090	0.048	0.376	-0.350	.792**	-0.378	.821**	0.162	.613*	0.301

* $p < 0.05$ (2-tailed); ** $p < 0.01$ (2-tailed); N=12

Appendix Q

Descriptive Statistics and Correlations for STOE Questions

Descriptive Statistics and Correlations for STOE Questions

Variables	*M*	*SD*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1. Pre Q1	2.58	0.51																			
2. Post Q1	2.33	0.49	0.239																		
3. Pre Q4	2.42	0.51	0.029	0.120																	
4. Post Q4	2.18	0.60	-0.090	0.418	-0.239																
5. Pre Q7	3.17	0.72	0.205	.600*	0.287	0.194															
6. Post Q7	2.83	0.72	-0.205	0.429	-0.041	0.301	0.235														
7. Pre Q9	2.42	0.51	0.029	0.478	0.314	0.090	.779**	0.451													
8. Post Q9	2.18	0.75	0.232	0.336	0.072	0.429	.645*	-0.113	0.600												
9. Pre Q10[a]	3.42	0.90	-0.180	0.479	0.180	0.228	.586*	0.258	.768**	0.472											
10. Post Q10[a]	3.42	1.00	-0.162	-0.309	-.724**	-0.146	-0.360	-0.275	-0.369	-0.013	-0.313										
11. Pre Q11	2.92	0.67	0.418	.644*	0.110	0.000	0.410	0.347	0.374	0.225	0.063	-0.080									
12. Post Q11	2.75	0.75	-0.059	0.490	0.293	0.326	0.420	0.252	0.527	0.431	0.301	-0.454	0.316								
13. Pre Q13[a]	2.92	1.38	-0.309	0.446	-0.203	0.365	0.383	-0.015	0.437	0.565	.763**	0.226	0.090	0.241							
14. Post Q13[a]	3.67	1.30	-0.090	0.189	-.587*	0.067	-0.032	-0.259	-0.181	0.151	-0.103	.607*	-0.035	0.185	0.388						
15. Pre Q14	2.75	0.45	0.293	0.000	0.488	-0.161	0.140	-0.140	0.098	0.156	-0.391	-0.353	0.225	.600*	-0.474	0.000					
16. Post Q14	2.67	0.65	-0.181	0.094	0.181	-0.029	0.519	.648*	.723**	0.341	0.413	-0.187	0.139	0.185	0.067	-0.357	0.000				
17. Pre Q15	2.58	0.67	0.506	0.184	-0.506	-0.067	0.158	0.410	0.286	-0.018	0.013	0.148	0.322	-0.045	-0.140	0.139	-0.075	0.278			
18. Post Q15	2.75	0.62	-0.071	0.297	0.355	0.239	0.509	.713**	.639*	0.318	0.365	-0.404	0.164	0.243	-0.027	-0.449	0.081	.898**	0.164		
19. Pre Q16	2.42	0.79	0.019	0.078	.649*	-0.149	0.027	-0.027	0.204	0.210	-0.138	-0.355	0.243	.646*	-0.215	-0.117	.824**	0.117	-0.329	0.231	
20. Post Q16	2.83	0.58	0.051	0.533	0.255	0.375	0.512	.585*	0.561	0.522	0.321	-0.342	.667*	0.522	0.209	-0.322	0.174	0.564	0.039	.633*	0.364

* $p < 0.05$ (2-tailed). ** $p < 0.01$ (2-tailed). N=12. [a] = reverse coded questions

Appendix R
Descriptive Statistics and Correlations for FAMILIARITY Questions

Descriptive Statistics and Correlations of FAMILIARITY Questions

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Pre FAM Q1																	
2. Post FAM Q1	-0.378																
3. Pre FAM Q4	-0.241	0.049															
4. Post FAM Q4	-0.414	0.000	0.269														
5. Pre FAM Q6	0.486	-0.378	0.538	0.000													
6. Post FAM Q6	-0.414	0.000	0.269	1.000**	0.000												
7. Pre FAM Q8	0.286	-0.408	.700*	0.000	.682*	0.000											
8. Post FAM Q8	-0.486	-0.076	0.130	.828**	0.029	.828**	-0.154										
9. Pre FAM Q10	0.022	-0.408	.700*	0.319	.682*	0.319	.797**	0.374									
10. Post FAM Q10	-0.414	0.000	0.269	1.000**	0.000	1.000**	0.000	.828**	0.319								
11. Pre FAM Q12	.717**	-0.316	0.155	0.000	.717**	0.000	0.552	-0.239	0.368	0.000							
12. Post FAM Q12	-0.378	-0.200	0.049	0.548	0.076	0.548	-0.058	.832**	0.291	0.548	-0.316						
13. Pre FAM 14	0.293	-0.155	.646*	0.000	.644*	0.000	.857**	-0.176	.676*	0.000	.653*	-0.155					
14. Post FAM Q14	-0.561	0.270	0.033	.739**	-0.255	.739**	-0.275	.866**	0.196	.739**	-0.426	.674*	-0.313				
15. Pre FAM Q16	0.022	-0.058	.872**	0.319	.682*	0.319	.797**	0.110	.797**	0.319	0.552	-0.058	.857**	-0.039			
16. Post FAM Q16	-0.486	-0.076	0.130	.828**	0.029	.828**	-0.154	1.000**	0.374	.828**	-0.239	.832**	-0.176	.866**	0.110		
17. Pre FAM Q18	0.527	-0.155	0.342	0.000	.644*	0.000	.676*	-0.176	0.496	0.000	.816**	-0.155	.840**	-0.313	.676*	-0.176	
18. Post FAM Q18	-0.143	-0.529	0.130	0.414	0.371	0.414	0.110	.657*	0.374	0.414	0.000	.832**	0.059	0.255	0.110	.657*	0.059

Appendix S
Descriptive Statistics and Correlations for CONFIDENCE Questions

Descriptive Statistics and Correlations of CONFIDENCE Questions

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Pre CON Q2																	
2. Post CON Q2	0.376																
3. Pre CON Q5	0.243	0.273															
4. Post CON Q5	0.236	.638*	0.343														
5. Pre CON Q7	.683*	0.110	0.213	0.000													
6. Post CON Q7	0.098	.682*	0.071	.828**	0.029												
7. Pre CON Q9	0.404	-0.164	.765**	0.000	0.497	-0.213											
8. Post CON Q9	0.348	.746**	0.380	.739**	0.357	.866**	0.127										
9. Pre CON Q11	0.280	0.347	.713**	0.297	0.451	0.287	0.509	0.512									
10. Post CON Q11	0.488	.682*	.639*	.828**	0.371	.657*	0.355	.866**	0.533								
11. Pre CON Q13	.827**	0.119	0.055	0.000	.814**	-0.022	0.273	0.196	0.410	0.242							
12. Post CON Q13	0.111	0.526	-0.081	0.471	0.098	.683*	-0.081	0.522	0.140	0.293	-0.075						
13. Pre CON Q15	0.467	0.045	.825**	0.283	0.410	0.059	.825**	0.313	.756**	0.527	0.406	-0.067					
14. Post CON Q15	0.293	.682*	0.355	.828**	0.029	.657*	0.071	0.561	0.287	.657*	-0.022	.683*	0.293				
15. Pre CON Q17	0.243	0.273	1.000**	0.343	0.213	0.071	.765**	0.380	.713**	.639*	0.055	-0.081	.825**	0.355			
16. Post CON Q17	0.488	.682*	.639*	.828**	0.371	.657*	0.355	.866**	0.533	1.000**	0.242	0.293	0.527	.657*	.639*		
17. Pre CON Q19	.775**	0.291	0.564	0.274	.605*	0.076	0.564	0.337	.705*	0.529	.757**	0.000	.775**	0.302	0.564	0.529	
18. Post CON Q19	0.000	0.000	0.000	0.500	0.000	0.414	0.000	0.369	0.000	0.414	0.000	0.000	0.000	0.000	0.000	0.414	0.000

* $p < 0.05$ level (2-tailed),**$p < 0.01$ level (2-tailed), N=12, CON=Confidence

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